The myths of trabecular metal: 'the next best thing to bone'

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Orthopedic-related disease is one of the leading clinical burdens worldwide. It represents one of the top three core service areas in many hospitals in the USA. With the increasing longevity in most of the countries, a good percentage of the population is over the age of 65 years. Most of the patients suffer from either primary or secondary arthritis, and joint replacement surgery has emerged as the treatment of choice. In fact, the demand for total joint replacement (TJR) is substantial and growing rapidly. This is measured by the number of total hip replacements and total knee replacements performed every year.

Further, there is an increasing rate of joint replacements among the younger and more active population. This incidence is expected to grow because of the expanded range of indications for TJR.

As expected, with the increasing number of primary TJRs the rate of revisions also increased. The most common causes of revision are infection and aseptic loosening. Generally, revisions are characterized by longer operating times, lengthy hospital stay, and increased requirements for bone grafts, especially in total hip replacement.

Implants manufactured using conventional orthopedic implant materials, including titanium and cobalt–chromium alloys, often use cement to achieve fixation and stability. The relatively high stiffness of some solid metal implants may cause low load transfer to the host bone, leading to the potential for stress shielding and bone resorption over time.

In contrast, some other implants have porous bone interface surfaces designed to allow for biological fixation through bone ingrowth into the implant. However, this does not address the need for the host bone to be physiologically loaded. In addition, some bone defects would need massive bone grafts that would not be available in many instances.

Trabecular metal material is a unique, highly porous biomaterial that is designed with structural and functional properties similar to those of trabecular metal. It is made of elemental tantalum, which has been used to make implantable materials for over 50 years. It is known as a material with a porous structure. In addition, it is biologically inert, ductile, corrosion resistant, and has high fatigue strength [1,2].

What is trabecular metal technology?

Trabecular metal is a three-dimensional material and not an implant surface or coating. Its structure is similar to that of cancellous bone [3–5] (Fig. 1).

Tantalum

Tantalum is element number 73 in the periodic table. It is a highly biocompatible and corrosion-resistant metal [6–8]. It has been used in various implantable devices, including dental implants, for decades [9,10].

Although the high biocompatibility and passive characteristics of tantalum have been documented long ago, its cost and methods of production have limited its use until recently [11].

How is trabecular metal material made?

The trabecular metal material preparation process demands strict specifications for pore size, shape, and interconnectivity to ensure that a cancellous bone-like structure is obtained. Through a thermal deposition process, elemental tantalum is deposited onto a substrate, creating a nanotextured surface topography to build trabecular metal material, one atom at a time. This process utilizes the physical and biological properties of tantalum to create a unique material that has a structure similar to that of cancellous bone. Now it is used to produce many implants that have proven to be of great help in difficult primary and revision TJR, as well as in spinal surgery [3–5] (Fig. 3).

Material properties

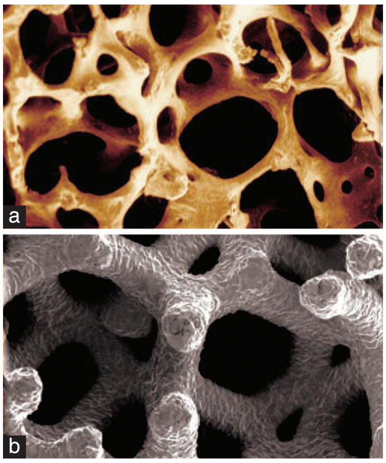
Trabecular metal material has a low modulus of elasticity (2.5–3.9 GPa), which is closer in value to that of cancellous bone, compared with titanium (106–115 GPa) [3–5]. In compression testing, trabecular metal material exhibits high ductility without mechanical failure [3–5] (Fig. 5). Because of its high coefficient, trabecular metal material has been shown to contribute to the primary stability of the implant, on the basis of in-vitro insertion torque testing [12,13] (Fig. 6).

A glimpse into the trabecular metal material reveals its uniform three-dimensional cellular architecture with up to 80% porosity [14] (Fig. 7). This would allow for profuse vascular invasion and bone ingrowth. Further, the entire surface area of the trabecular metal material exhibits a nanotextured topography [15].

Osseoincorporation

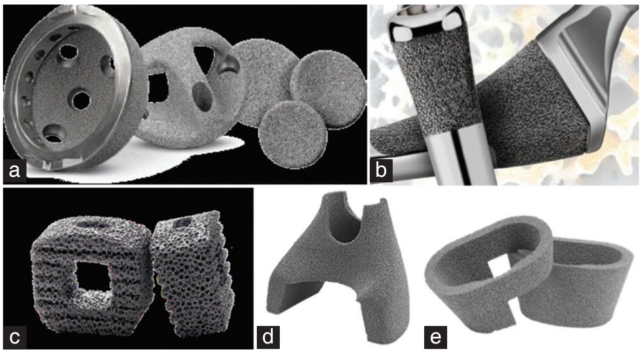
Conventional textured or coated implant surfaces achieve bone-to-implant contact, or ongrowth. However, trabecular metal material's consistent, open and interconnected network of pores is designed for both ongrowth and ingrowth, or for osseoincorporation. Bone has the potential to grow onto the nanosurface of the trabecular metal material, into its interconnected pores, and around its struts. Evidence of ingrowth by maturing bone has been documented as early as 2 weeks after implantation. The cancellous-like structure, interconnected porosity, and bone ingrowth potential are a unique combination of attributes that contribute to the osseoconductive properties of trabecular metal technology [16,17].

Figure 1



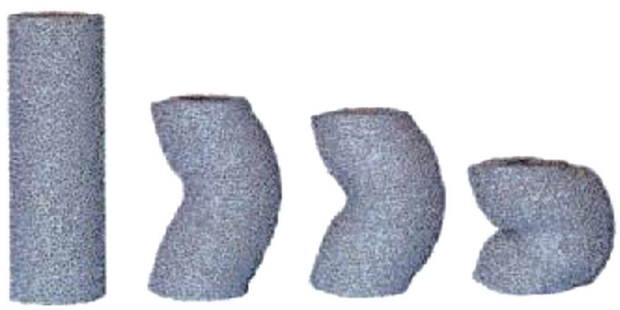
(a, b): Trabecular Metal Material's structure is similar to cancellous bone.

Figure 2



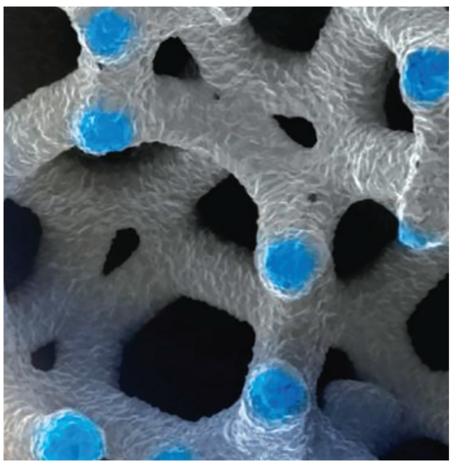
(a-e): Numerous Zimmer Implants contain Trabecular Metal Material.

Figure 3



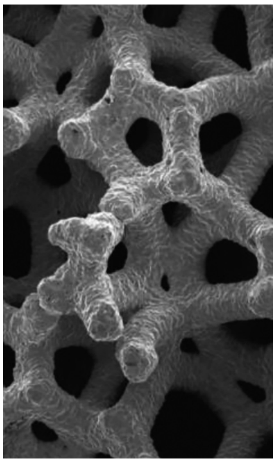
Ductility without mechanical failure.

Figure 4



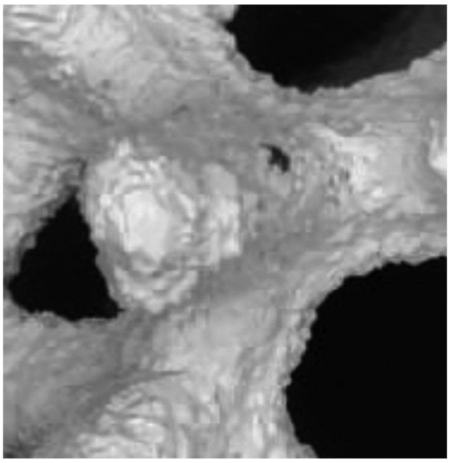
Trabecular metal material forms a frictional interface with bone.

Figure 5



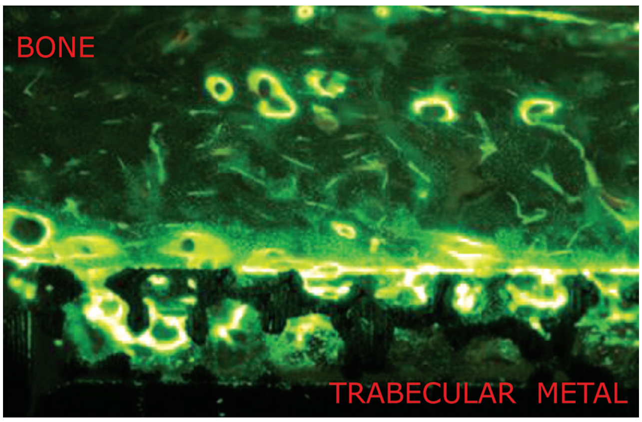
Three-dimensional uniformity with up to 80% porosity.

Figure 6



Nano-textured surface topography of Trabecular Metal struts.

Figure 7



Ingrowth of bone into the trabecular Metal.

The promising clinical value of trabecular metal

The quality-of-life considerations leading to joint arthroplasty are substantial when compromised functional status impairs a patient's ability to perform routine activities of daily living.

Patients with TJR complications have reduced quality of life and functioning as compared with patients without complications. Patient function after revision TJR is lower than that after primary TJR, indicating a potential unmet need for more successful revision surgical techniques and implants.

Porous technology has several clinical advantages. The mechanical properties of tantalum metal material are similar to those of bone, with less stress shielding. It is also highly porous, which permits more conducive bone ingrowth. Finally, its high strength/rigidity ratio allows its usage as a stand-alone load-bearing structure (Figs 2, 4).

Acknowledgements

Conflicts of interest

There are no conflicts of interest.

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