TOTAL ANKLE ARTHROPLASTY AND CONE BEAM PLANIFICATION

GI EIF – Internship February-July 2024 - ***Elise SALES***

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Arthroplastie totale de la cheville

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HCL 2021 : Prothèse Quantum™
- guides de coupe sur mesure,
- impression 3D.

Source.

In2Bones
a CONMED company

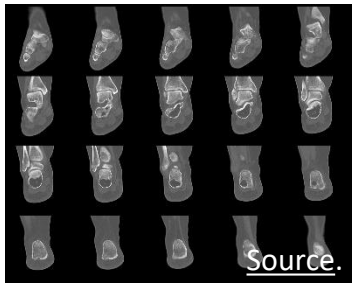
Planning pré-op.

Source.

Radiographie (lien).

CT scan (lien).

HCL 2022 : ConeBeam HiRise (3ème en EU, 1er en France)



Source.

CurveBeam AI

➔ **Alternative for planning ?**

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INTRODUCTION: PRE-OPERATIVE PLANNING

- Pre-operative planning can be carried out using a **conventional CT scan or a loaded CT scan (CB, Cone Beam).**
- **Classic CT scan**: high radiation dose, correction needed (patient laying down), high resolution images
- **CB (loaded CT scan):** low radiation dose, no correction needed, low resolution images
- CB also provides **information on the bone mineral density**

➔ **Can the CB replace the CT?**

Source: Bioluxe medical

Source: CurveBeam AI

OBJECTIVES

Objective 1: Clinical parameters

1. Assess the performance of the Cone Beam for pre-operative planning.
2. Compare the performances of the CB vs CT.

(Performance based on the measure of clinical parameters)

Objective 2: Densitometry

1. Study of the effect of the Bone Mineral Density (BMD) on the surgical follow-up *(So et al., 2022)*

BMD taken into account for other types of arthrosis (hip, knee) but not for the ankle

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ALIGNEMENT IN THE FRONTAL AND THE SAGITTAL PLANES

➔ Ankle alignment is said to be neutral if it shows less than 5° of varus or valgus.

➔ Several angles can help to perform a correct alignment in the frontal and sagittal planes:

Angle α:

Angle β

➔ **Surgical Performance:**

looking for alignment both in the frontal and sagittal planes

Source: Usuelli et al., 2017

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COMPUTATION OF GEOMETRICAL PARAMETERS

Compute **α** and **β** for **14** patients

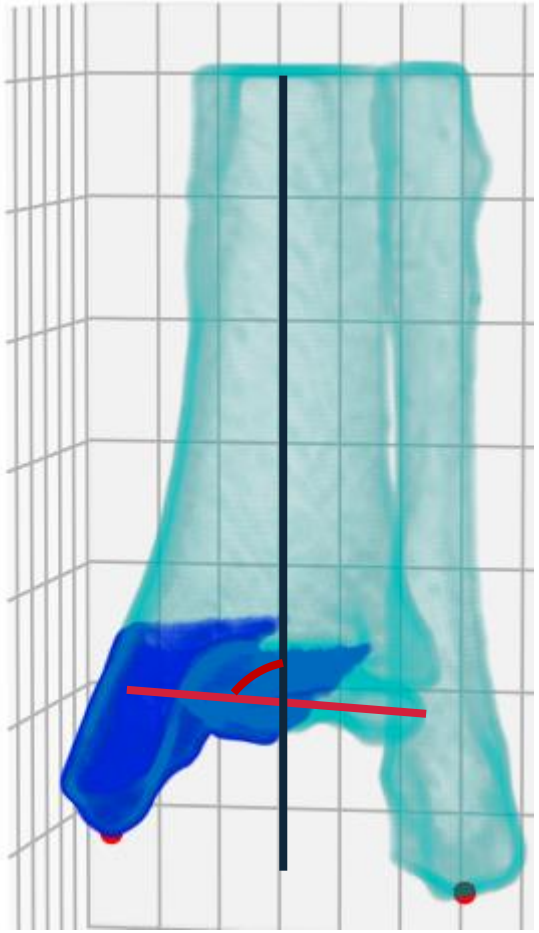
Reference = surgeon's measurement done on X-rays

~~**X-ray**~~ ➔ Scans

Post-op. scans: 14 CB, 4 months after surgery (M+4/post-op)
+ 8 scans at D+1, the day after the surgery

Pre-op. scans: 7 CB, 7 CT, done 6 weeks before surgery (D0/pre-op)

➔ Need to automatize the measure of **α** and **β** from segmentations (method developed in a previous internship)



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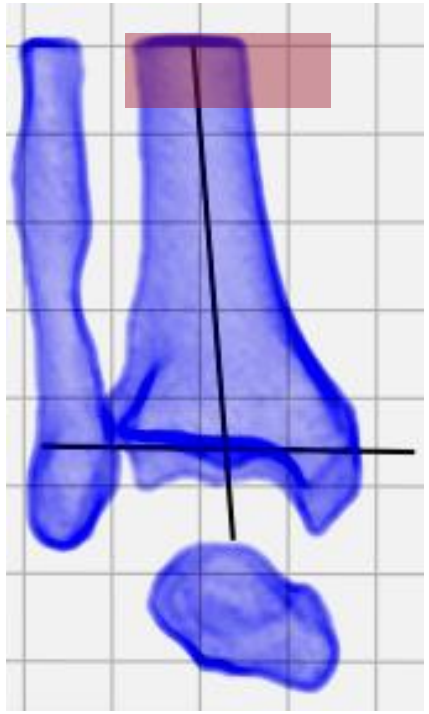
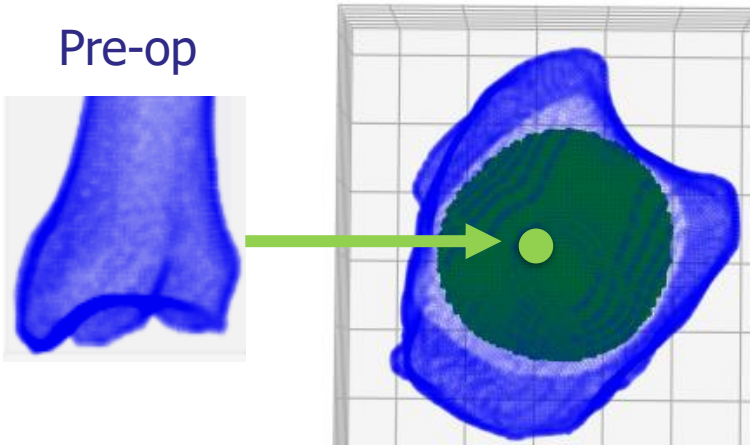
RECONSTRUCTION OF 2D PARAMETERS FROM 3D PARAMETERS (PROJECTION-BASED METHOD)

a) Main tibial axis

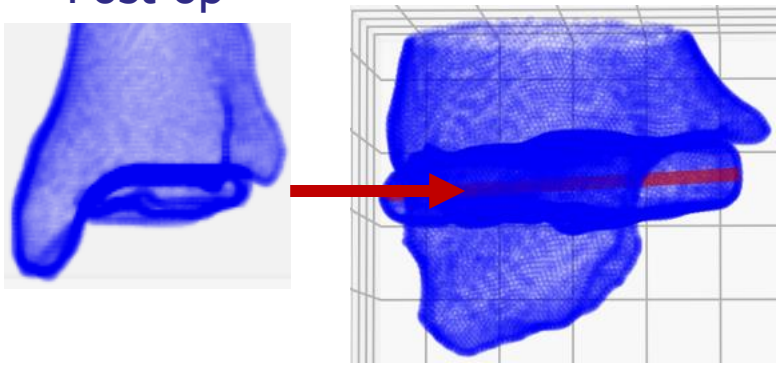


b) Tibial plafond

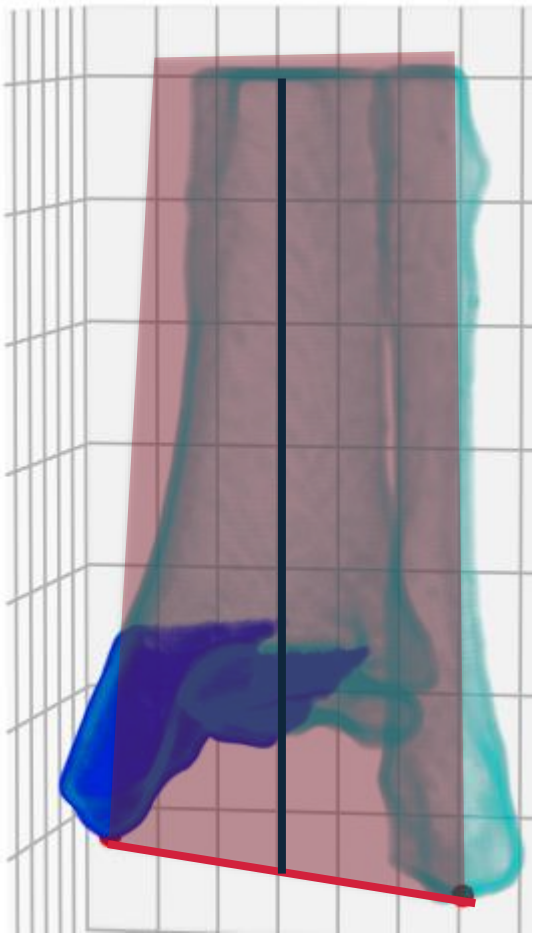
Pre-op



Post-op



c) Projection planes



⚠ **Implant → artifacts on CT scan**

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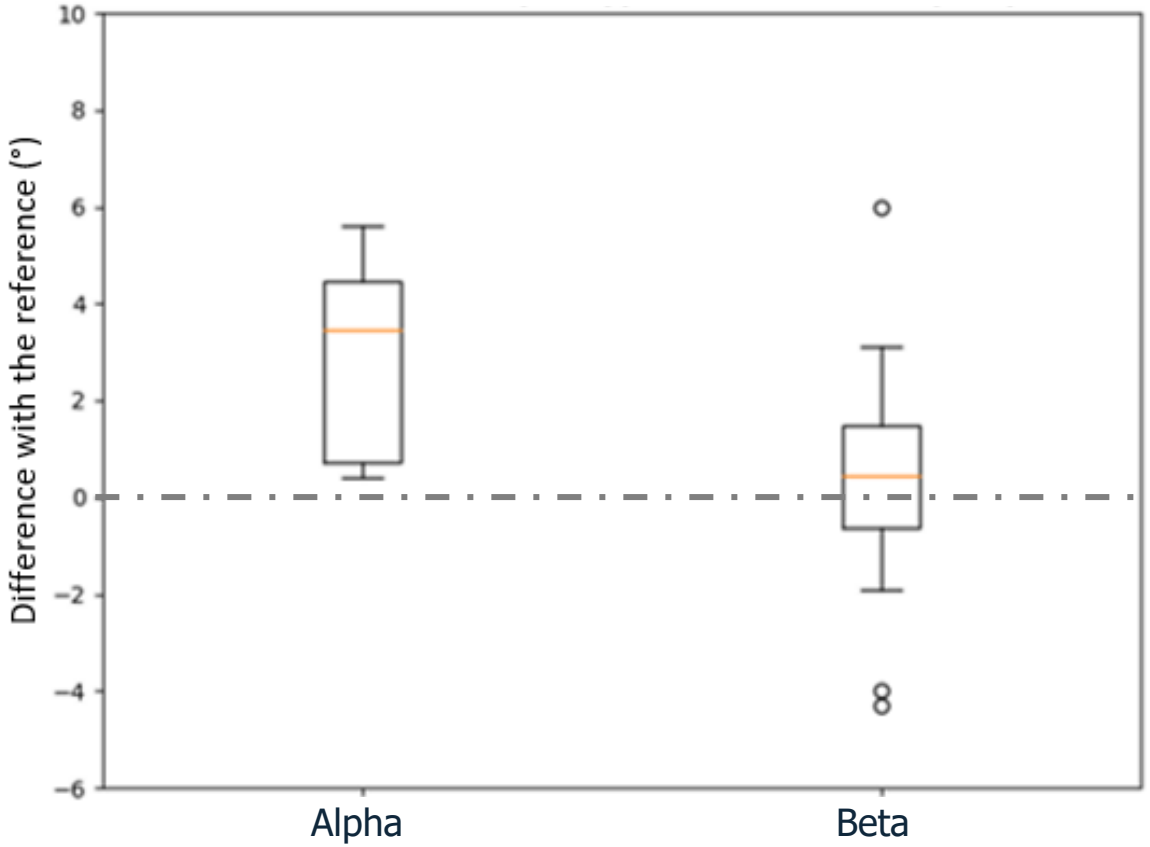
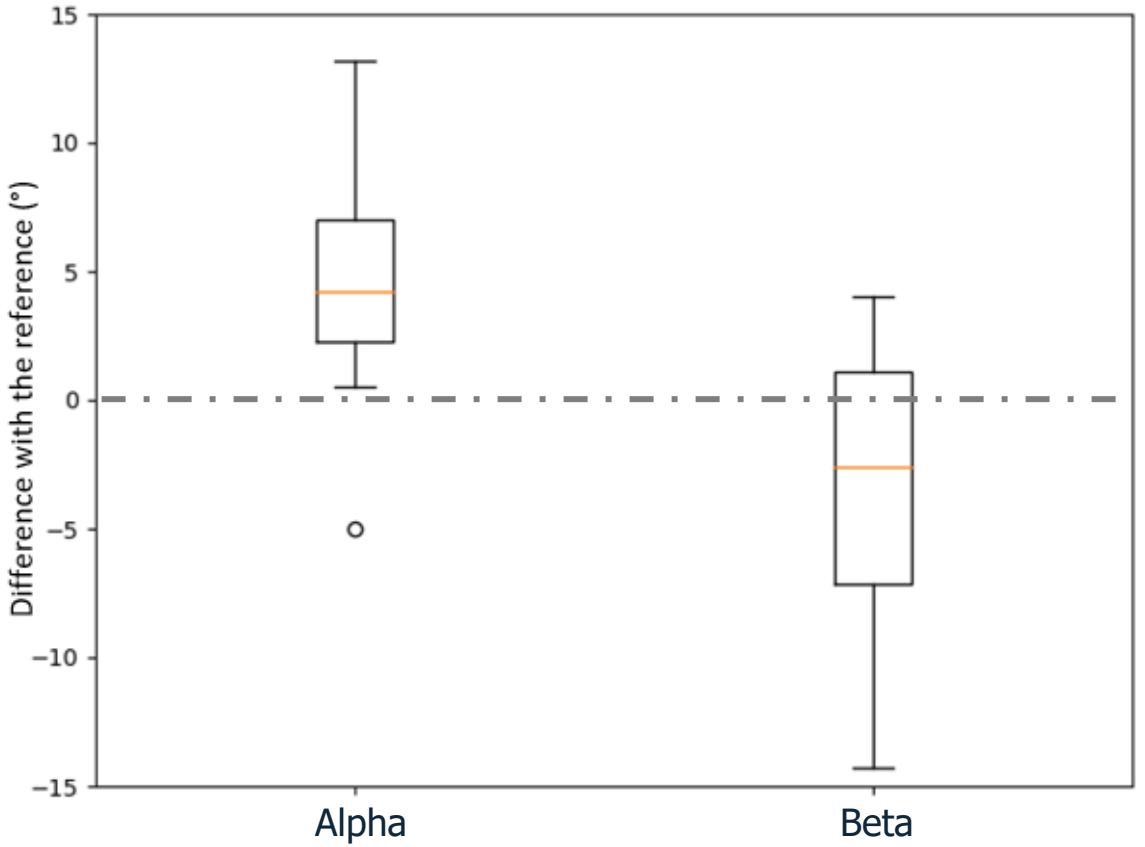
RESULTS: PRE-OP

Projection-based method
(presented previously)



Simulated X-rays
(not reported here)



- **Overestimation of α** with both methods
- Higher dispersion of β for the simulated X-rays

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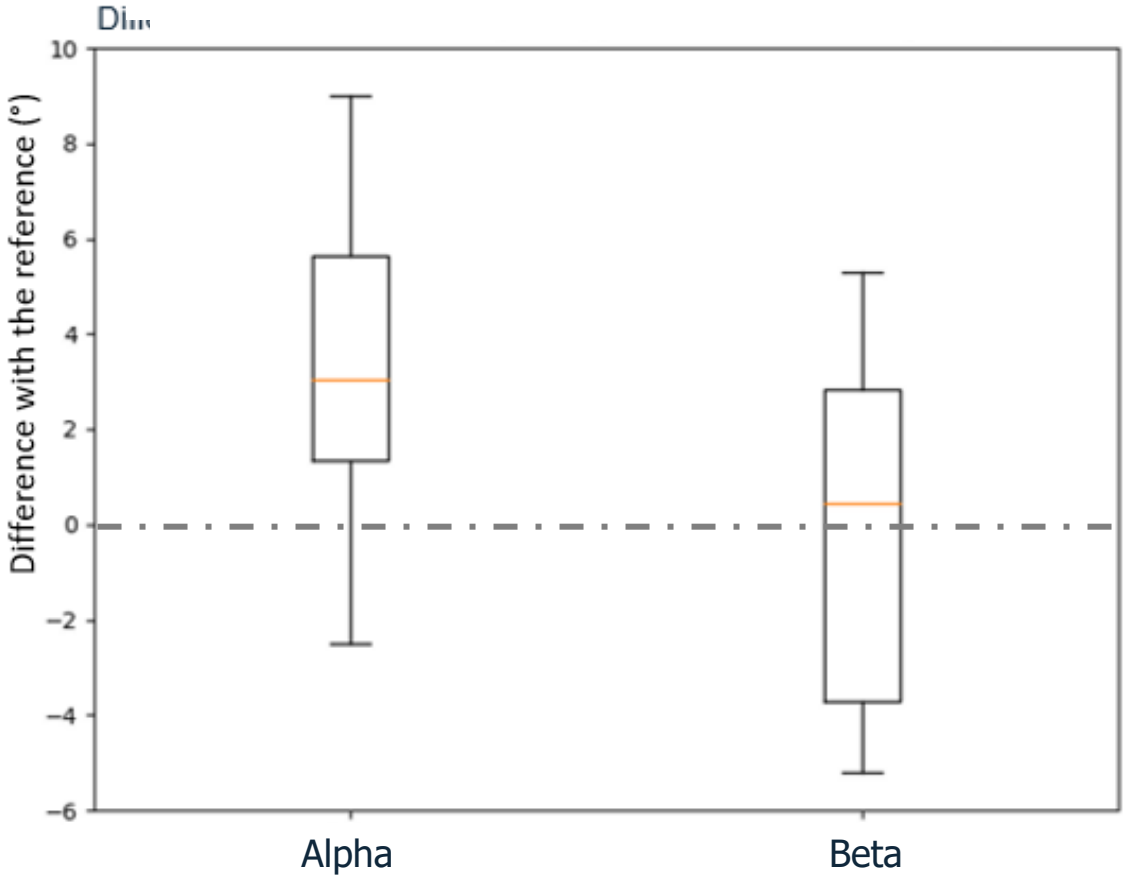
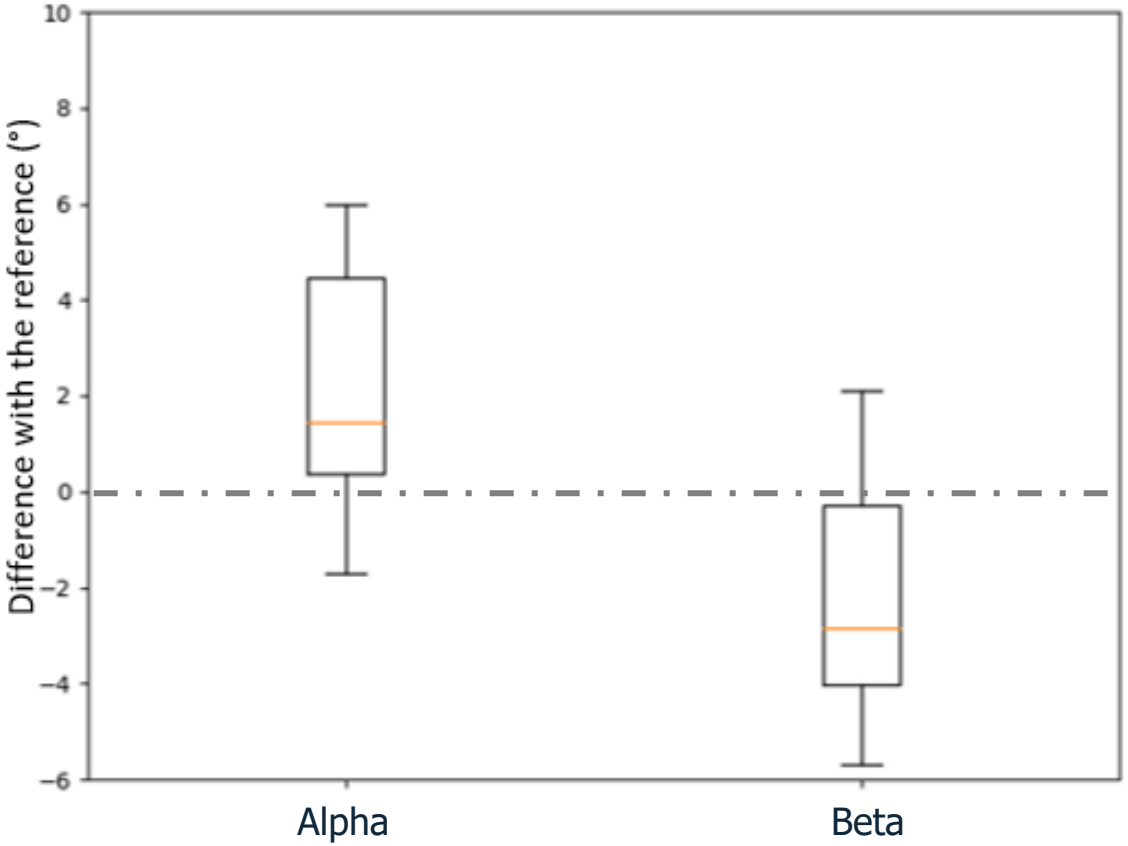
RESULTS: POST-OP

Projection-based method
(presented previously)



Simulated X-rays
(not reported here)



- Lower dispersion with the **simulated X-rays** for both α and β
- **Median difference close to 0:** for β with the pojection-based method
  for α with the simulated X-rays method

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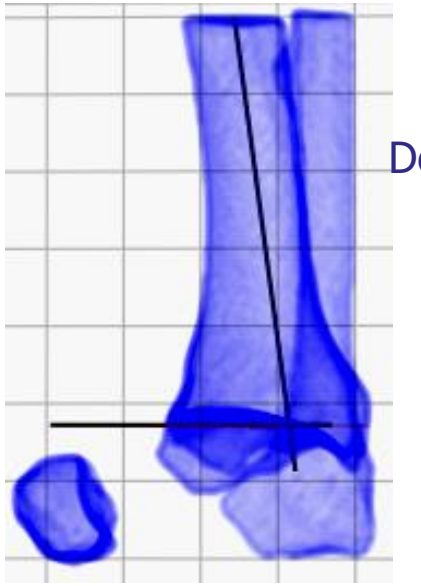
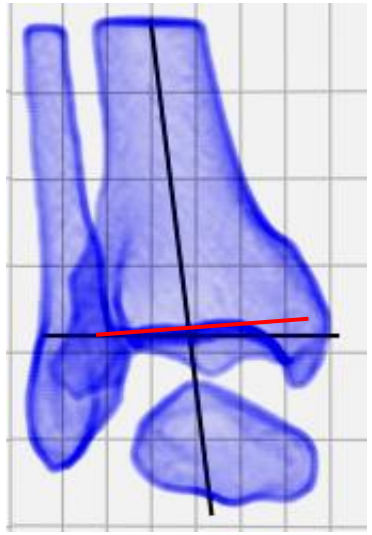
DISCUSSION: SOURCES OF ERROR

- **3D method**



Deformed tibia ➔ unusual axis

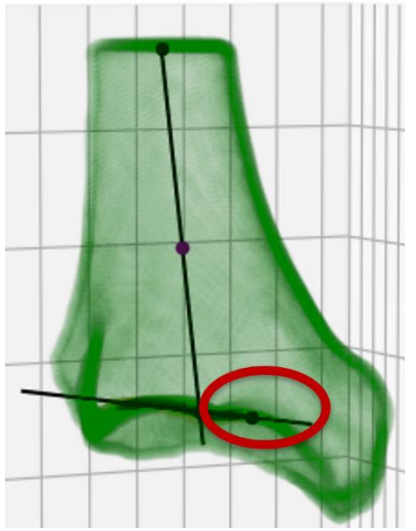


Various approximations of the tibial plafond

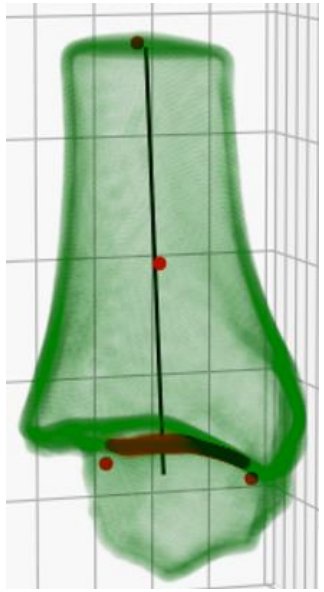
Surgeon's measure

Automated measure

- **2D method**



Highly sensitive to the segmentation quality



Reference = 1 radiological (2D) measure, done by 1 surgeon ➔ **reproducibility study?**

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OBJECTIVES

Objective 1: Clinical parameters

1. Assess the performance of the Cone Beam for pre-operative planning
2. Use of segmented CT/ CB scans : method developped during a thesis last year

11 patients Post-op (M+4), 14 patients Pre-op

(Performance based on the measure of clinical parameters)

Objective 2: Densitometry

1. Study of the effect of the Bone Mineral Density (BMD) on the surgical follow-up *(So et al., 2022)*

➔ Assessment of the CB as a tool for densitometry

(BMD taken into account for other types of arthrosis (hip, knee) but not for the ankle)

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BMD IN REGIONS OF INTEREST (ROI)

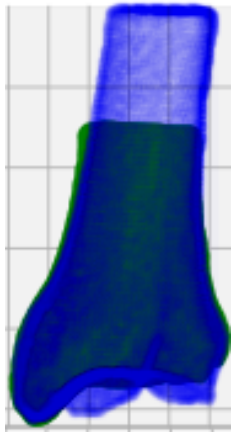
Issue: the distal part of the tibia is resected during the surgery.

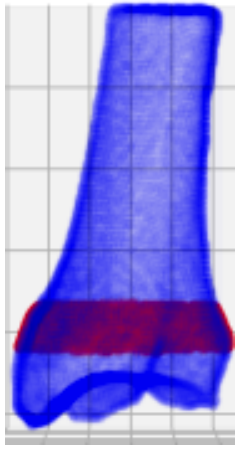
➔ **How to choose similar areas in pre/post-op?**

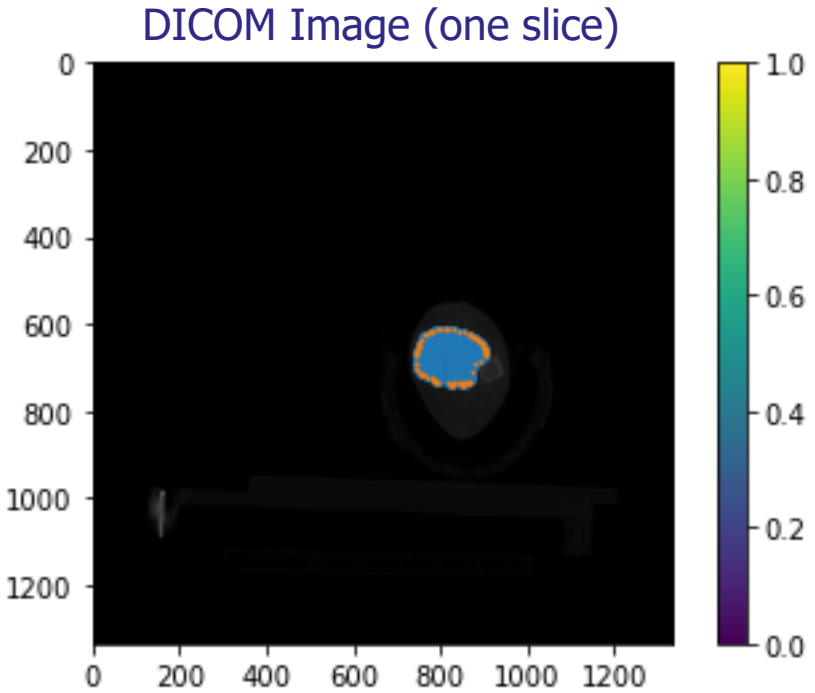
A) Bone alignment: ICP based on the highest point of the implant

B) Definition of ROIs

C) Differentiation cortical vs. trabecular bone (filtering)







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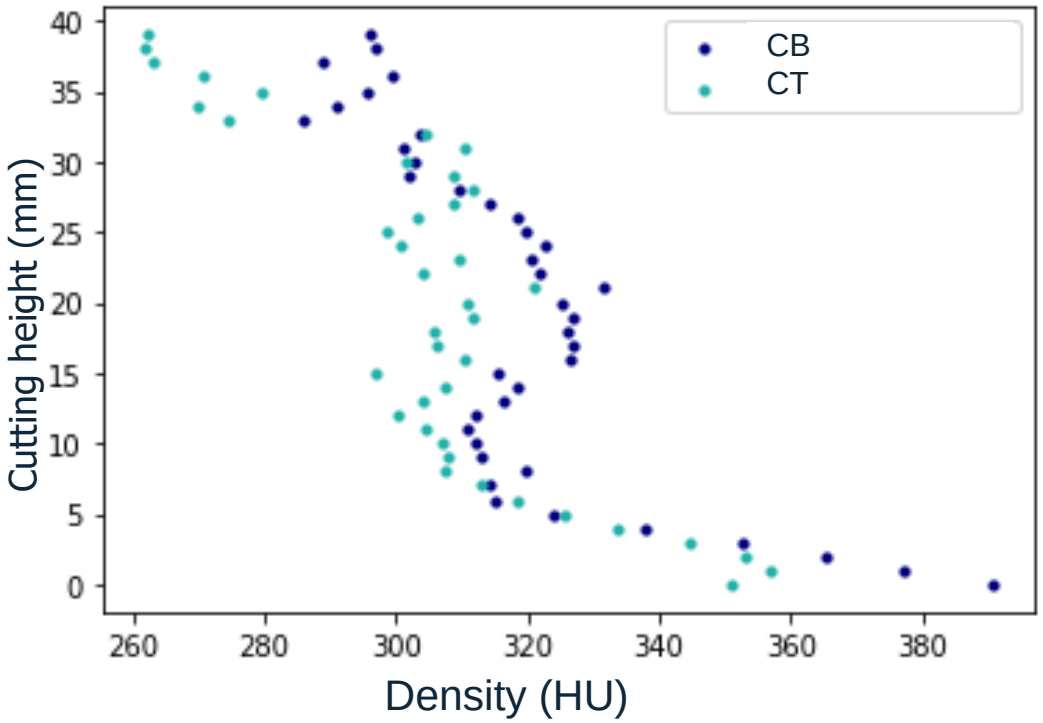
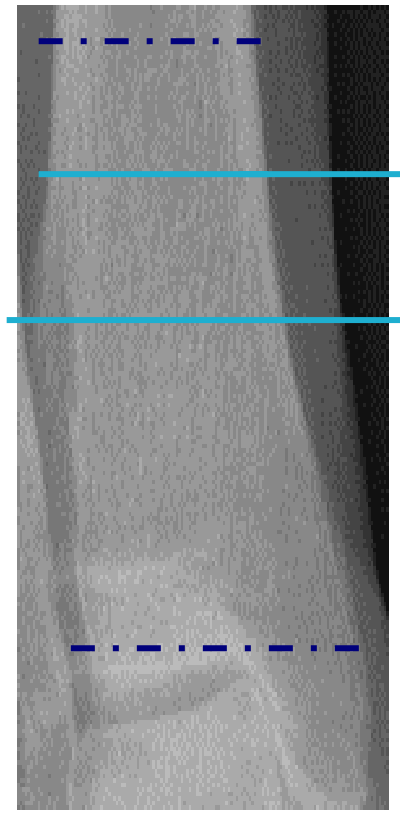
1) BMD: CT vs CB

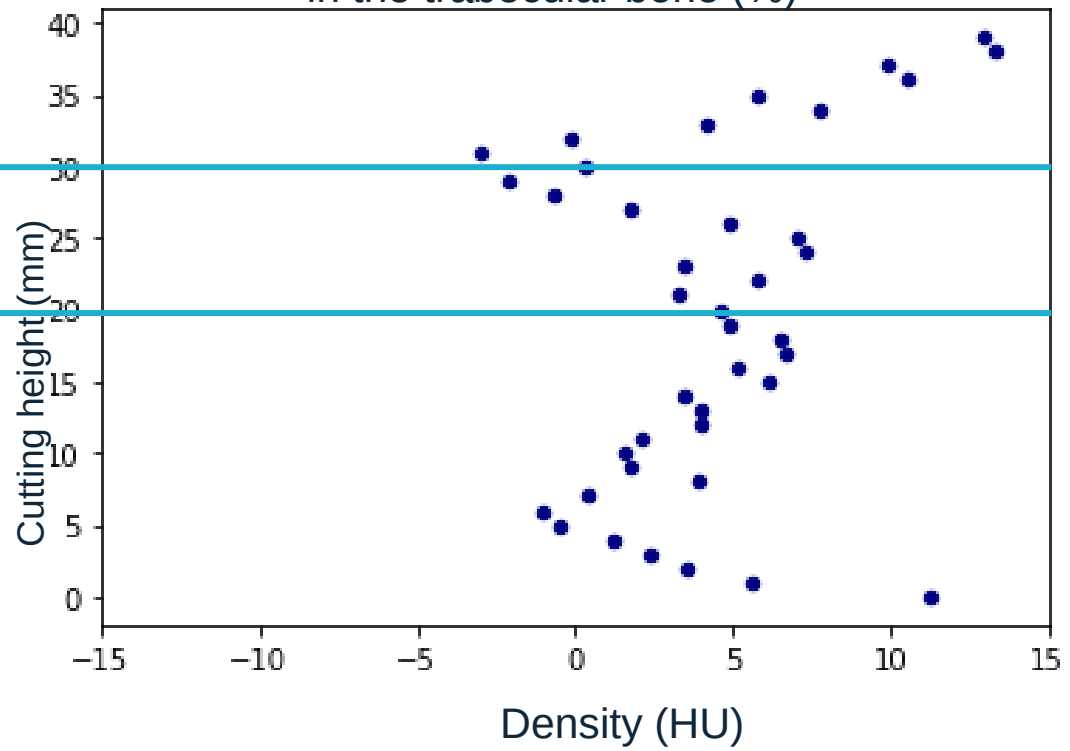
- 1 patient with 2 pre-operative scans: 1 CB + 1 CT
- Comparison of the density per slice in the trabecular bone

CT vs. CB: Comparison of the density per slice





CT vs. CB: Difference of density per slice in the trabecular bone (%)



20-30 mm above the implant = lower differences ➔ **area choosen for the step**

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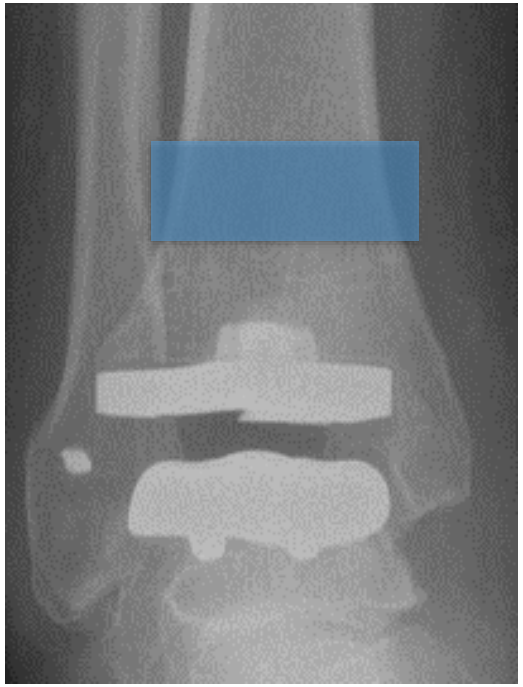
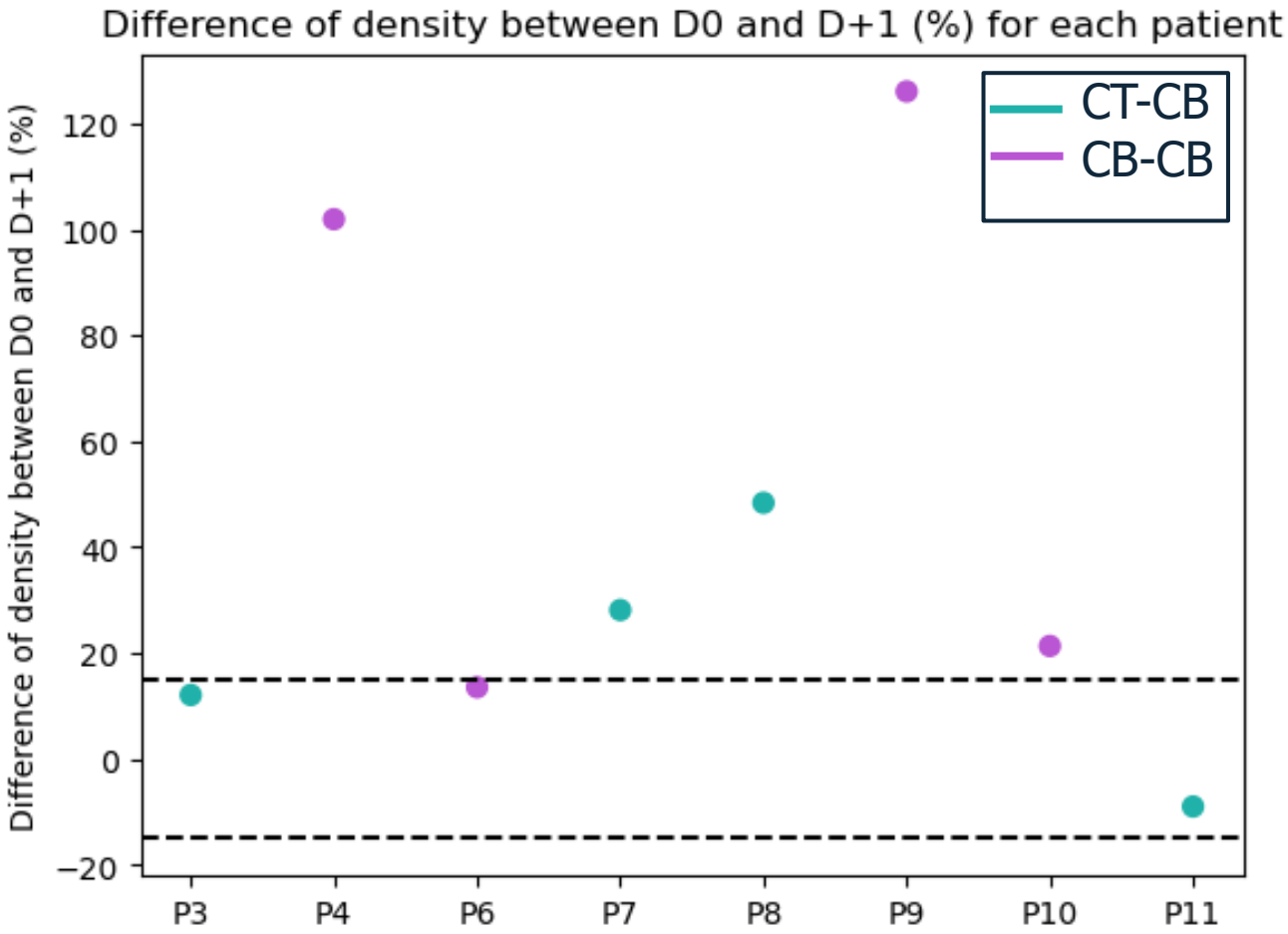
2) COMPARISON OF DENSITY D0/D+1

(H): No density variation between D0 and D+1



No metal artifact



High differences (>15%), even between CB ➔ **hypothesis (H) rejected**

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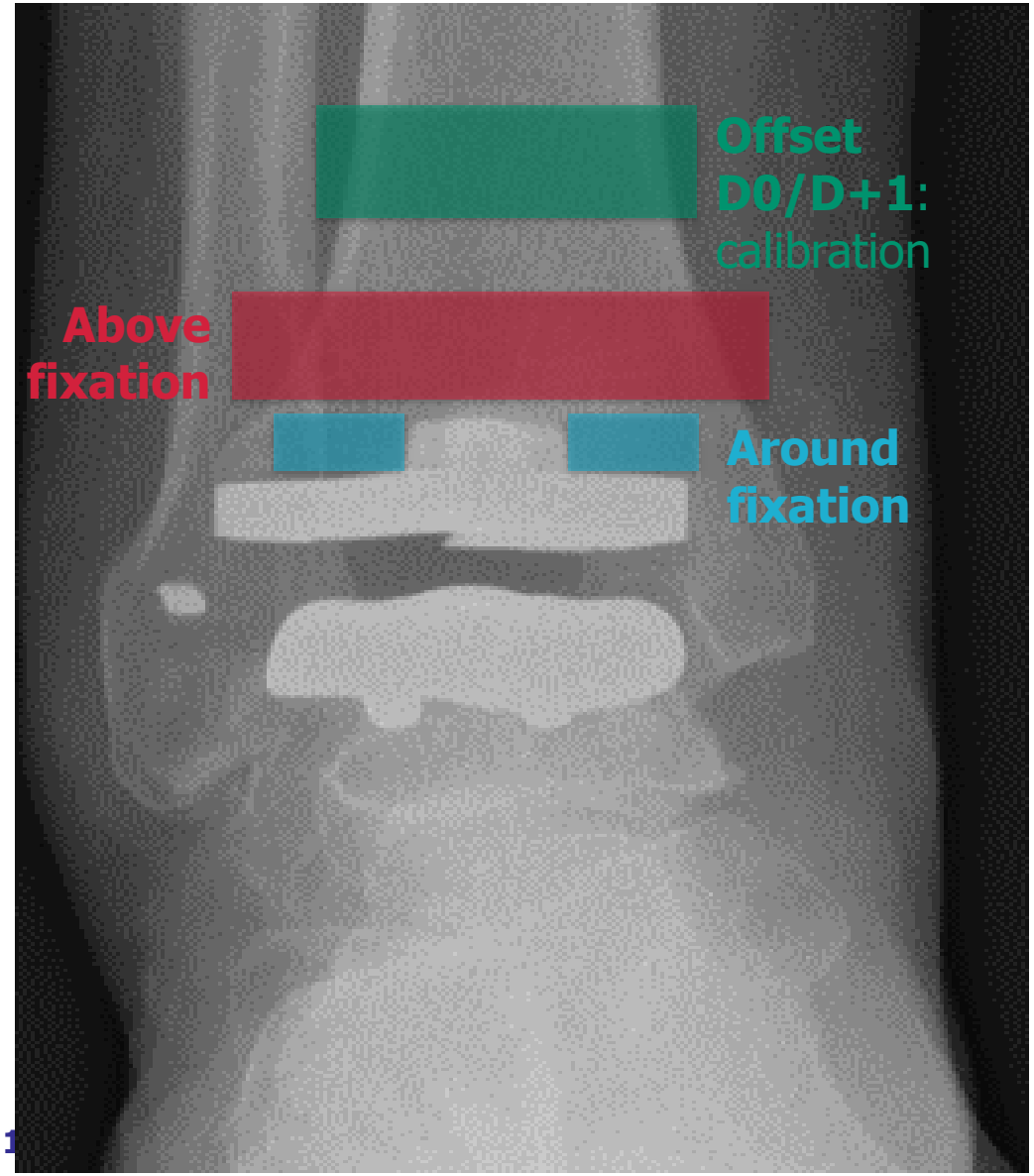
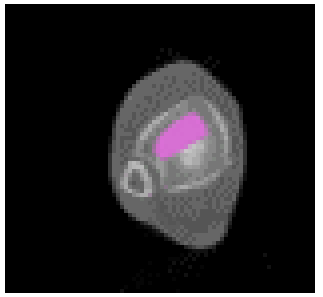
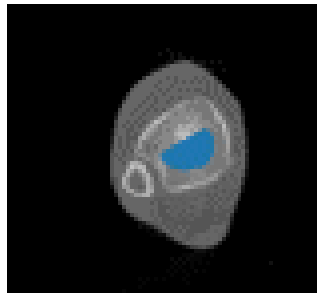
3) APPLICATION: BONE REMODELLING AND RE-ALIGNEMENT OF THE ANKLE



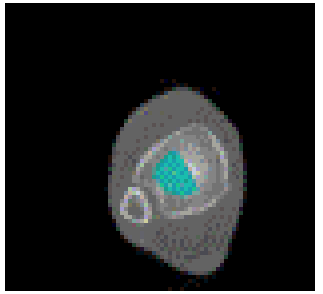
Subdivision in ROIs:



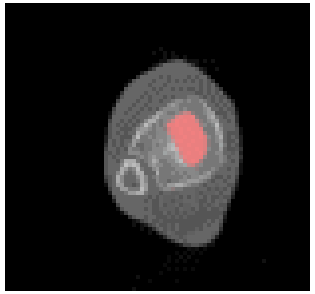
Anterior



Posterior



Medial



Lateral

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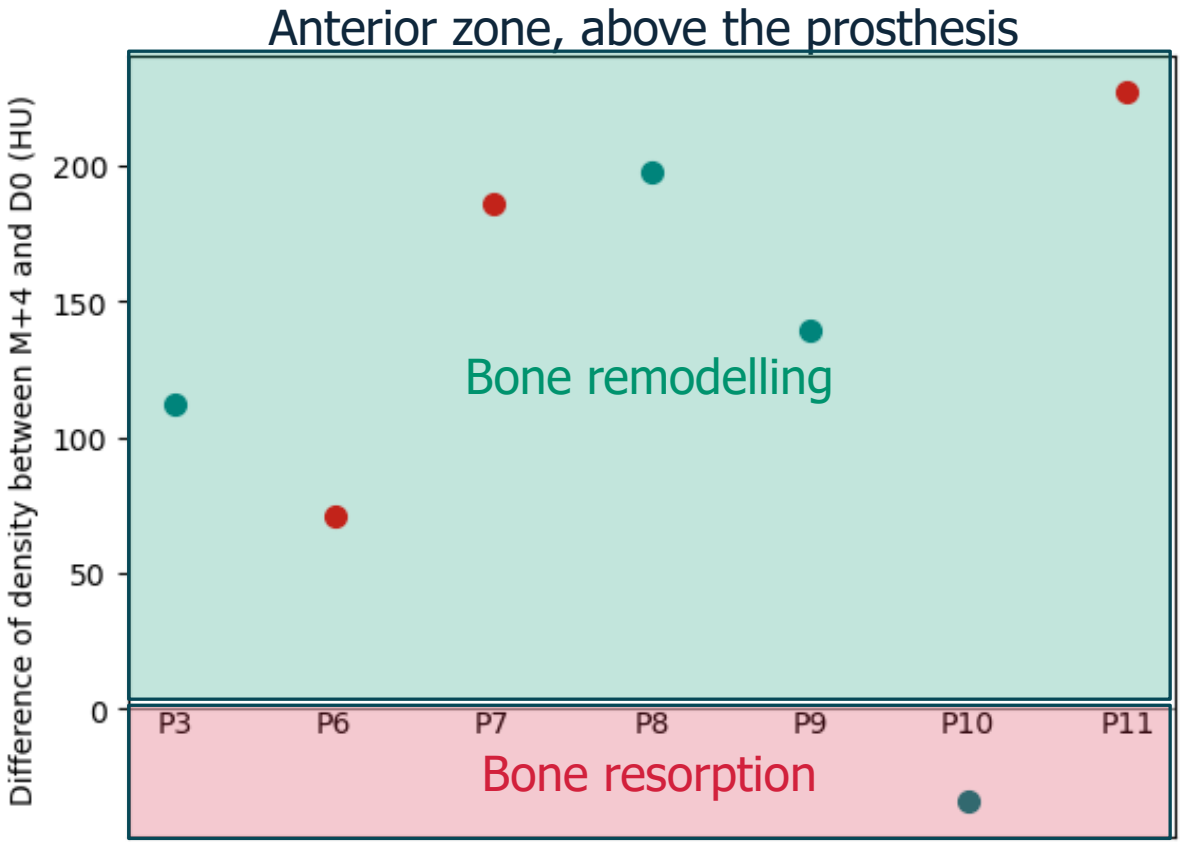
3) BONE REMODELLING AND BONE RESORPTION

(H): Patients with a prosthetic failure suffer from bone resorption
Method: Check the BMD evolution between M+4 and D0 in 4 ROIs for 7 patients (3 with a failure, 4 without)



Statistically significant ($p<0.05$) **bone remodelling** for patients with **prosthetic failure ➔ (H) rejected**

➔ Failure due to prostethis misalignment?

CONCLUSION

- CB ➔ innovative, recent, beneficial for patients (low dose, fast)
- Can the CB replace the CT?

Geometrical information

☑ Information on 3D geometry

☑ Access to new 3D parameters

☐ Relevance of 3D vs. 2D parameters

☐ Reproducibility study on 2D parameters

Densitometry

☑ Information on BMD in various ROIs

☐ Asynchronous calibration of CB images using a phantom

☐ Integration in a clinical routine

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ACKNOWLEDGMENTS

- GI-EIF graduate school for funding this intership!
- Dr JL. Besse, Pr JB. Pialat, Pr A. Viste, operators in the Radiology Department

Thank you for your attention !