DEVELOPMENT OF NEW CLINICAL DIAGNOSTIC TECHNIQUES IN PROSTHESIS REJECTION CASES BY USING PARTICLE INDUCED X-RAY EMISSION (PIXE)

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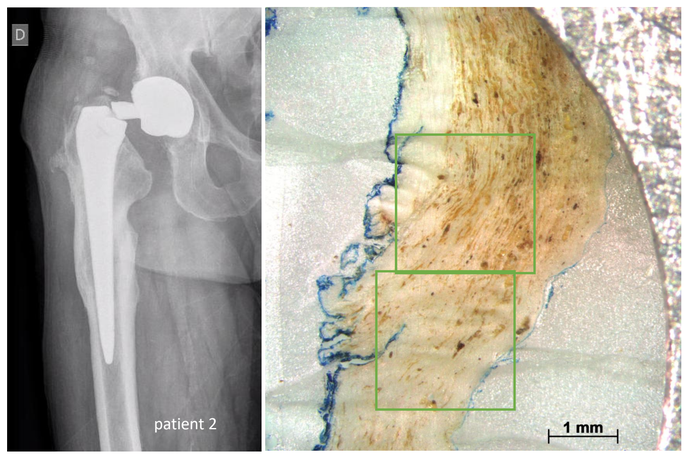
Introduction

Hip prosthesis replacement is one of the **most frequent and costly treatments** in developed countries. The increased number of patients and the insufficient understanding of physiological processes leading to prosthesis failure make **necessary the use of complementary techniques to better understand the degradation of implants** [1]. We present two cases of prosthesis failure: **Patient 2**, with a **modular hip prosthesis** made **of TiAlV alloy (Profemur®),** presents a **broken neck**; and **Patient 7**, with a **Ceramic on Ceramic articulation made of zirconia toughtened alumina (Biolox® Delta),** presents a **broken acetabular inlay**. The presence of **metallic debris coming from the prosthesis has been studied by using Particle-Induced X-ray Emission (PIXE).** This technique combines **high elemental sensitivity** (detection limit 0,1 ppm) **with high lateral resolution** (600 nm) [2]. The analysis was performed with the **2 MV tandem accelerator** available at **Jožef Stefan Institute (JSI)** [3].

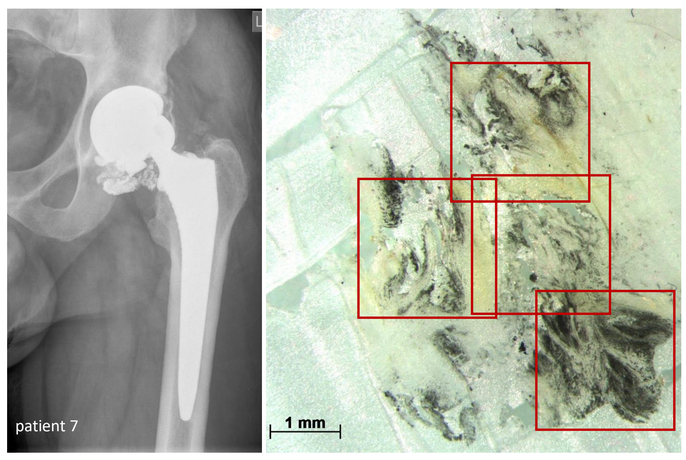
Methods

We **study the distribution and concentration of biologically active wear particles** (Zr, Ti, Al, V, etc.) **in the peri-prosthetic tissue**, obtained by biopsy during the hip-replacement surgery. Tissue samples are fixed in formalin and embedded in paraffin. Blocks are sliced (from 10 to 40-µm thickness) for analysis. Tissue samples are scanned with a **3 MeV focused proton beam for PIXE** analysis.

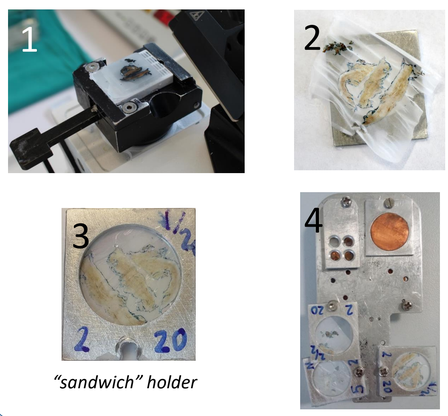
Patient 2 — Broken neck TiAlV alloy



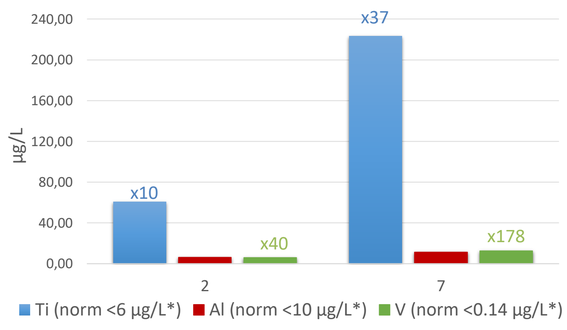
Patient 7 — Broken acetabular inlay



SAMPLING

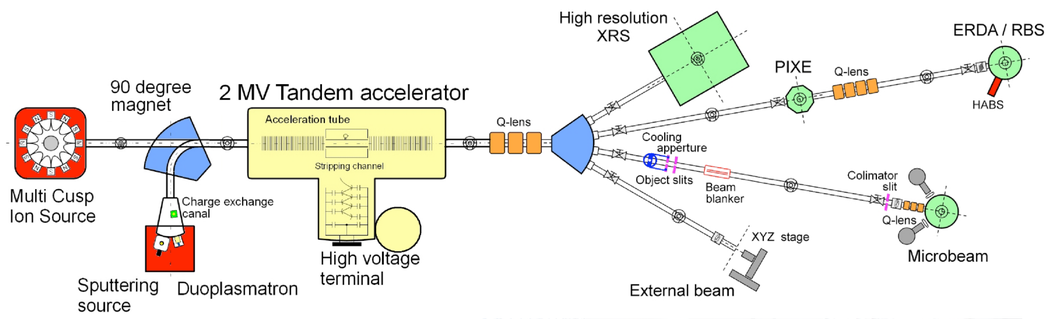


Metallic content in blood serum

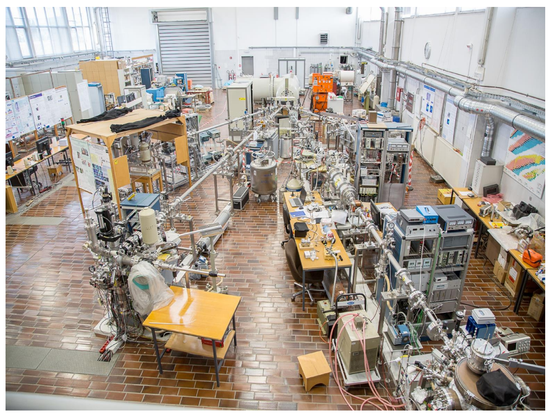


PIXE MEASUREMENTS

PIXE technique measures characteristic X-ray (**fingerprint**) emitted from an ionized atom after passage of a fast particle (proton) that induced ionization



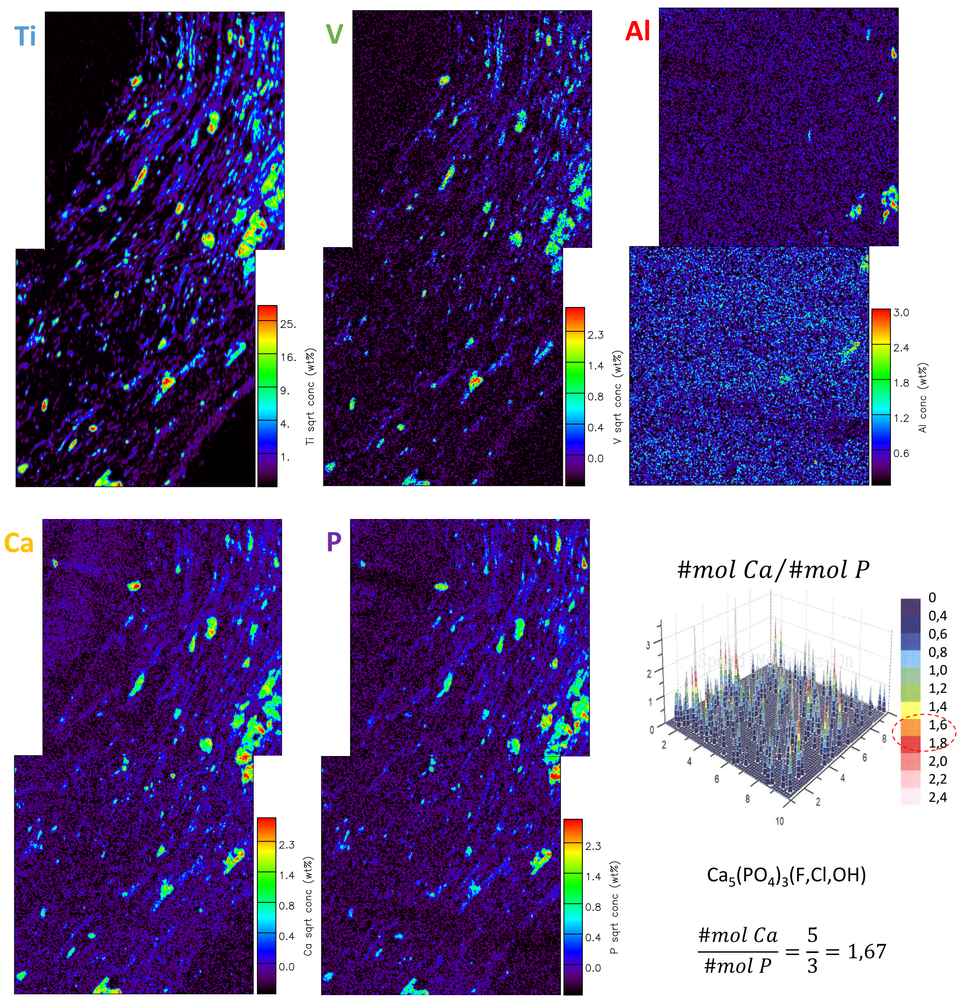
Ljubljana 2MV Tandem accelerator and beam lines schematics and picture



Results

PIXE elemental tissue maps, obtained with GEOPIXE software, show element **distribution and quantification** in two patients after suffering from a broken hip prosthesis.

Patient 2 (TiAlV alloy)

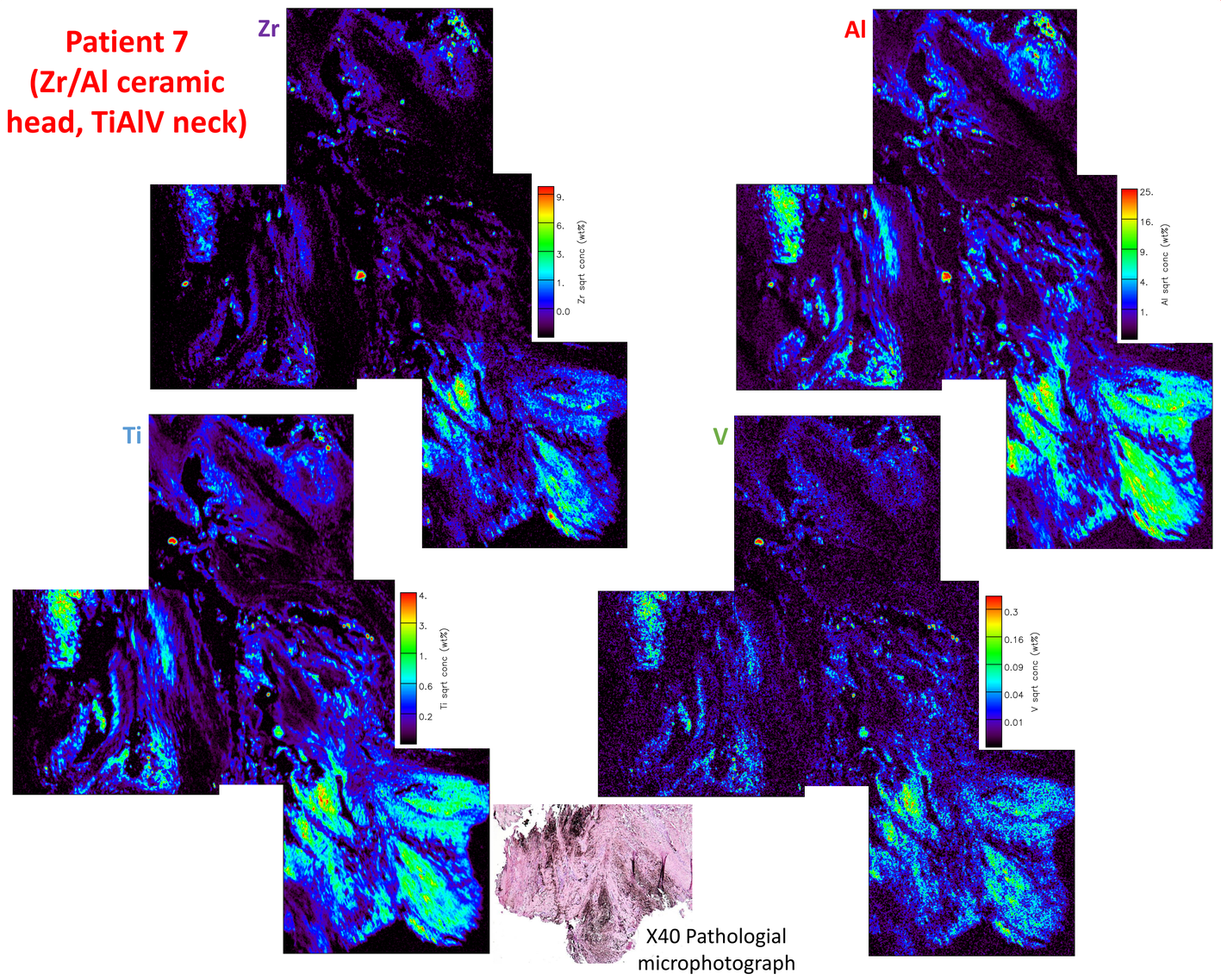


$\#mol\ Ca / \#mol\ P$

$Ca_5(PO_4)_3(F,Cl,OH)$

$$\frac{\#mol\ Ca}{\#mol\ P} = \frac{5}{3} = 1{,}67$$

Patient 7 (Zr/Al ceramic head, TiAlV neck)



X40 Pathologial microphotograph

Conclusions

- **In agreement** with the **serum analysis results, PIXE maps show high amount of metallic elements in both patients.** During the prosthesis degradation the periprosthetic tissue accumulated solid metal debris, with sizes ranging from **powder to micron-size debris. More powder-like and smaller particles were found in patient 7**.

- **The selective Al leaching** from the debris into the physiological fluid, **specific for the Ti-Al-V alloys (patient 2)** is **clear if we compare the Al content** in the PIXE maps of tissue in contact **with Zr/Al ceramic (patient 7)** where Al is coming from Zr/Al ceramic and TiAlV alloy.

- The **colocalization of Ca and P with Ti debris (patient 2)** is compatible with the formation of **Apatite-like layer on Ti**. We have confirmed the same ratio Ca/P as Apatite (1,67).

- **Micro-PIXE** has been **proved to suit well for element localization studies in biological tissues, by combining high elemental sensitivity with high lateral resolution.** Micro PIXE allows to obtain the **element distribution and quantification** (from F to Zr in this case) and the univocal **identification of the different features** observed with optical microscopy.

References

[1] Fokter SK, et al., *Acta Orthopaedica*, 87(2), p.197-202, 2016. [2] P. Vavpetič et al., *Nuclear Instruments and Methods in Physics Research B*, vol. 306, pp. 140-143, 2013. [3] Primoz Pelicon et al., Nuclear Instruments and Methods in Physics Research B, vol. 332, pp. 229-233, 2014

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