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Modern markers in non-metalic implants for spine surgery - Practical significance in CT imaging

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Abstract
Surgical implants require special biocompatible biomaterials. Currently in spine surgery, mainly used materials are titanium, titanium alloys, biopolymers (PEEK,PEK) and tantalum. Tantalum, like titanium and titanium alloys - is used as implant material, and may act as a marker for non-metallic radiologically translucent PEEK implants. The question is, what practical benefits tantalum brings to spine surgery? When compared to titanium it is heavier, has lower strength properties, and much higher price. Or is it just a marketing ploy? Study to verify the use of titan and tantalum in radiology was performed. Investigated were the identification properties of both biomaterials when exposed to various CT power magnitudes, and samples of different thicknesses were used. The results showed that use of tantalum in implantology might be justified only in special cases.

Introduction

Biocompatibility with human tissue and adequate strength properties are key requirements for a material to be used in implant. Currently used materials in spine implants are PEEK, titanium (Ti), titanium alloys (Ti6Al4V), and sometimes tantalum (Ta). Each material has a different X-ray absorption resulting in different shades of gray present on CT images, which allows their identification. The higher material density, the greater radiation power is needed to properly visualize interior, what unfavourably exposes patient to a greater dose of radiation. In Tab. 1 listed are properties of following materials: PEEK, titanium (pure), Ti6Al4V ELI alloy and tantalum, ordered by density. Nowadays, for various reasons, there is a requirement to use tantalum markers within PEEK implants to replace the titanium markers. It is expected to be a marketing ploy, not justified by medical needs. Aim of this study is comparison of titanium and tantalum properties under terms of radiological exposure, as in verification of their identification possiblities under various magnitudes of radiation power and different sample thickness.

Materials and methods

In first part of the study, PEEK sample with titanium (Ti) marker and four tantalum (Ta) markers (Fig.1) was prepared. Markers were placed on a PPL (PROPYLUX HS2) 30x21x8 base mm in holes with distance of 3 mm. Tantalum samples had a diameter of ø2 mm, and two length variants of 2x19 mm and 2x12 mm. Titanium marker had a diameter of ø2 mm, length of 12 mm, and PEEK sample had diameter of ø17 mm and height of 10 mm. In order to verify the identification possiblities of individual materials the samples were exposed to following magnitudes of power:

Tab.1. *Properties of materials: PEEK, titanium, Ti6Al4V ELI alloy and tantalum*

Material properties of PEEK, Titanium (pure), Ti6Al4V ELI and Tantalum					
Material Properties		PEEK	Titanium	Ti6Al4V ELI	Tantalum
Mechanical	Yield point	min 70 MPa	min 170 MPa (grade 1)	min 795 MPa	min 345 MPa
	Tensile strength	min 90 MPa	min 240 MPa (grade 1)	min 860 MPa	min 482 MPa
	Young's modulus	min 3 GPa	103 GPa	114 GPa	min 186 GPa
Physical	Density	1300 kg/m³	4500 kg/m³	4470 kg/m³	16 600 kg/m³
	Melting point	330-350°C	1650-1670 °C	1650°C	2996°C
*According to ISO and ASTM norms and articles referring to them					


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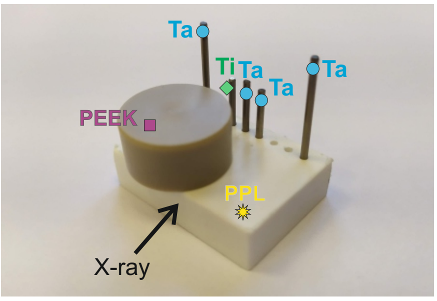
6W, 9W, 12W and 24W (Fig. 2), industrial CT (CTt) was used. Another CT imaging was performed using a CarRLIF implant from 3D-Truss-Ti implant family (Fig. 3), which was placed instead of PEEK sample in front of the tantalum markers. Imaging of this sample was done at 30W of power (U= 100kV, I= 300 μA). To verify the translucency of the material, depending on sample thickness, a CT of titanium element with thickness of 10, 15 and 30 mm in the background of the adjacent tantalum marker was performed (Fig. 4). All images were taken at 30W (U = 100kV, I = 300 μA).

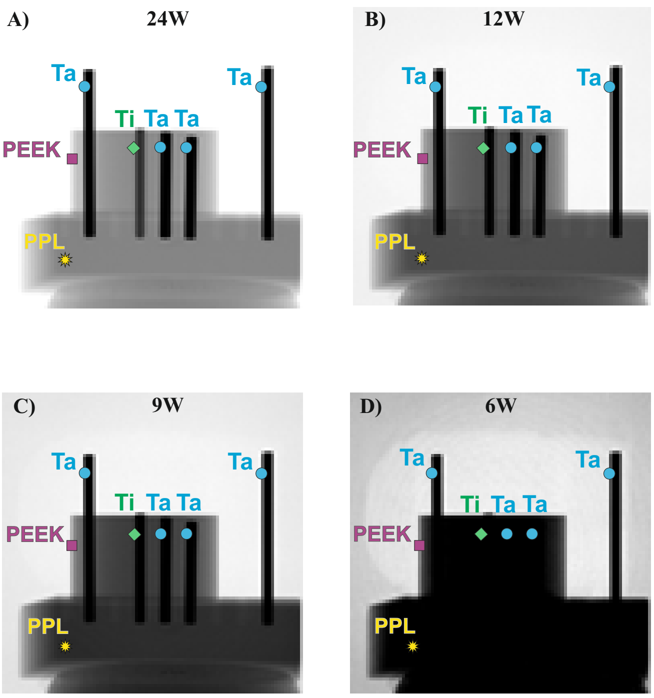
Results

To visualize materials with different radiological density using CTt, use of appropriate radiation power is required. Imaging of PEEK sample with tantalum markers and titanium marker was done with: 6W, 9W, 12W and 24W. Scanning performed with the lamp set at 25% of maximum power showed, that it was insufficient for identification of individual biomaterials. Increase to 38% of maximal power allowed differentiation of biomaterial groups: metal and polymer, however distinction between metals was not possible. Only use of 24W allowed to distinguish tantalum markers from titanium ones. Tantalum markers, which have higher material density have higher absorbency, thus appear darker on the images. Observed was that only 50% of maximal power was needed for proper visualization of PEEK sample. It was also sufficient for identification of metal elements placed within the PEEK sample (Fig. 2). X-ray of titanium implant with tantalum markers with use of 30W of power allowed precise identification of boundaries between metals (Fig. 3). Imaging of titanium samples of different thickness, proves that with increase of thickness increase of radiation power is required for correct identification (Fig. 4).



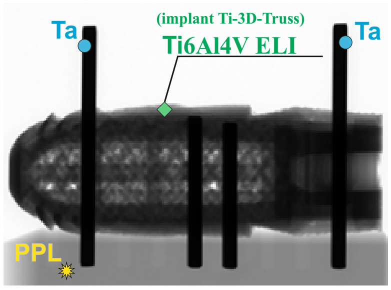
Legend:
- :Ta - tantalum
- :Ti - titanium
- :PEEK - biopolimer
- :PPL (PROPYLUX HS2)

Fig.1. *CTt X-ray sample containing tantalum, titanium, PEEK and PPL base (PROPYLUX Hs2)*



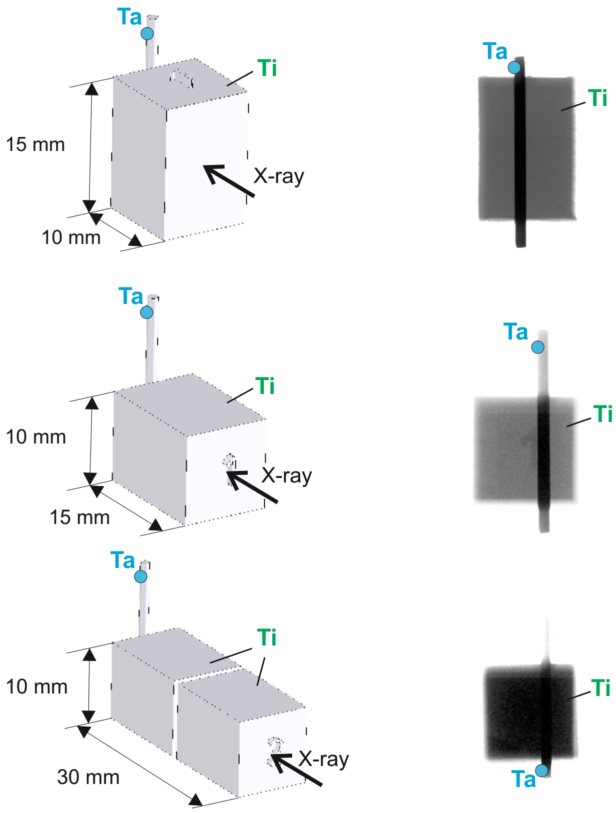
Legend: Ta - tantalum; Ti - tiatnium :PEEK; :PPL (PROPYLUX Hs2 base)

Fig.2. *Visibility of titanium and tantalum markers in X-ray CTt at the radiation dose: A) 24W, B) 12W, C) 9W, D) 6W*



Legend:
- :Ta - tantalum
- :Ti6Al4V ELI - titanium alloy
- :PPL (PROPYLUX HS2)

Fig.3. *Visibility of Ta markers on the background CarRLIF Ti-3D-Truss in CTt; radiation dose with a power of 30W*



Legend: Ta - tantalum; Ti - titanium

Fig.4. *Visibility of the Ta marker in the CTt images at different thicknesses of the Ti sample: 10, 15 and 30 mm; radiation dose with a power of 30W*

Discussion

Titanium is a commonly used metal for markers and implants, including the spine surgery implants (Fig.5, Fig. 6). Sometimes, for some reason tantalum is used. Why is marketing introducing such requirement? The conducted study showed, that both titanium and tantalum can be distinguished on CT images with radiation power not greater than required for visualization of PEEK. According to all of the above, when used as a marker in PEEK biopolymer, there are no arguments for replacing titanium (Ti) with tantalum (Ta). The same CT power is required for good visualization of both metals. Taking into consideration, that a tantalum is much heavier and more expensive than titanium, there are no economical or practical reasons behind use of tantalum. Furthermore, titanium is lighter, thus generates less CT artifacts than tantalum[1], making it easier to trace. It was found that, the more and more frequently introduced requirement to use tantalum as an implant material is only a marketing ploy. Use of tantalum with higher material density is reasonable only in complex stabilizations, where other metal biomaterials are used, or in case where patient has allergic reaction to alloy components. Ability to distinguishing tantalum from titanium can be very useful in analysis of intraoperative and postoperative images. A good example is CarRLIF 3D-Truss-Ti implant (Fig. 3), which design allows insertion of two cages at the same level of the spine (one by another). Insertion of second implant with tantalum markers makes visual interpretation on CT images easier, i.e. offering surgeon the information on positioning of both implants. Present on Fig.5 and Fig.6 are examples of PEEK implants made by LfC, in which use of tantalum markers may have practical application. Cervical interbody fixation with C-Disc (Fig. 5A) and EasySpacer (Fig. 5B) PEEK with tantalum markers and titanium cervical plate (airScrew Cervical plate – asCp) are an example of complex stabilization, where overlap of metal components is observed on X-ray images. The same situation may occur with lumbar interbody implants (Fig. 6), such as R-PLIF used with the screw fixation. Greater density of tantalum supports intra- and postoperative identification of implant with tantalum markers with the titanium stabilizations in the background.

Conclusions

Complete replacement of titanium with tantalum for spinal implant applications is uneconomical and unnecessary. Tantalum has a higher price and weight per unit than titanium, furthermore X-ray dose needed for “good” imaging of tantalum and titanium is dependent on PEEK properties as X-ray power needed for imaging of biopolymer is enough to identify both metals. Tantalum can be used

Fig.5. *Examples of complex multi-material fusion of the cervical region with PEEK implant and tantalum markers - 3D model and X-ray photos: A) interbody cage, B) vertebral body prothesis*

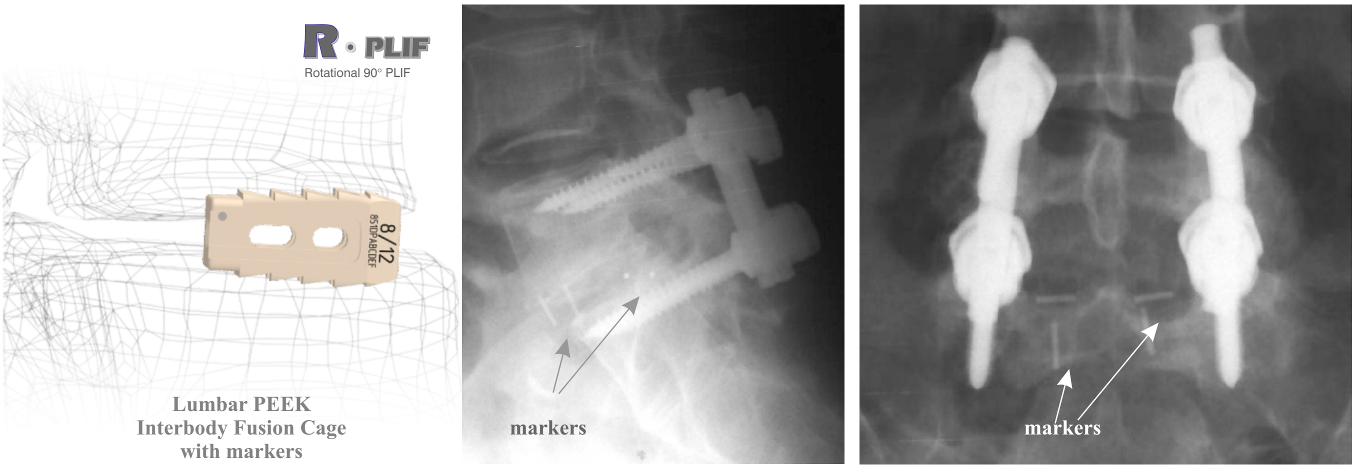


Fig.6. *Example of complex multi-material fixation of the lumbar region with a PEEK implant and tantalum markers - 3D model and X-ray photos*

as a marker in titanium implants in complex stabilizations, when one metal implant can cover other metal implant, making it difficult for health-care professional to identify the position of both implants. Use of tantalum as the only metal biomaterial in spinal surgery is considered just as a marketing ploy.

References

[1] M.R. Back, Biomaterials: Considerations for Endovascular Devices in: T.J. Fogarty, R.A. White, *Peripheral Endovascular Inrventions*, DOI: 10.1007/978-1-4419-1387-6_12, Springer Science+Business Media, LLC 1998, 2010