Comparison of surface topography in machining Ti alloys for biomedical applications: Correlative microscopy approach for qualitative and quantitative analysis.

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ABSTRACT

In the last decades, the demand for biocompatible materials has increased because they are widely selected to manufacture medical devices such as dental and surgical implants. The improvement of these materials used to fabricate biocomponents is a constant objective in research focused on reducing negative impacts on patients. Currently, the most commonly used metal alloy in the biomedical industry is Ti-6Al-4V. Although it has interesting properties, this material may present a risk to the patient due to the presence of vanadium. Alternatively, the Ti-6Al-7Nb alloy may be a candidate to replace traditional alloys, however more studies are required for understanding the machining techniques of biomedical components. The study of surface topography, through modern microscopy techniques, presents great potential to optimize the machining process of this material. The objective of this work was to propose a correlative microscopy technique for a comparative analysis of surfaces machined by the turning process of the Ti-6Al-4V and Ti-6Al-7Nb alloys. This technique was based on the association of the extended field-depth method from Optical Microscopy (OM) with Scanning Electron Microscopy (SEM) and microanalysis modes.

RESULTS & DISCUSSION

The machined surfaces of two biomedical titanium alloys, Ti-6Al-4V and Ti-6Al-7Nb were studied using two sets of cutting parameters for dry turning operations. The defects observed on the machined surfaces were well-defined uniform feed marks running perpendicular to the tool feed direction, the pit machining, re-deposited workpiece material (chip) on machined surface and some irregular scratches. Using the 3D reconstruction the random surface defects (re-deposition, pits, scratches) shown at the SEM micrographs can be better analyzed since the elevation map shows if those specific regions are peaks or valleys.

The use of correlative microscopy, assisted by digital image processing, was an advantageous technique for a semi-quantitative inspection of the deformation process during the turning processes because allowed to simultaneously analyze the topography and chemical element distribution on the machined surfaces. Moreover, concerning the biomedical applications, several authors agree that the rate and quality of osteointegration can be improved by controlling surface integrity parameters such as roughness, topography but also the chemical composition and distribution. The proposed technique can be applied as a tool to optimize the cutting parameters accordingly with the surface requirements to be accomplished. For the tested cutting conditions, the niobium alloy presented lower surface roughness (0.6 µm and 0.16 µm) associated with smoother surface topography when compared with the vanadium alloys (0.7 µm and 0.31 µm). Also, the distribution of chemical elements on the surface was more homogeneous for Ti-6Al-7Nb for the tested cutting conditions, which is beneficial considering the possibility of using these alloys in the biomedical field.

ACKNOWLEDGEMENTS:

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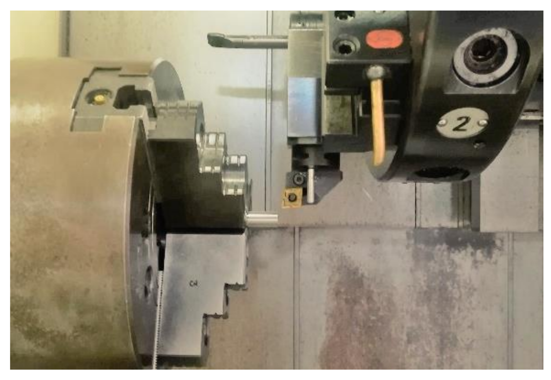
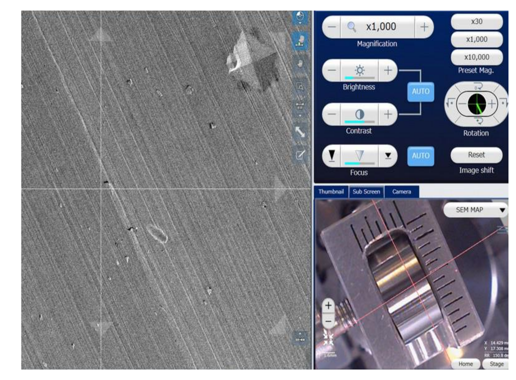
MATERIALS & METHODS

External Turning Operation in Ti-6Al-4V and Ti-6Al-7Nb in Dry Conditions

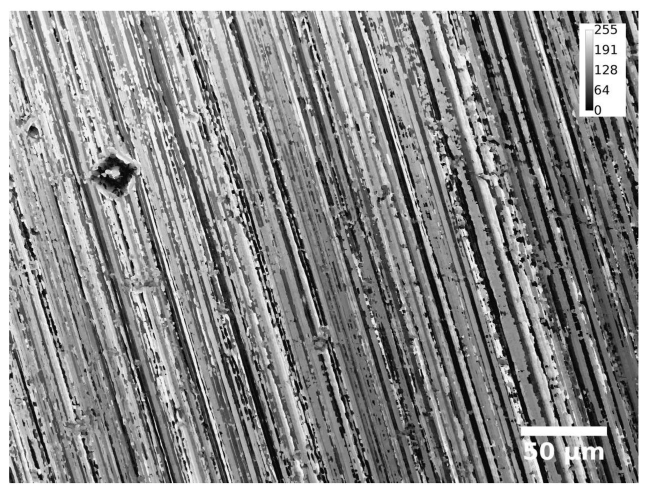


Surface Roughness Measurements

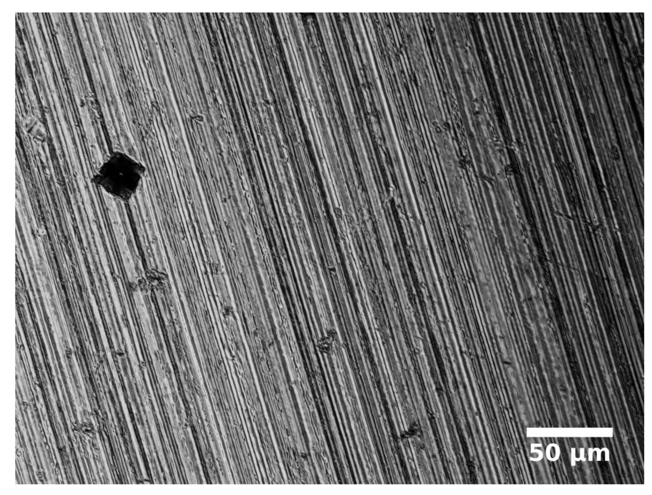
Bidimensional Scaled Sample Holder to Locate the Indentation Mark



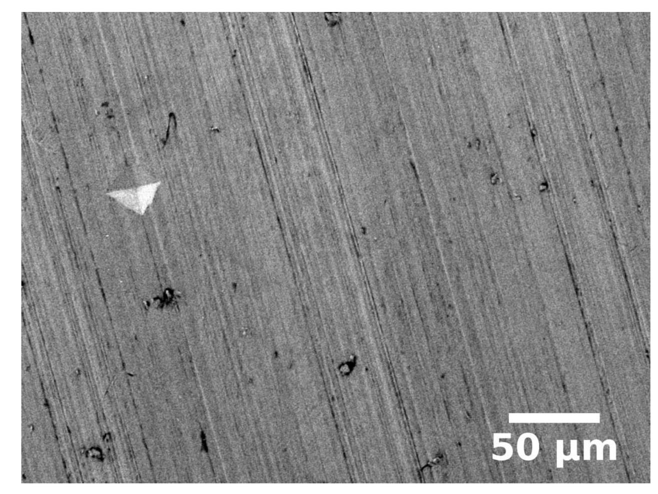
Bright-field OM Elevation Map



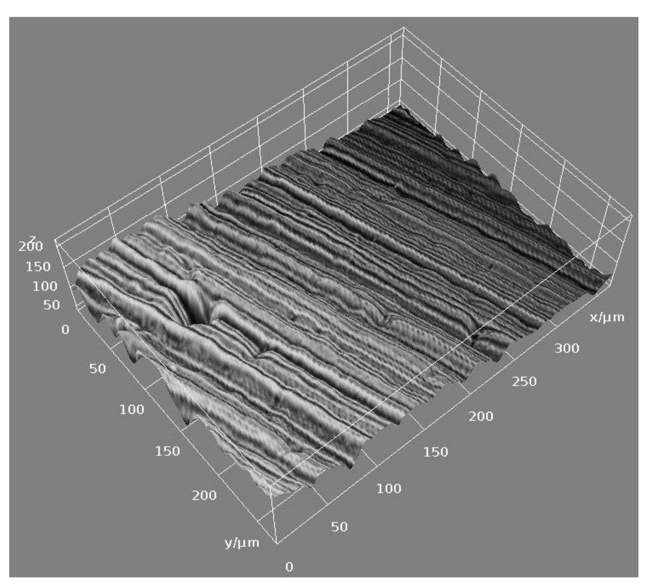
Focused Image by Extended Depth-of-Field Method



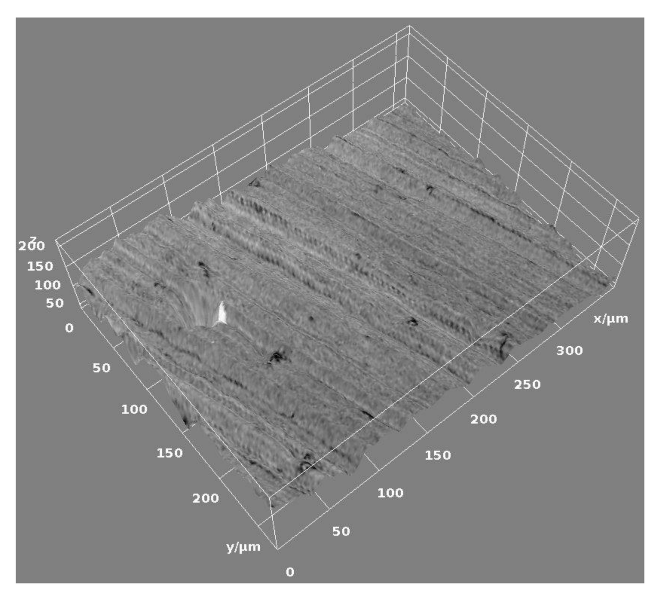
SEM Image at 5 keV



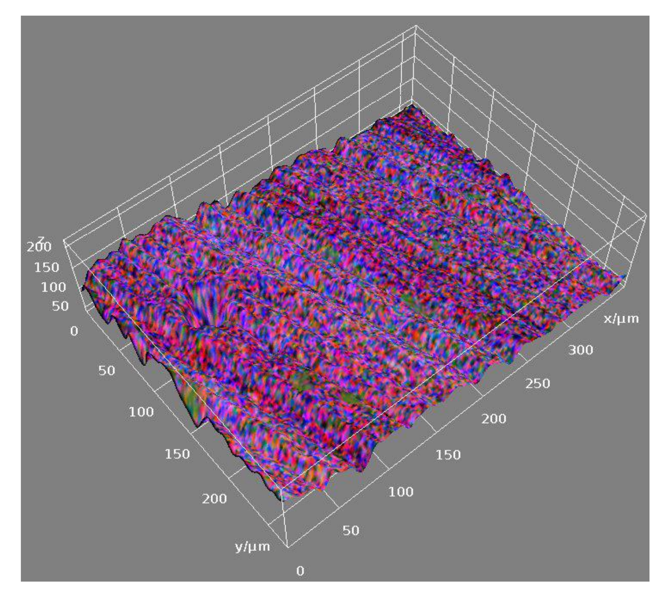
3D Representation of Height Map

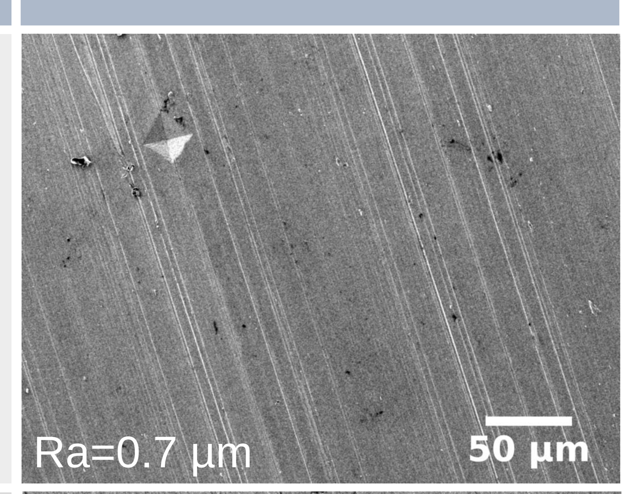
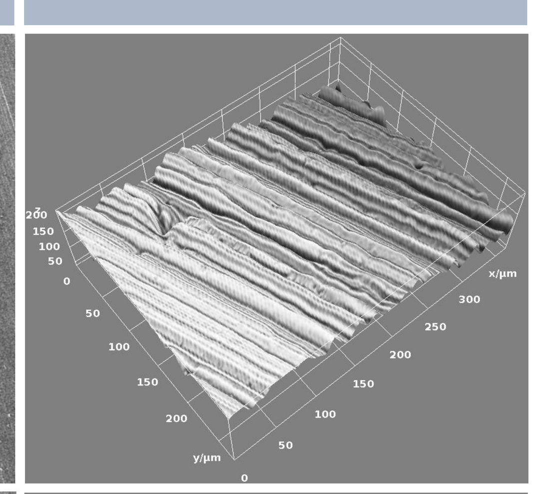
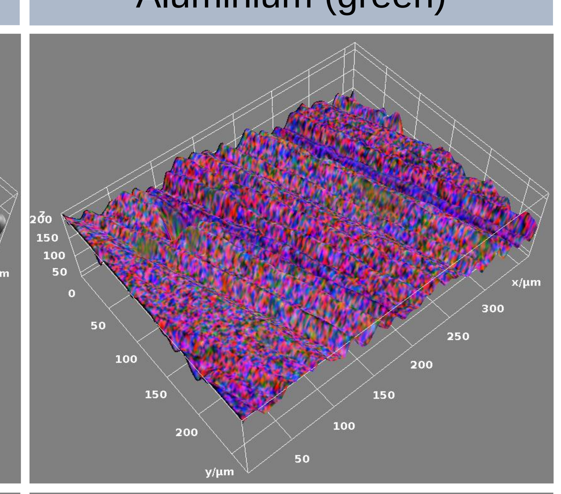
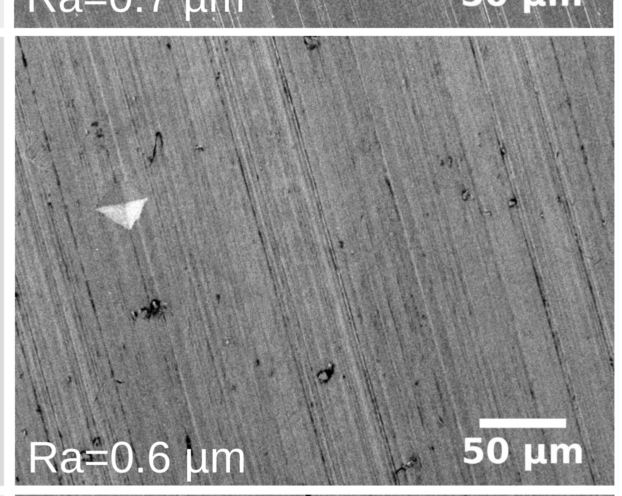
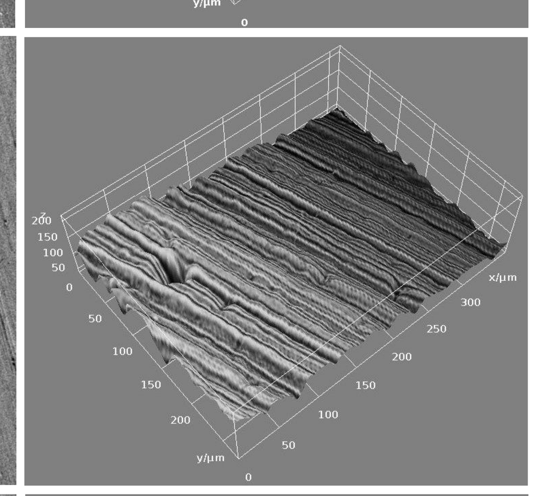
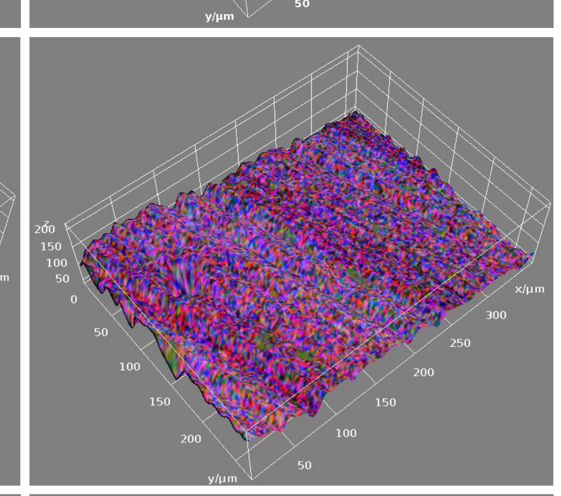
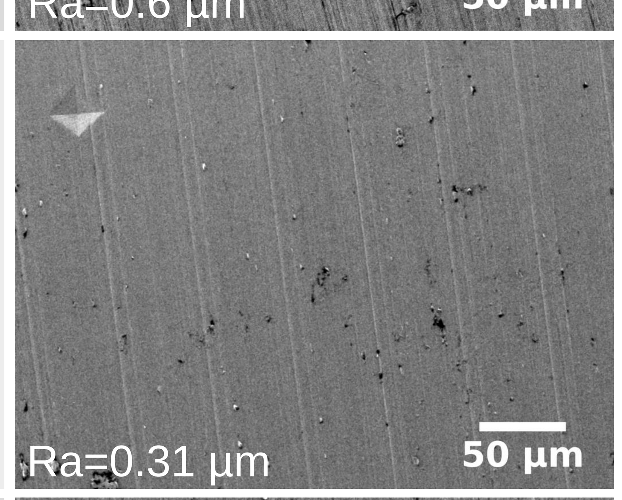
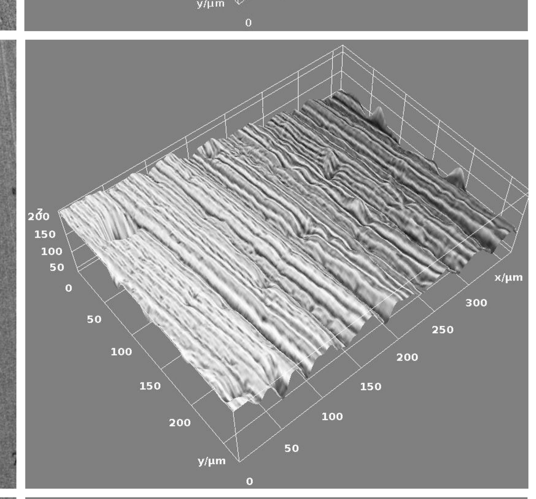
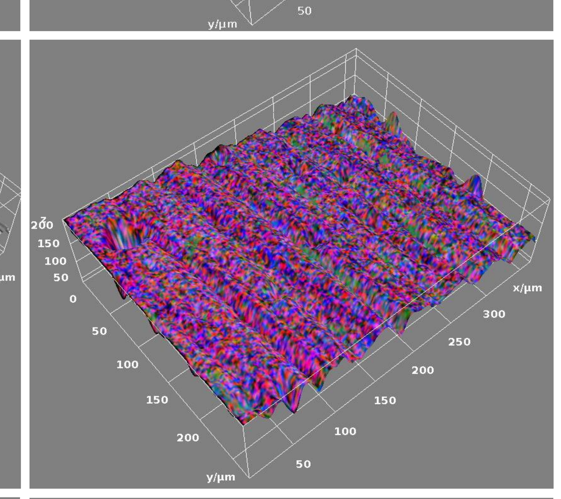


3D Representation of Height Map With the SEM Image as Loaded Texture



3D Representation of Height Map and EDS Map as Loaded Texture. Titanium (red), Niobium (blue), Aluminium (green)



Machining Settings	Titanium Alloy	Scanning Electron Micrograph	3D Representation of Height Map	3D Representation of Height and EDS Map as Loaded Texture. Titanium (red), Niobium/Vanadium (blue), Aluminium (green)
Cutting Speed 30 m/min Feed Rate 0.15 mm/rev Depth of Cut 0.5 mm Dry Turning	Ti-6Al-4V			
	Ti-6Al-7Nb			
Cutting Speed 90 m/min Feed Rate 0.05 mm/rev Depth of Cut 0.5 mm Dry Turning	Ti-6Al-4V			
	Ti-6Al-7Nb