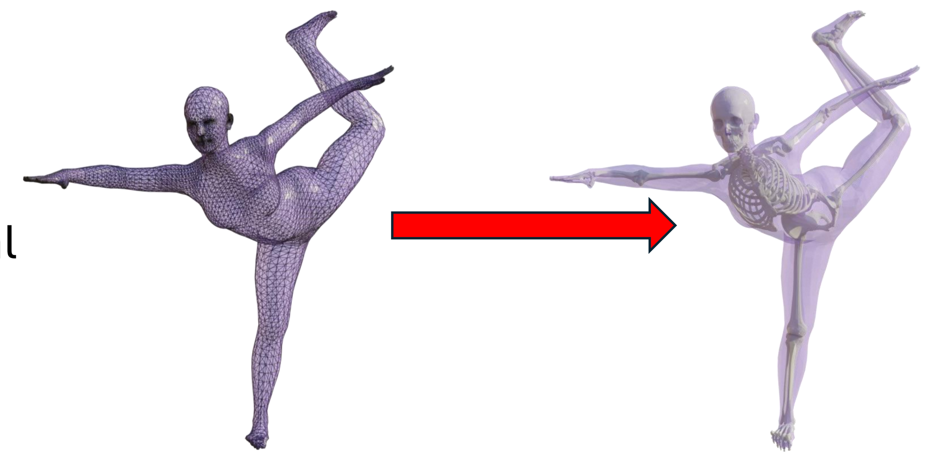
On predicting 3D bone locations inside the human body

Abdelmouttaleb Dakri[1*], Vaibhav Arora[1*], Léo Challier[1], Marilyn Keller[2], Michael J. Black[2], and Sergi Pujades[1]
[1] Univ. Grenoble Alpes, Inria, CNRS, Grenoble INP, LJK, France
[2] Max Planck Institute for Intelligent Systems, Germany
* Equal contribution

Context

Objective: Predict The location of internal structures from external surface observations.



Previous approaches & applications:

1. Traditional approaches: Medical imaging (CT scan – X Ray) ➔ Radiation.
2. Learning based: OSSO[1] from 2D DXA images, SKEL[2] for synthetic biomechanics simulation with MoCap data ➔ Lacks 3D information.

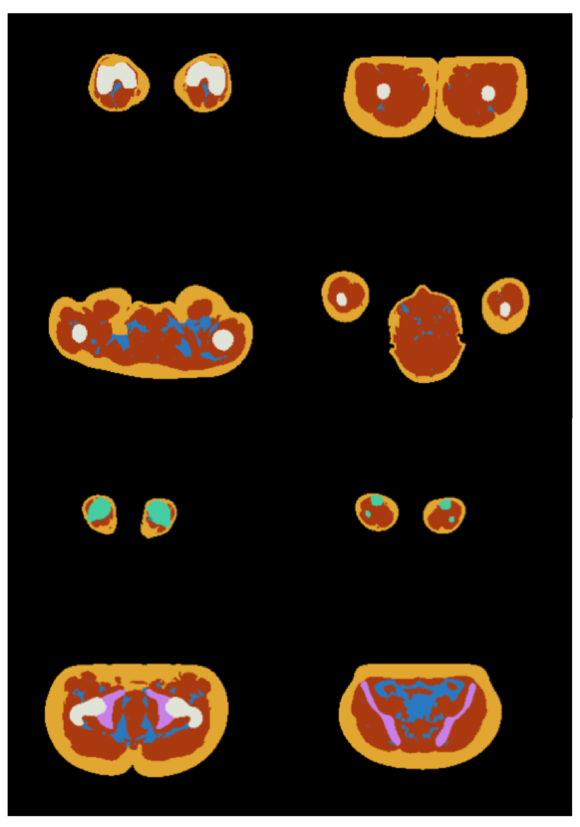
Our approach: Leverage the HIT[3] MRI dataset to create accurate 3D skeletal data to learn a better regressor for SKEL.

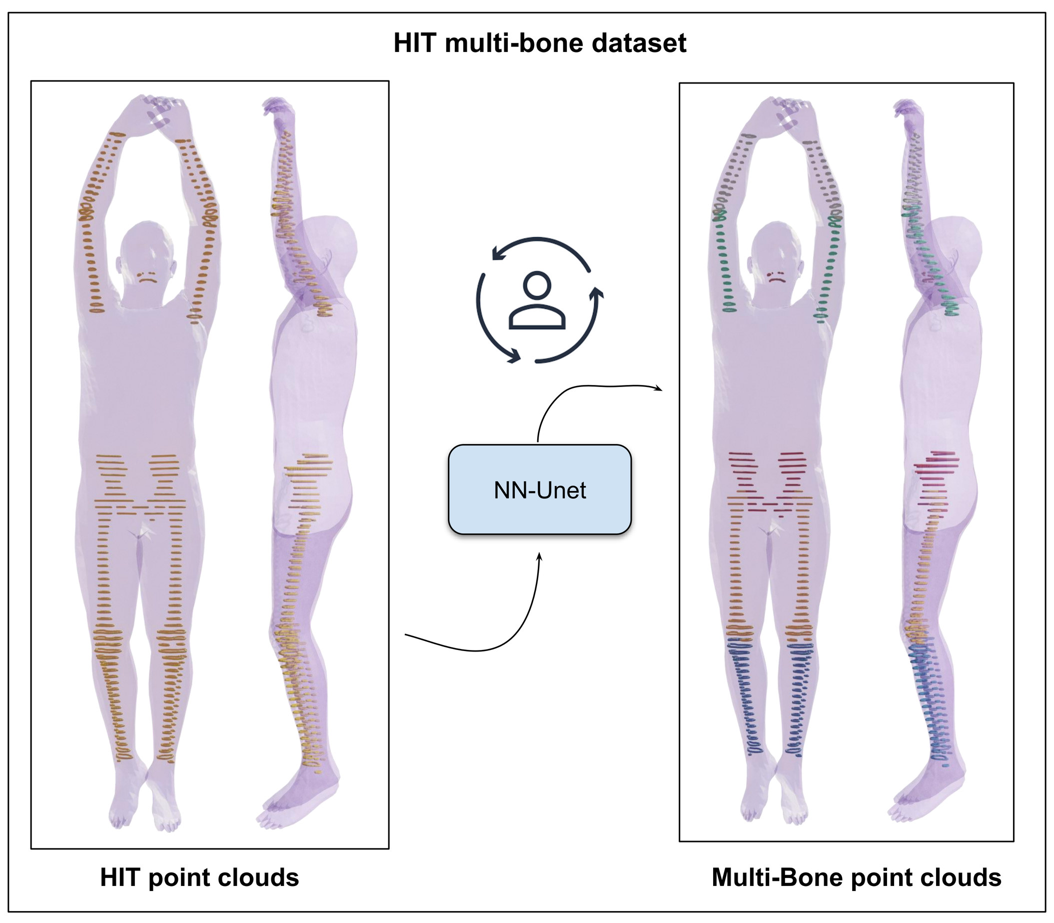
Contributions:

1. **Multi bone** segmentation data set w/ ground truth SKEL registrations.
2. A specialized **registration method and regressor**.
   1. An additional degree of freedom ΔJ to the skeleton from skin prediction.
   2. A trained joint regressor to replace standard SKEL based on 3D data.

(1) The HIT Multi-bone Dataset

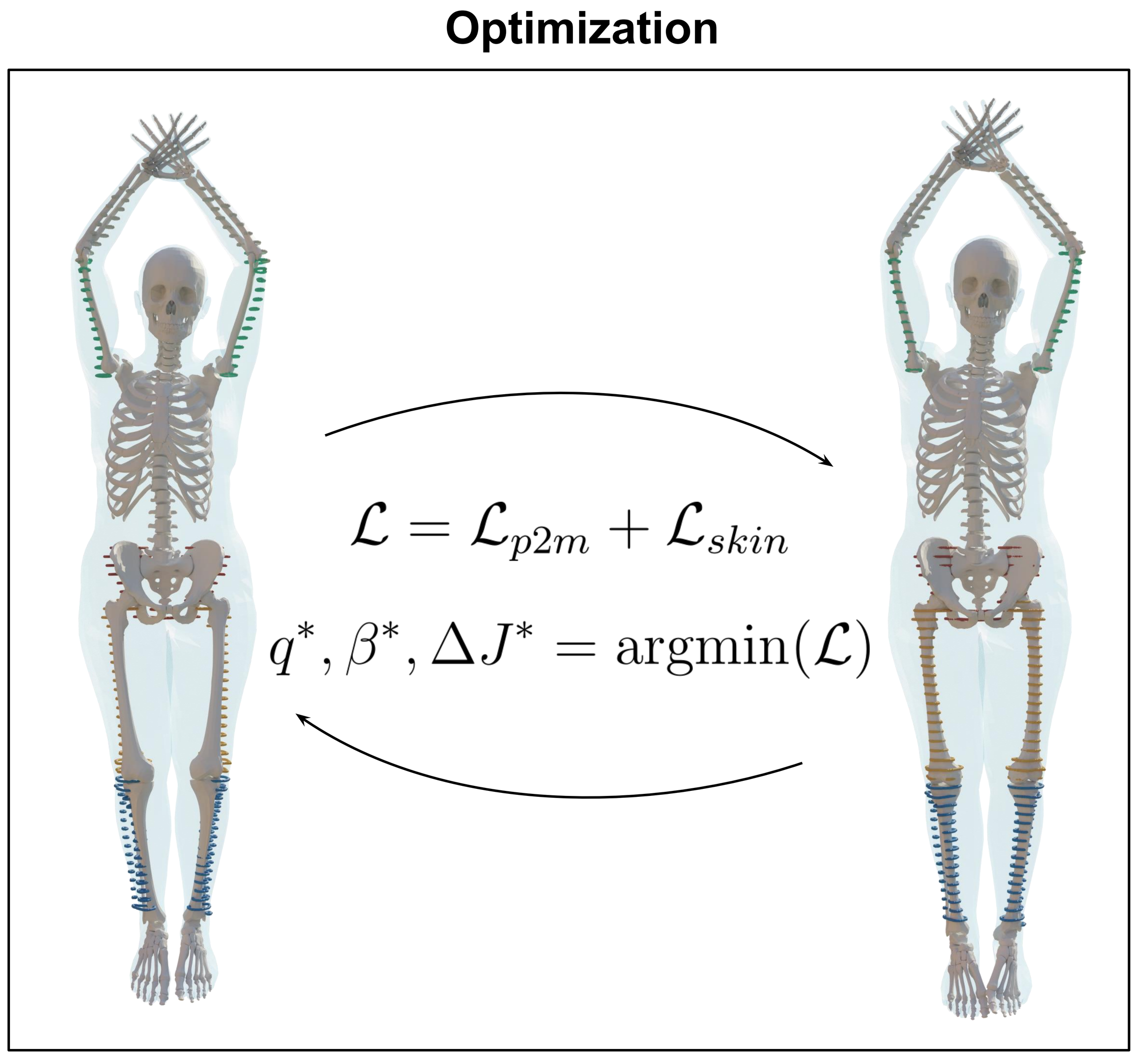
An MRI multi-bone dataset: 381 full body MRIs (235 females, 146 males) of **5 bone sub-groups (humerus, radius-ulna, pelvis, femur, and tibia-fibula)**.

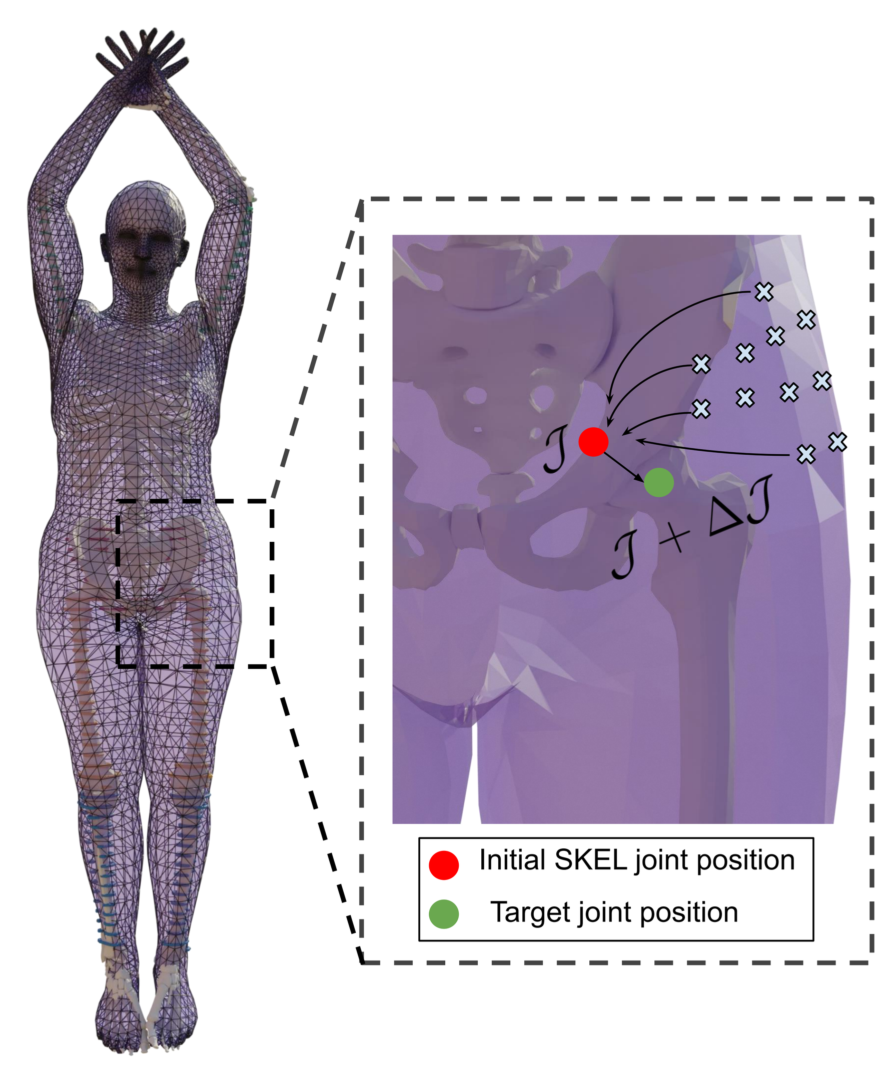


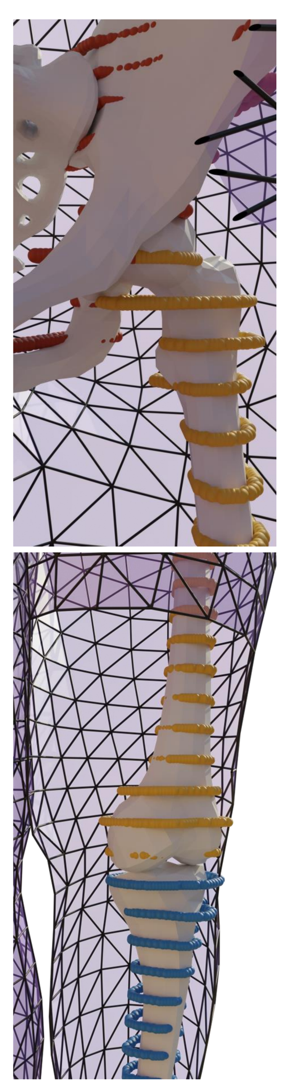


(2) Registration Process and SKEL-J

Optimization

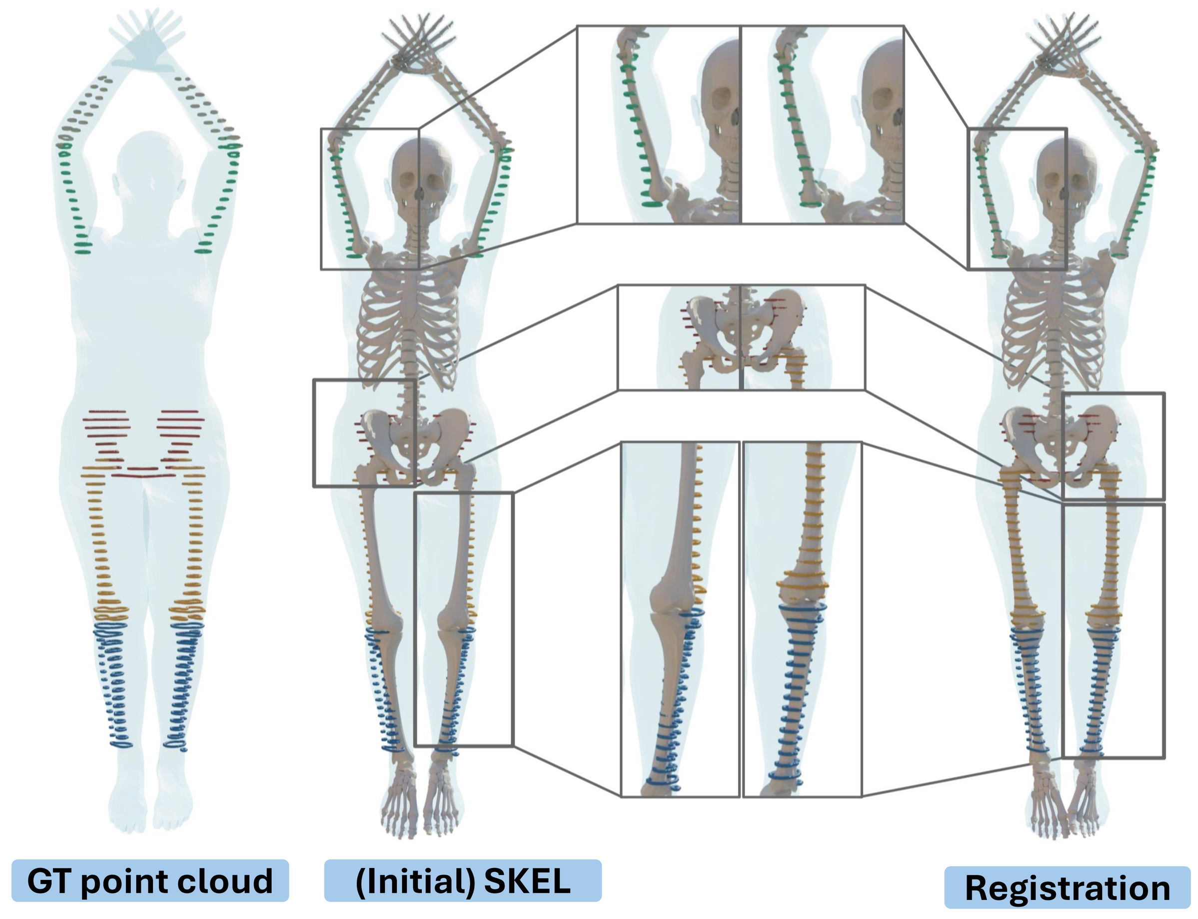


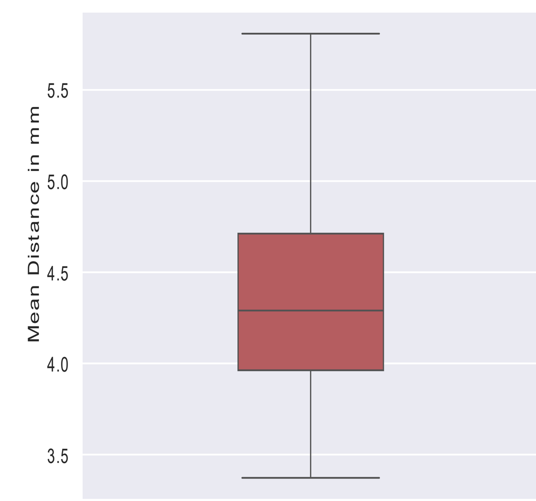




Experiments & Results

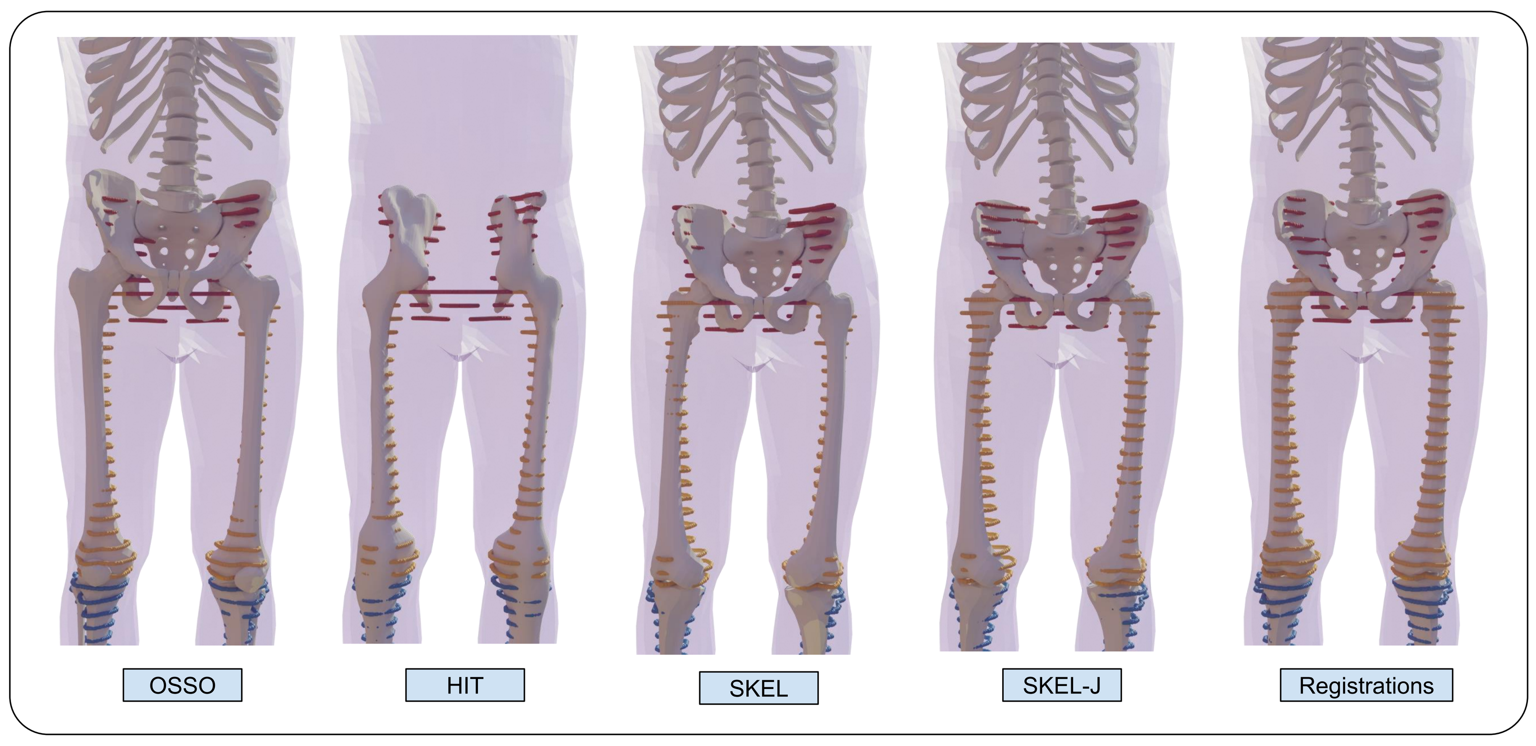
Bone registration accuracy



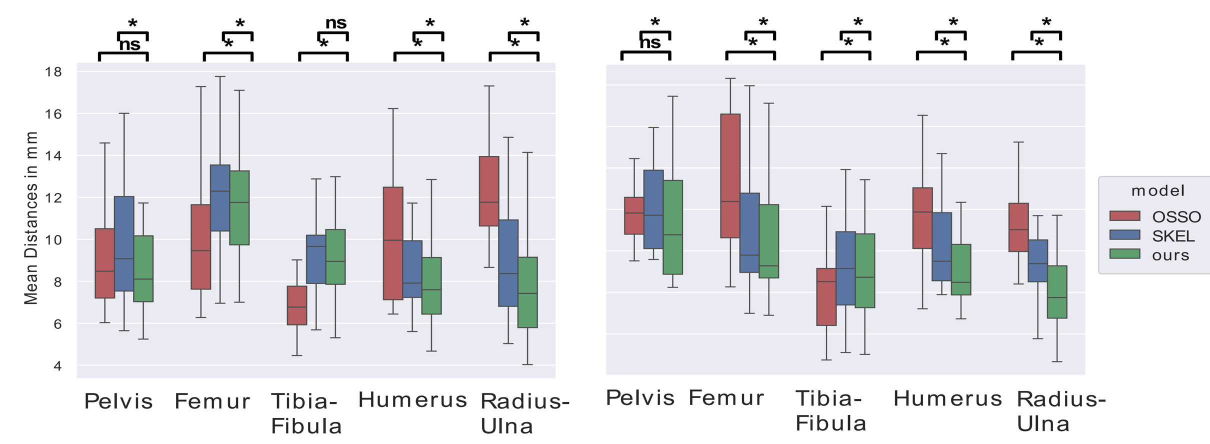


Mean template to bone distance

Bone prediction accuracy



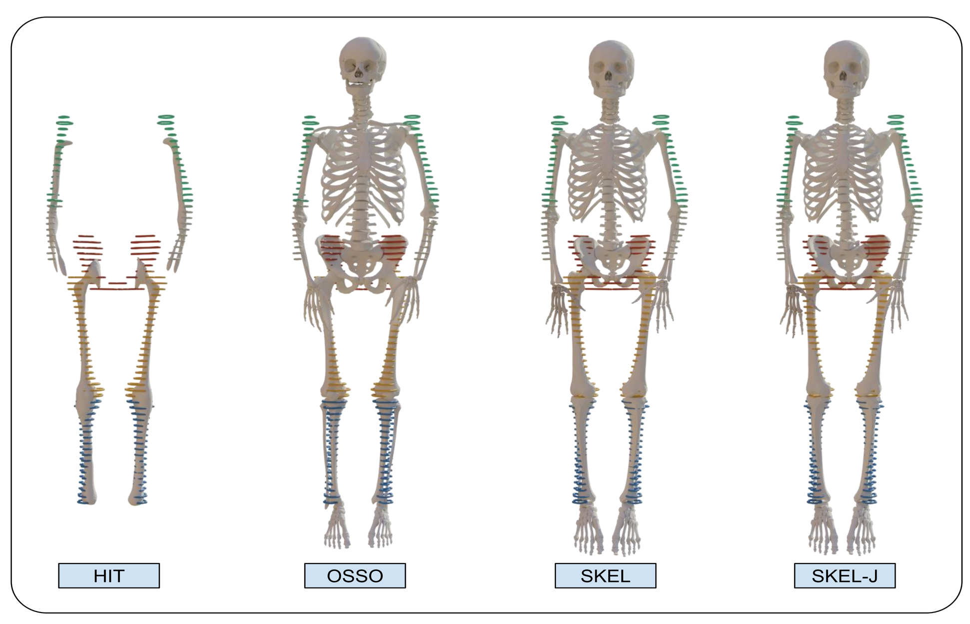
Mean per bone prediction error



Mean prediction error comparison

	Female				Male			
	Mean	Std	Min	Max	Mean	Std	Min	Max
OSSO	9.79	3.23	4.46	18.3	11.42	3.27	4.74	19.63
SKEL	9.95	3.34	5.02	22.74	10.67	3.06	5.09	19.59
SKEL-J	**9.32**	3.34	4.03	21.84	**9.72**	2.87	4.66	17.45

Evaluation on supine patients



References

[1] OSSO: Obtaining Skeletal Shape from Outside. *Keller, Zuffi, Black and Pujades (CVPR 2022).*

[2] From Skin to Skeleton: Towards Biomechanically Accurate 3D Digital Humans. *Keller, Werling, Shin, Delp, Pujades, Liu and Black (ACM siggraph Asia 2024).*

[3] HIT: Estimating Internal Human Implicit Tissues from the Body Surface. *Keller, Arora, Dakri, Chandhok, Machann, Fritsche, Black and Pujades (CVPR 2024).*