Finite element simulations of human gait in healthy and operated hip: a new method to evaluate prosthesis design.

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Introduction

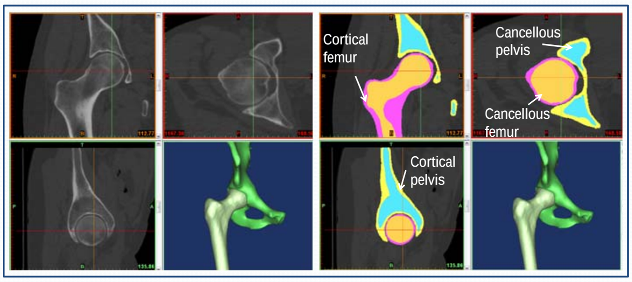
Hip disorders as cartilage degeneration or bone fracture are common pathologies which are often treated with prosthetic surgery. Although **hip prosthesis** have been widely studied, their life still being shorter than desirable. The aim of this work is to **compare** different stems and bearing materials to asses the best option based on the following criteria:

- Reduce the **stem loosening** which is caused by the lack of mechanical loads in bone.
- Reduce **wear** in bearing surfaces.

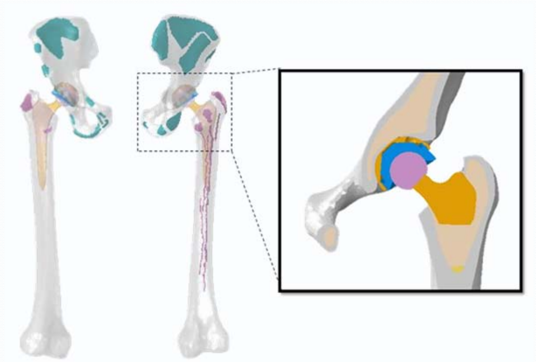
Previous works studied the hip joint computationally from two different points of view: inverse dynamic (Bergman et al.,2001) and finite element (FE) analysis (Dopico-Gonzalez et al., 2010, Stolk et al., 2001). In spite of the availability of reaction and muscle forces data during gait cycle, only quasi-static analysis have been made using FE.

Here a **continuous gait cycle** has been simulated and validated in a healthy hip joint introducing reaction and muscle forces. This model has been modified to introduce different prosthesis allowing the comparison between geometries and bearing materials.

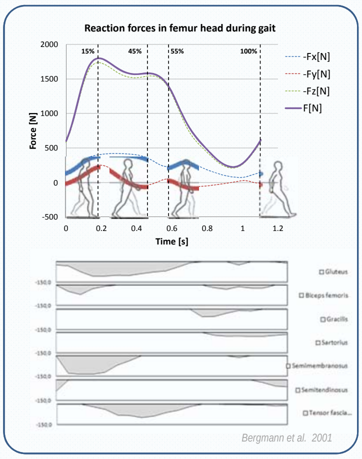
Materials and methods



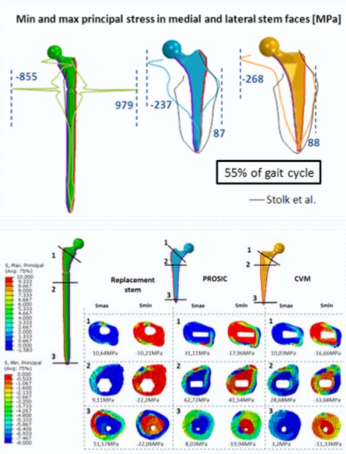
A healthy hip joint was segmented with **Mimics®** distinguishing between cortical and cancellous bone and bone marrow based on pixel intensity. The geometry was extracted from **Mimics®** and was modified to introduce the implants. Muscles, ligaments and articular cartilages were modelled in accordance with anatomic atlas.

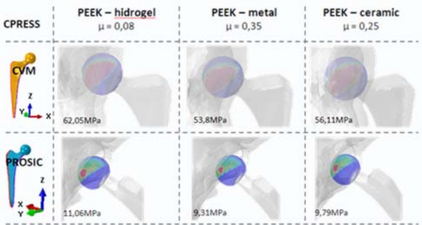


Results



A gait cycle was simulated introducing the reaction forces and the principal muscle contributions. Tension and compression stresses were analysed in lateral and medial stem surfaces. A stress concentration peak was found in replacement stem. Also the mechanical loads transmitted to the bone were measured. While replacement stem did not transmit high loads, PROSIC one maintains a stress distribution avoiding bone resorption and stem loosening.





Shear stress [MPa]	PEEK – hidrogel μ = 0,08	PEEK – metal μ = 0,35	PEEK – ceramic μ = 0,25
15%	0,63	11,76	9,11
45%	0,313	2,71	2,15
55%	-1,65	-18,82	-14,02
100%	1,59	20,03	15,13

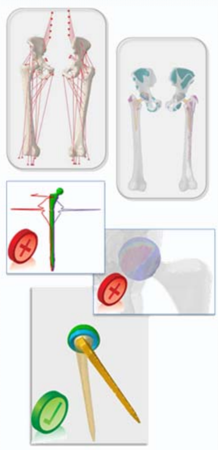
Shear stress [MPa]	PEEK – hidrogel μ = 0,08	PEEK – metal μ = 0,35	PEEK – ceramic μ = 0,25
15%	0,051	0,72	0,5
45%	0,81	1,14	0,8
55%	-0,299	-3,26	-2,45
100%	0,272	4,124	2,81

Finally, contact pressure and shear stresses were compared for different stems and bearing materials. CVM showed elevated pressures and shear stresses. Hidrogel interface reduced shear stresses because of its low friction coefficient.

Conclusions and future works

A musculoskeletal FE model was validated in a continuous gait cycle. It was concluded that long replacement stem may present fracture risk and also could cause bone resorption and stem loosening.

Also it was noticed that geometry could influence in surface wear as well as bearing materials. Reduce the friction coefficient seems to be a good practice to prolong prosthesis life.



This work has several limitations and could be improved introducing some future advances such as:

- Patient-specific models segmented with Mimics® introducing the prosthesis with 3-Matic ®.
- Considering bone density from the data of pixel intensity.

References

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Stolk J. et al. Hip-joint and abductor-muscle forces adequately represent in vivo loading of a cemented total hip reconstruction. Journal of Biomechanics, 34(3):469-478, 2014

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