Advanced Radiographic Imaging Results in Patients with Trabecular Metal™ Spinal Implants

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Abstract

Trabecular Metal implants (TM) mimic desirable bone qualities of porosity and elasticity while maintaining excellent compressive strength. Despite these biomechanical advantages, metal spinal implants often cause metal artifact on postoperative computed tomography (CT) or magnetic resonance imaging (MRI). Although tantalum-based spinal implants have been used since 2002, the imaging properties of these devices have not been fully studied. The purpose of this study is to review the specific characteristics of commercially available tantalum implants (TM) (Zimmer Trabecular Metal Technology, Parsippany, NJ, USA) and compare their imaging profiles with titanium spinal implants.

Keywords

Tantalum; Trabecular Metal implant; Spinal fusion; Magnetic resonance imaging; Computed tomography

Introduction

Tantalum is a biologically-inert, dense elemental metal which has been shown to be highly stable as an orthopedic implant [1-3]. This metal has been developed for use as a Trabecular Metal implant (TM). The configuration of tantalum is processed in TM so as to achieve increased porosity, allowing for osteoblastic cellular infiltration and direct bone conduction [1,4,5]. The elasticity of TM and micro-architecture is similar to cancellous bone, with high fatigue strength and biochemical properties that allow it to bend prior to fracturing [6]. While these properties may facilitate bone growth and arthrodial, the flexibility of TM also allows load sharing with surrounding bone. Finally, TM has a high coefficient of friction, providing excellent initial stability and fixation in bone [4]. These properties are felt to be highly beneficial in orthopedic devices and Trabecular Metal implants have been commercially available for vertebral body reconstruction since 2002 and for cervical interbody fusion since 2011.

Metal implants are known to cause significant artifact and image distortion, particularly on image modalities such as CT or MRI, in which multiplanar data is combined [7,8]. Postoperative imaging, especially when used to assess the extent of bone fusion, may be compromised by metal spinal instrumentation due to the inherent properties and construction of these implants. Compared to stainless steel, titanium has a far more favorable imaging profile and high-quality MRI studies may be obtained with titanium instrumentation [9,10]. Although tantalum-based spinal implants have been used since 2002, the imaging properties of these devices have not been fully studied. The purpose of this study is to review the specific characteristics of commercially available TM spine implants (Zimmer Trabecular Metal Technology, Parsippany, NJ, USA) and compare their imaging profiles with titanium spinal implants.

Case Report

Porous tantalum Trabecular Metal implants, designed for use in the lumbar, thoracic, and cervical spine, were used in this study (TM-S, VBR-21, Zimmer Trabecular Metal Technology, Parsippany, NJ, USA) (Figure 1a). Postoperative images from specific cases using TM were reviewed and compared to the imaging profile of a titanium expandable spinal implant (Synex expandable vertebral body replacement, Synthes, Inc, West Chester, Pennsylvania, USA) (Figure 1b).

MRI images were acquired on a 1.5 Tesla MRI machine with routine clinical settings for T1-weighted and T2-weighted images [11,12]. CT images were acquired using 512 matrix scanner with 2-3 mm axial images parallel to the disc space or TM device. Sagittal and coronal reconstructions were performed with similar thickness.

Case 1

45 year old female with C7 radiculopathy, underwent anterior cervical discectomy and fusion at C6/7 with placement of TM interbody spacer. Figure 2 demonstrates plain radiographs showing bone remodeling and growth around the implant. The patient developed new onset C8 symptoms at 1 year postoperatively, prompting an MRI. Figure 3 demonstrates limited artifact created by a TM device on routine clinical MRI, with excellent resolution of neural structures.

Case 2

71 year old male with multiple myeloma, erosion and destruction

Figure 1: a) Trabecular Metal implant (VBR-21) for use in lumbar spine. b) Synex expandable titanium cage.
of L5 vertebral body, with posterior retropulsion of bone fragments causing cauda equina syndrome. This patient was treated with a posterior decompression and stabilization from L3 to S1, followed by an anterior corpectomy, placement of TM device, and L4 to S1 fusion. Figures 4a-4e demonstrates CT imaging characteristics of L5 TM device with adequate bone resolution in the immediate postoperative setting. The most severe artifact occurs on the axial images.

Case 3
25 year old female with T11/12 compressive lesion, presenting with severe back pain and incontinence. She underwent T11/12 corpectomy with placement of TM implant, followed by posterior decompression and stabilization from T9 to L2. Figure 5a and 5b demonstrates an axial T2-weighted MRI and a sagittal T2-weighted MRI of the TM device, both showing very good resolution of the neural structures. These images were obtained six days following surgery.

Case 4
67 year old female with metastatic colorectal carcinoma to L3 who presented with unrelenting back pain and epidural tumor extension. She underwent L3 corpectomy, placement of titanium expandable vertebral spacer with a posterior L1 to L5 fusion. Figures 6a-6c shows CT imaging in this patient, demonstrating appreciatively less artifact than in the CT images of the TM device (Case 2). Conversely, Figures 6d-6g depicts extensive image distortion on MRI in this patient, and the extent of artifact is clearly more than in MR images of the TM devices in Cases 1 and 3.

Discussion
Trabecular Metal implants have several advantages for application in spinal fusion including osteoconductivity, elasticity similar to bone, stability, and strength. There has been limited literature regarding the postoperative imaging characteristics of these implants, although tantalum Trabecular Metal implants have been in use since 2002 [9,10,13,14].

All metal spinal implants will distort MRI imaging and potentially limit the interpretation of such imaging due to the magnetic susceptibility of the material. Since the magnetic susceptibility or tendency to interact with an applied magnetic field, of metal differs from that of human tissue, image artifact is produced. Ferromagnetic metals, such as stainless steel, produce local magnetic fields during MRI imaging resulting in severe metallic artifact and with the theoretical possibility of movement of the steel implant [7]. For this reason, non-ferromagnetic metals such as titanium are now preferred since their magnetic susceptibility is less than steel. However, titanium still produces artifact in MRI studies due to local electric current induced by the alternating magnetic fields in the MRI scanner [15]. Tantalum has a lower magnetic susceptibility than titanium and therefore would be expected to cause less MRI artifact [16].
As evidenced by the cases presented in this study, the MR images with TM implants have excellent resolution, particularly with T1-weighted studies. Other studies have reported that optimization of MRI parameters, such as use of fast spin echo techniques, minimizing the echo time and decreasing the field of view, may lessen the degree of artifact [11,12,17,18]. T2-weighted MR images exhibit a greater degree of artifact than T1-weighted images, but the results are still sufficient for interpretation of neural element compromise. A recent randomized trial comparing cervical TM device to allograft reported that MRI of the TM device was successful in determining whether decompression of neural structures had been achieved, but not for radiographic assessment of bone fusion [13]. Levi et al. demonstrated that TM spinal implants were associated with less MRI artifact than titanium spacers, and therefore, improved visualization of neural structures [14]. Our results are consistent with this finding that TM devices allows better MR imaging compared to titanium. However, other studies have reported that the postoperative MRI of Trabecular Metal implants does not differ greatly from those with titanium, despite the lower magnetic susceptibility of tantalum [10,19].

Computed tomography is also an important tool for postoperative spinal evaluation. X-rays will be absorbed by metallic implants, creating missing data that results in severe artifact after the images are reconstructed. The degree of image distortion depends on the degree of x-ray attenuation or the attenuation coefficient. Metals such as titanium have a lower attenuation coefficient, thus resulting in less image distortion, than stainless steel [20]. CT imaging is particularly useful for determining the extent of bone fusion or detecting a pseudoarthrosis. CT is superior to x-rays for showing lucencies surrounding spinal instrumentation, but lucencies are more visible with nonmetallic implants compared to metallic devices [21,22]. However, recent work by our group indicates that the extent of fusion may be under represented radiographically in Trabecular Metal implants compared to polyetheretherketone (PEEK) intervertebral spacers when histologic bone staining is also performed [23]. Bone fusion of TM implants has also been studied in a prospective randomized study by evaluating intervertebral range of motion (angular & translational) and radiolucencies on plain x-ray [24].

Porous tantalum devices such as Trabecular Metal implants facilitate host bone attachment through in growth in the pores, thereby improving mechanical support and limiting motion [25]. Bobyn et al. showed that porous tantalum devices are effective scaffoldings for complete incorporation with new bone by 16 weeks, with little change after one year in a simple transcortical canine model [4,26]. Although the host bone in-growth through Trabecular Metal implants results in solid fusion, it is difficult to image this in-growth with conventional imaging modalities. In our cases, CT imaging demonstrated adequate resolution of the bone detail surrounding the TM implant. Sagittal and coronal reconstructions from 2-3mm slices provide the highest quality CT images. However, the resolution of CT imaging was not fine enough to visualize actual osteointegration of bone into the TM implant. As shown in Figure 2, plain x-rays allow greater visualization of the TM-bone interface and is often the primary imaging technique to evaluate both the fusion and the TM implant position after surgery. The extent of CT image artifact produced by TM devices was greater than titanium, especially in the axial slices. This finding is consistent with that of other studies in which tantalum spinal implants produced CT distortion similar to that of stainless steel, and far greater than titanium [9,14]. In our study, the increased artifact seen on CT imaging is more likely the result of greater metallic density of the spinal TM implant compared to the titanium expandable mesh cage, which has an open interior, rather than an intrinsic characteristic of tantalum. However, more studies are required to fully investigate this question.

**Conclusion**

*Trabecular Metal* spinal implants have improved imaging characteristics compared to titanium on postoperative MRI, but have slightly greater artifact on CT imaging. Bone fusion occurs through host-in-growth into the Trabecular Metal implant, although assessment of this in-growth is difficult to visualize on CT reconstructions. The
biomechanical advantages of these implants and osteointegration when used as spacers in the intervertebral space suggest that these implants may be of benefit for spinal fusion procedures. Additional studies are required to further investigate the imaging properties of these implants and optimize MRI and CT parameters to minimize artifact and image distortion.

References


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