Characterisation of Ti6Al4V conditioned surfaces for enhanced wear resistance in biomedical applications

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Outline:

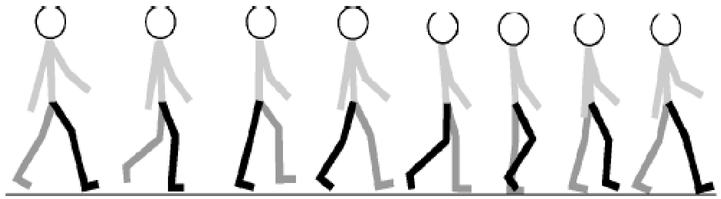
- **Introduction**
  - Industrial and scientific problem
- **Experimental**
  - Machining tests on industrial equipment
  - Surface characterization after machining
  - Wear tests
  - Surface characterization after wear tests
- **Results:**
  - Results of characterization of machined surfaces
  - Results of wear tests
- **Conclusions**

Expectancy of life is continuously increased in recent years and consequently the number of surgeries for hip replacements

Problem:

- Lower wear of hip implants is required

- Sliding at acetabular cup- hip head interface in corrosive environment



Solution:

Prostheses with improved wear properties are needed

Electron Beam Melted Ti6Al4V provided by Eurocoating EXCELLENCE AS YOU DESIGN IT

Main Advantage:
- Manufacture of Near Net Shape component;

Main Problem:
- Machining operations are still required in order to obtain the final shape of AM products.

Fabrication → EBM product → Machining step

Aim of the study: Which are the effect of the machining parameters on the wear behavior of EBM Ti6Al4V for biomedical applications?

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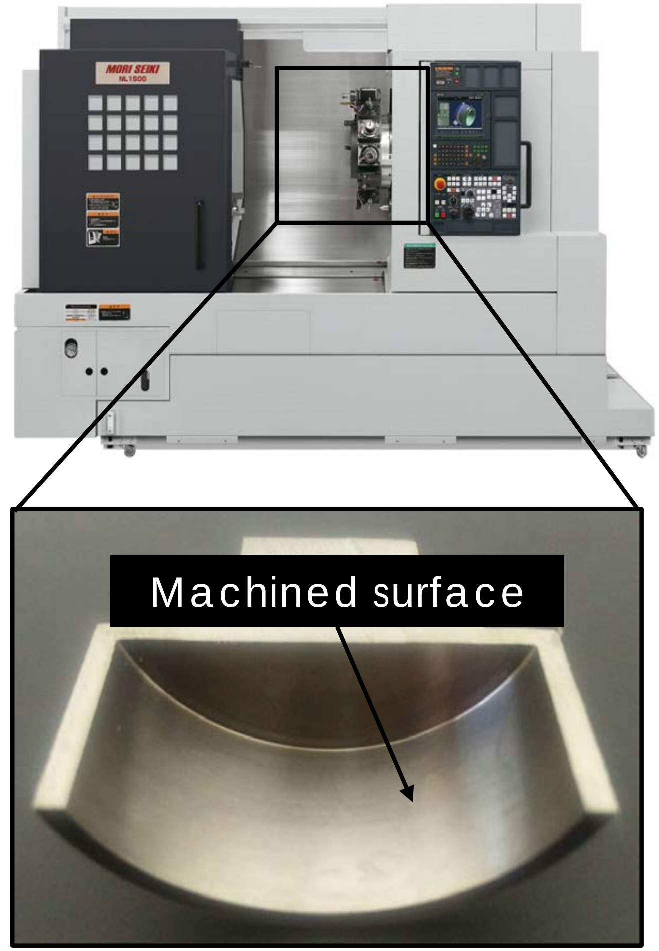
- Machining tests performed on a **Mori Seiki CNC** lathe;
- Internal turning of **the acetabular cup's surface**;
- Special **designed line** to fulfill cryogenic cooling;
- **Finishing** conditions.

Experimental plan:

⇨ **Number of passes** (one & five) to obtain the final shape

⇨ **Lubrication** (Oil emulsion & Cryogenic)



Benefits of Cryogenic Machining:

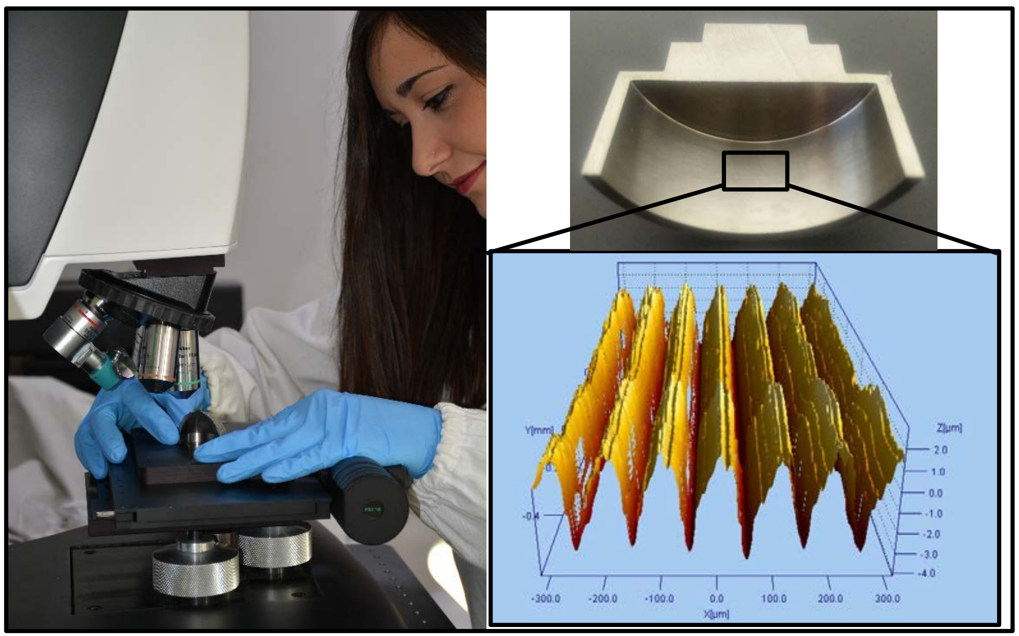
- Reduction of lubricant disposal costs;
- Reduction of sterilization step for surgical implants;
- Increase of the cutting speed;
- Improved surface integrity of the workpiece;

Cryogenic machining is a suitable technique for manufacturing medical devices

Ti6Al4V surface characterization after machining tests

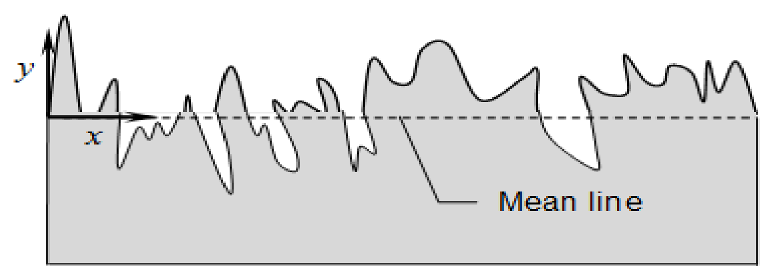
Surface evaluation of the machined surface:

Acquisition of the **topographies** using the Sensofar Plu Neox™ Profilometer using the 20 x objective;

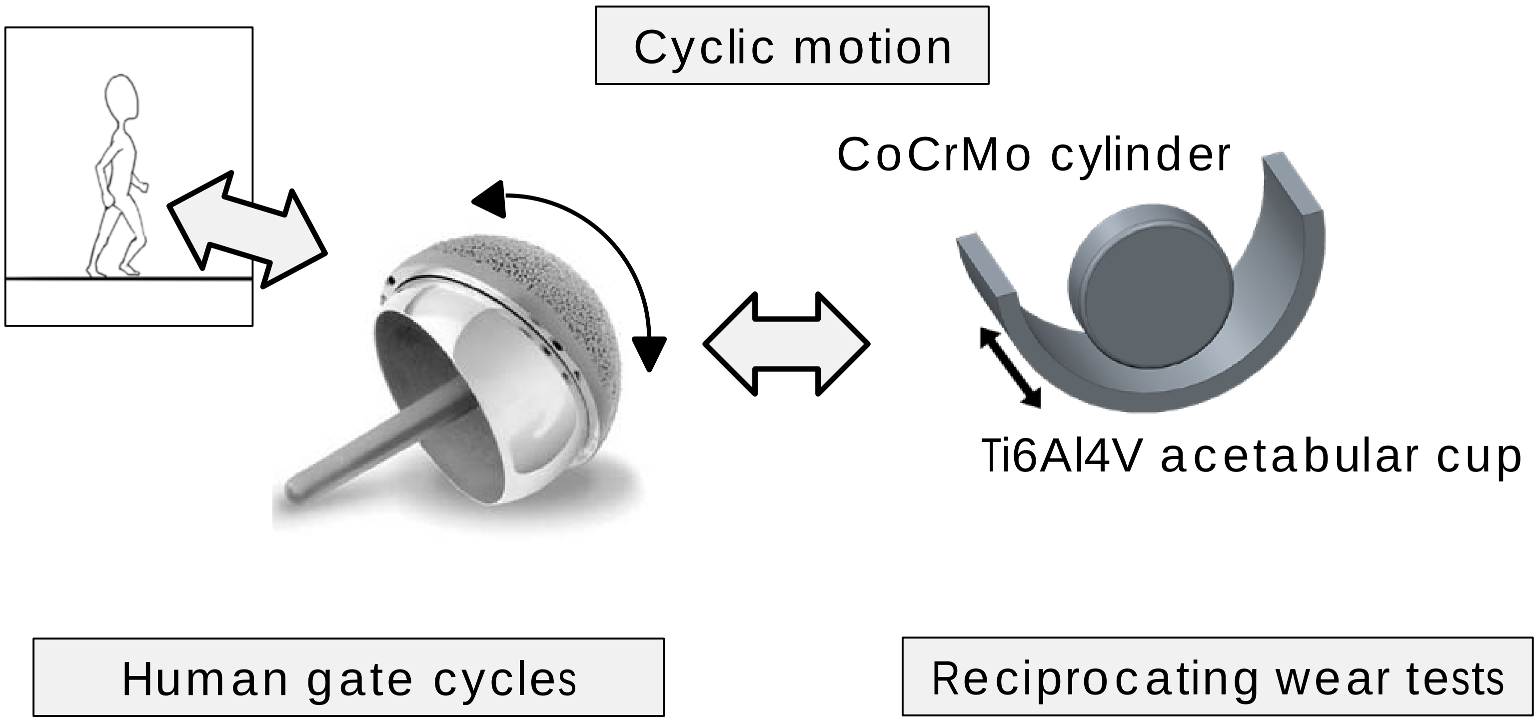


Parameters evaluated:

1. **Sa** (arithmetical mean height);
2. **Ssk** (skewness);
3. **Sku** (kurtosis);
4. **Sk** (core roughness depth);
5. **Svk** (reduced dale height);
6. **Spk** (reduced peak height).



- Simplified wear tests were designed in order to replicate as much as possible human conditions of the acetabular cup-femoral head interfaces.



Wear tests

Equipment:

- Rtec^{TM} tribometer featuring an integrated optical profiler

↓

Online topography characterization allowed;

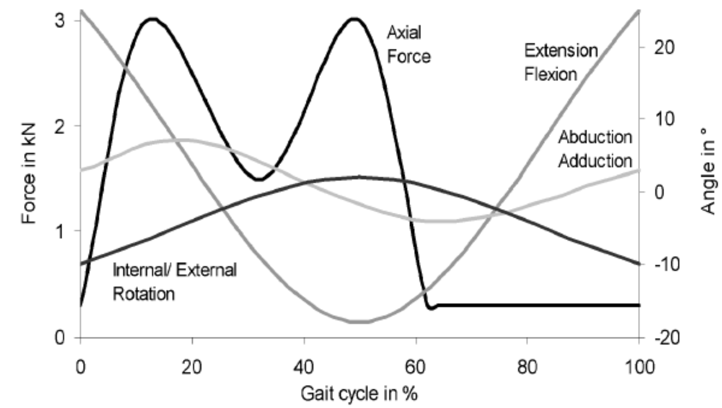
10x confocal objective

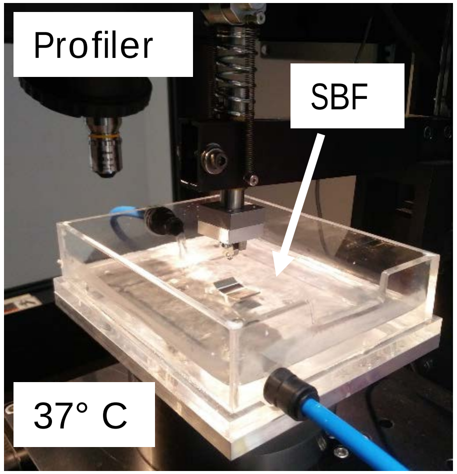
Experimental conditions:

- Sliding length: 3 mm;
- Frequency: 1 Hz (human walk);
- Duration: 3600 cycles;
- Environment: saline solution;
- Temperature: body temperature;
- Load: 3 N in order to reproduce human load;

ISO 14214-1-2002(E)

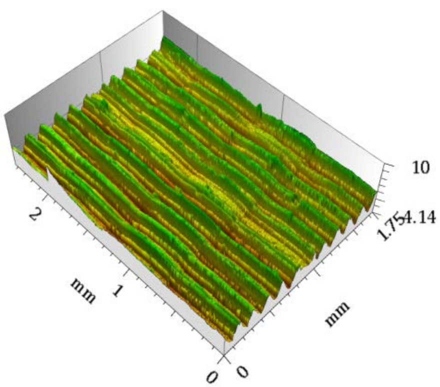
Maximum angle

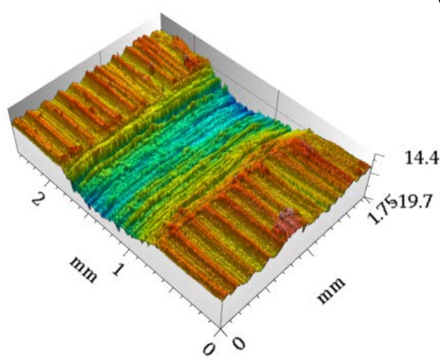


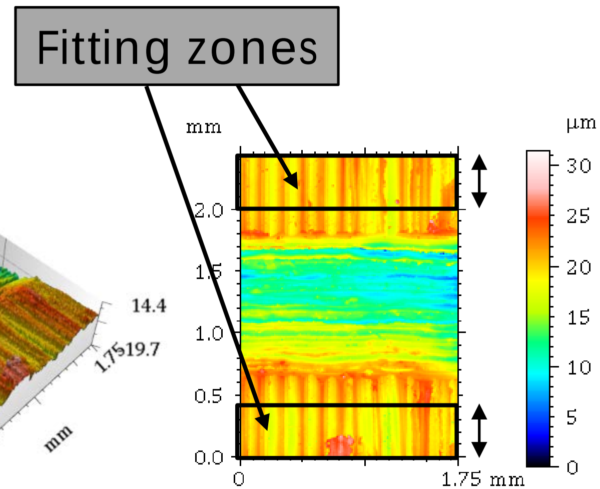


Ti6Al4V surface characterization after wear tests

- Wear volume calculation procedure;







Topography acquisition before tests → **Topography acquisition before tests** → **Processing and fitting corresponding zones** → **Computing of wear volume**

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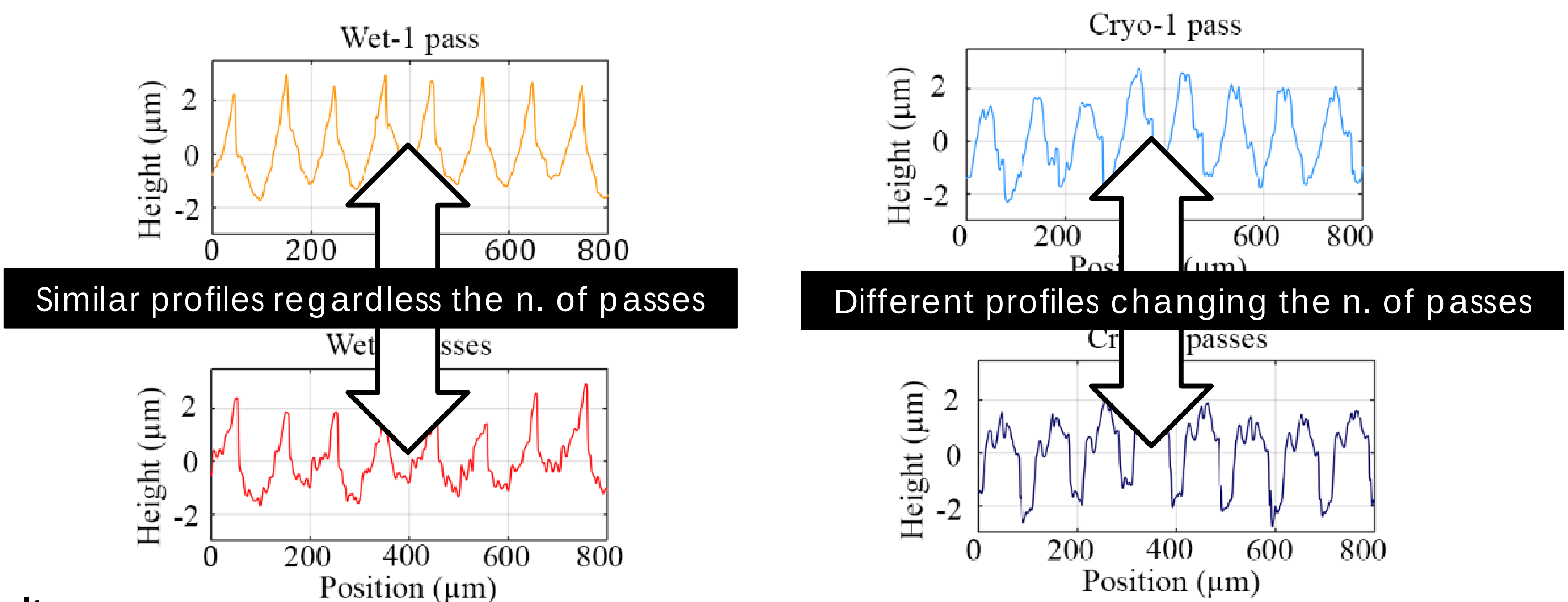
Ti6Al4V surface characterization after machining tests

- Results of surfaces profiles evaluation:

Effect of the number of passes on the machined profiles's surfaces:



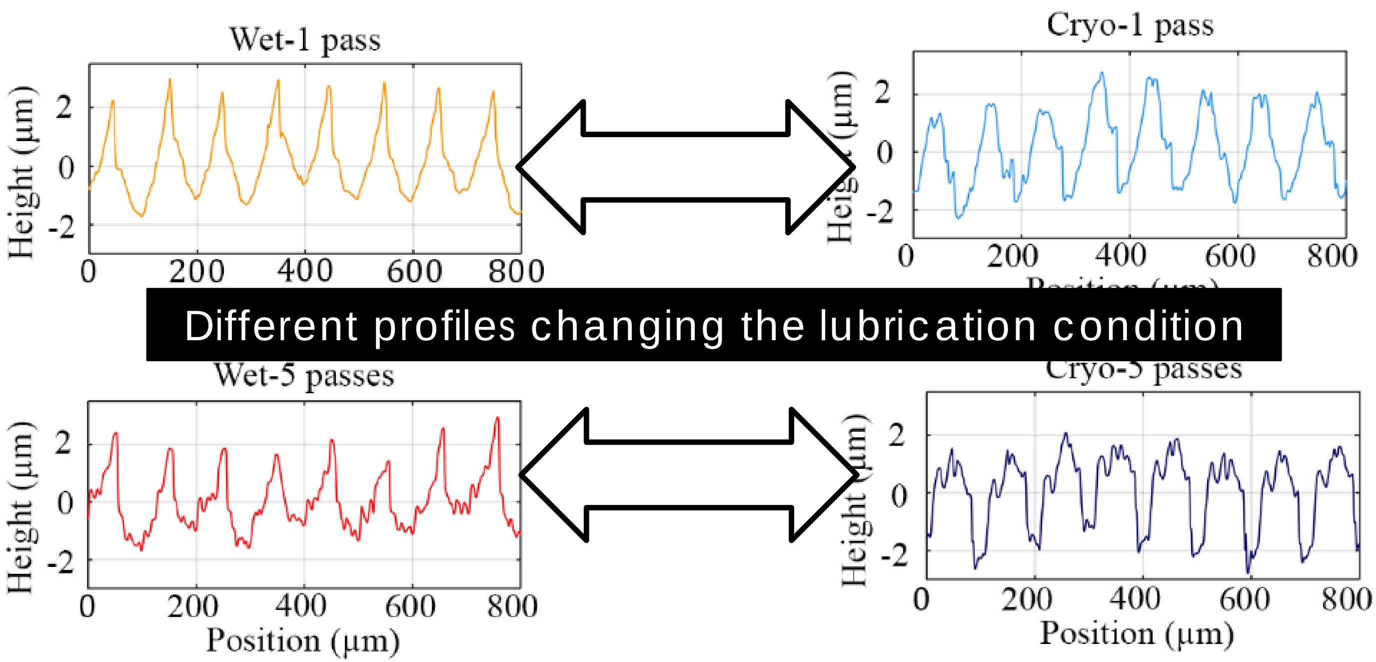
Results:

The number of passes has an effect only in the case of cryogenic condition.

Ti6Al4V surface characterization after machining tests

- Results of surfaces profiles evaluation:

Effect of the lubricant condition on the machined profiles's surfaces:



Results:

Lubrication condition influences the profile distribution

	Sa (µm)	Ssk	Svk (µm)	Spk (µm)	Sk (µm)	Sku (µm)
Wet-1 pass	0.97 ± 0.03	0.43 ± 0.01	0.11 ± 0.01	1.23 ± 0.02	0.67 ± 0.02	2.53 ± 0.02
Wet-5 passes	0.79 ± 0.02	0.72 ± 0.04	0.19 ± 0.08	1.27 ± 0.03	0.82 ± 0.03	2.63 ± 0.03
Cryo-1 pass	1.13 ± 0.04	0.25 ± 0.02	0.41 ± 0.03	0.48 ± 0.03	1.32 ± 0.01	2.56 ± 0.03
Cryo-5 passes	0.99 ± 0.05	-0.55 ± 0.01	0.74 ± 0.01	0.22 ± 0.03	1.36 ± 0.02	2.29 ± 0.02

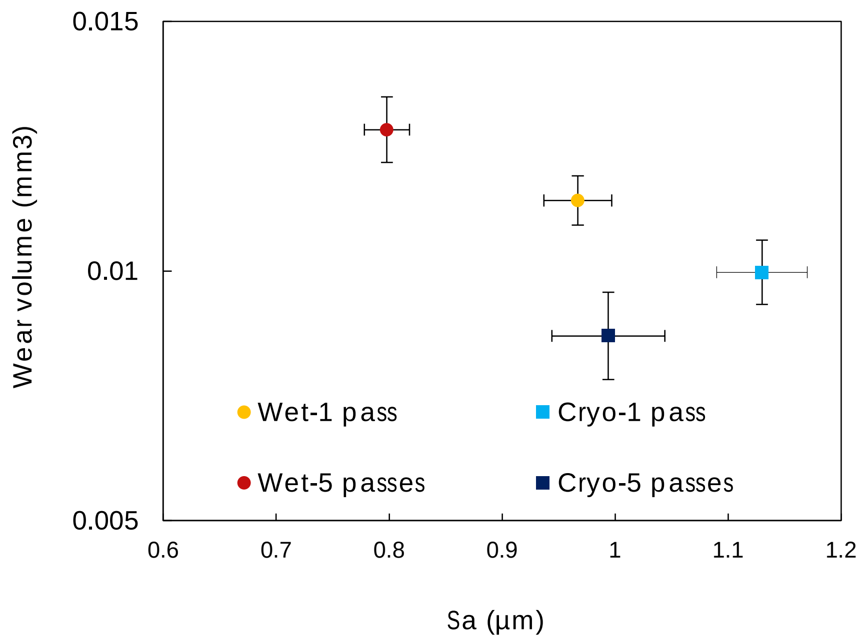
- Surface roughness increases in cryogenic condition and decreases when using multiple passes ;
- The skewness decreases using cryogenic cooling and multiple passes in order to manufacture the final shape;

  → Surfaces are characterized by larger peaks; → Less detrimental surfaces
- The Svk increases in cryogenic condition and using multiple passes;

  → Surfaces with broader valleys → Valleys can work as fluid reservoir

Ti6Al4V surface characterization after wear tests

Wear volume as a function of **Sa**

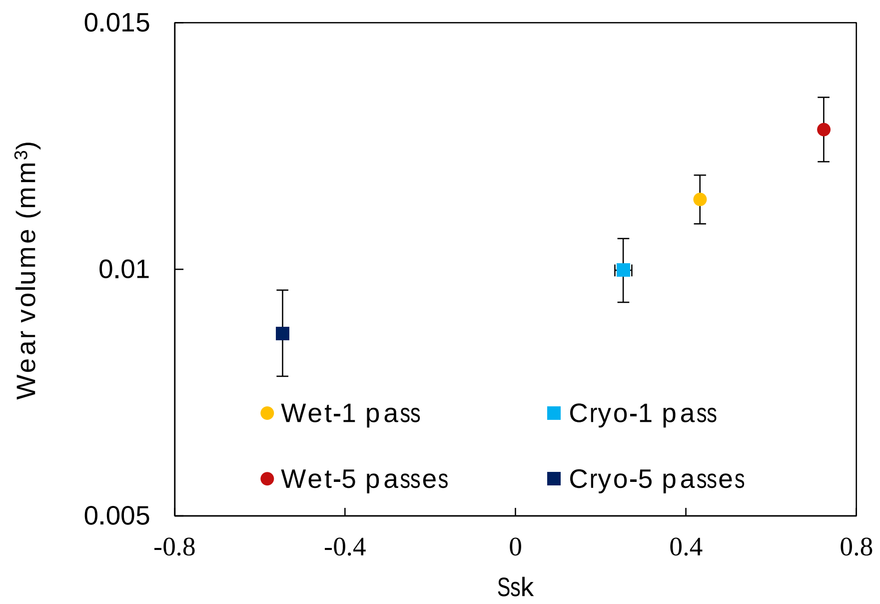


Results:

Sa is not a suitable parameter in order to predict wear of MoM prosthesis

Ti6Al4V surface characterization after wear tests

Wear volume as a function of **Ssk**

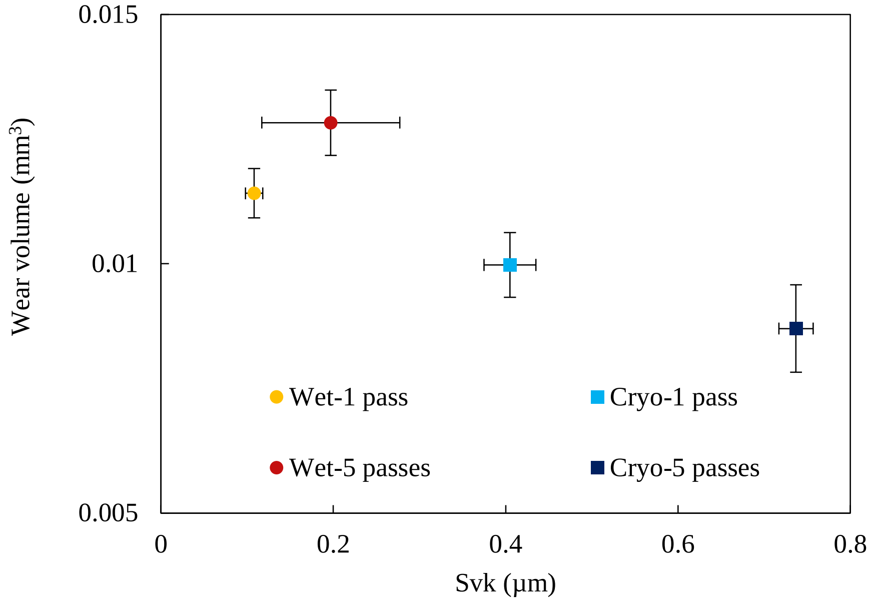


Results:

Sska can be used in order to predict wear of MoM prosthesis

Ti6Al4V surface characterization after wear tests

Wear volume as a function of **Svk**



Results:

Svk is a more suitable parameters than Sa in order to predict wear of MoM prosthesis.

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The main findings of the study are the follows:

- Sa is not a useful parameter in order to study wear of MoM;
- Svk is a better predictors than Ra to predict wear of MoM;
- Ssk is the best parameter to predict wear of MoM.

⇩

The best way to manufacture the internal surface of the acetabular cup is using:

- cryogenic cooling as lubricant conditions;
- multiple passes in order to obtain the final shape.

Thank you for your attention!

TE.SI.

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