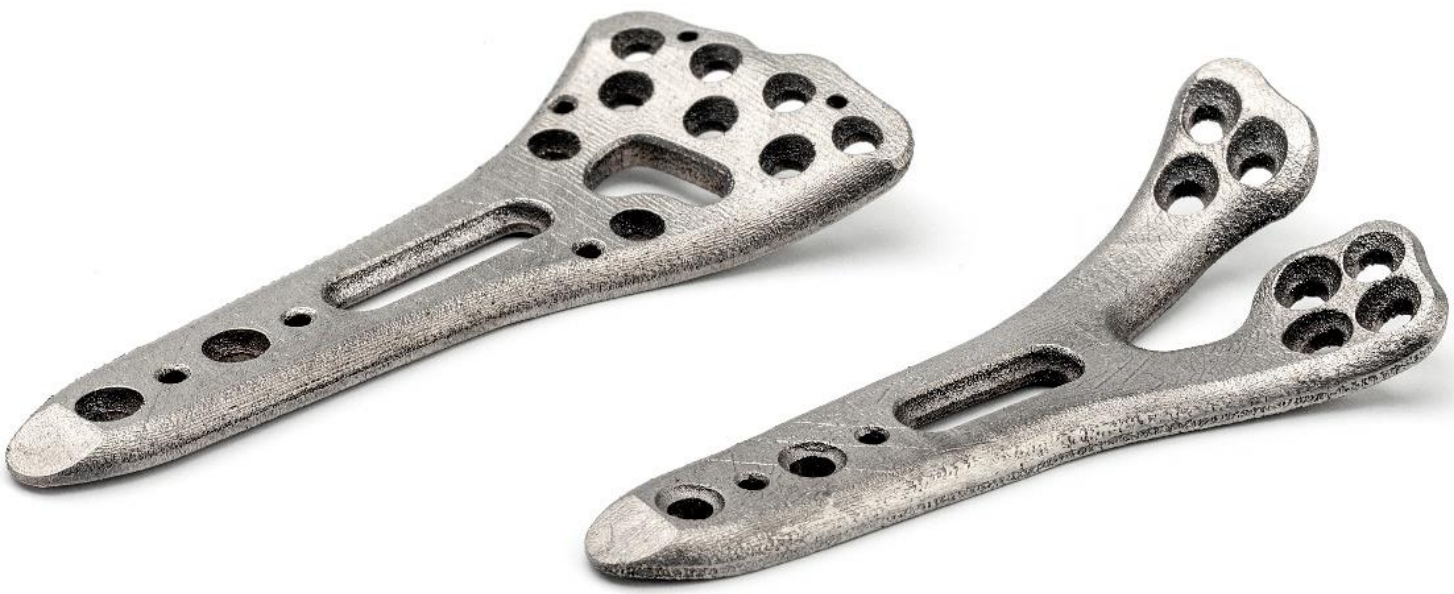
Heraeus

AMLOY
Amorphous Alloy Technologies

CASE STUDY

Medical Implants



Challenge

- Mechanical properties of available materials
- Individual fitting work on implants prior to fixation
- Permanent loading, biomechanical stress and fatigue fractures
- Stiffness vs. flexibility
- Patient recovery speed

Solution

- 3D printing of amorphous metals
  - ✓ Biofunctionality
  - ✓ Material savings
  - ✓ Individual design freedom
  - ✓ Biocompatibility
  - ✓ Stabilization with simultaneous freedom of movement

Challenge

Materials for medical implants are subject to **high demands** in terms of biocompatibility, mechanical properties and surface functionality. In addition, there is a constant pressure on costs and efficiency combined with high safety requirements and patient-specific adaptations in the medical technology industry.

A number of preferred materials attempt to meet these criteria in various combinations and grades:

- Titanium and its alloy range
- Stainless steels
- High-performance polymers
- Ceramics

Despite good tissue compatibility, resistant and biocompatible durability of these materials, there are always **compromises in the selection of implant materials**. Sustained bone healing can only occur if the surgical reposition as well as the stabilization of the fragmented bone structure by attached force carriers (implants) enables the intact bone tissue to engage osteoplastic activity.

Conventional materials reach their limits in this case. While metallic and ceramic materials promote bone resorption due to their high stiffness, soft polymer chains lead to overloading of the damaged bone tissue.

The example of the shoulder fracture and the use of a humeral plate or the rib arch replacement in the thorax illustrates precisely this **need for simultaneous stability of the bone with high mobility** (see *Wolff's law*). The continuous load in the rib area corresponds to up to 8 million respiratory movements per year. Fatigue fractures or an unstable sternum fixation result in a **material solution that currently has no alternative**. In almost every case, the implant must be re-exposed and adjusted or even replaced after a short period of time which results in a high invasiveness for patients.

> **The bone builds up and increases in strength and thus also in bone density when it is loaded.**
>
> **If, on the other hand, the bone is not loaded or only loaded slightly, it degrades.**
>
> – *Wolff's law*

Few basic sizes and **only simple basic shapes of radius and trauma plates** also make it difficult to deal with lesions, especially in the craniomaxillofacial region, and improvisation is increasingly necessary. **Time-consuming adaptation work** by the surgeon on the implant is the result.

Although patient-specific individualization is always the less invasive route, the time-consuming adjustments are not realistic for patient groups requiring acute care.
Thus, there is also a need for standard implants with more **complex geometries** that can serve a larger patient population.

Solution

The **advantage of additive manufacturing** combined with the exceptional **properties of amorphous metals** remove the acute dilemma between load and movement in the bone healing process. Due to their atomic structure, amorphous metals exhibit high elasticity combined with high strength. Biomechanical forces in the jaw area or jerky impacts and blows are thus cushioned and stabilized.

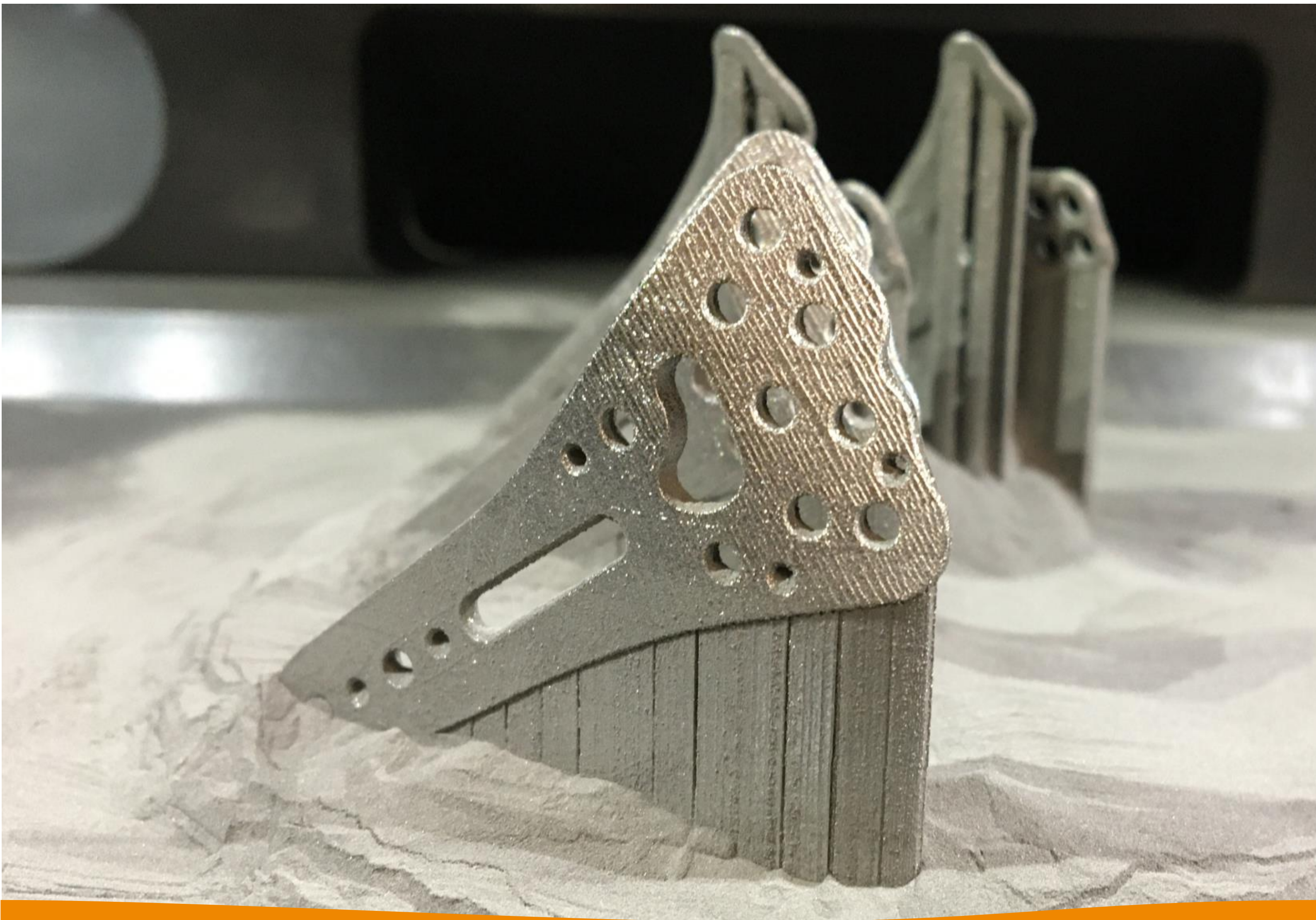
In the field of customized implants or the production of complex geometries for flexible and at the same time stable standard implants, tight tolerances can be realized.

Porous **surface structures** that facilitate bone ingrowth can be produced just as easily as smooth surfaces. While conventional materials require many post-processing steps for this, the amorphous alloy **AMLOY-ZR01** realizes **surface qualities** in the range of 1 µm without post-processing.

In case of even higher requirements, even values in the range of Ra 0.05 µm can be produced by glass bead irradiation. Powder particles are then cleaned during ultrasonic cleaning.

These possibilities are already feasible today.
The "Clinical Additive Manufacturing for Medical Applications" (CAMed) project at the Medical University of Graz is supporting these solutions. [*]
Here, representatives of science and research as well as industrial manufacturers are pursuing the focus of developing a process chain that investigates 3D printing of implants centralized and personalized in the clinic.

Especially for complex orthopedic fractures, the **potential for AMLOY-ZR01 is enormous**.
The **improvement of the recovery process**, **individualization** and **component optimization** as well as **elasticity and strength under permanent load** is achieved here compared to conventional solution approaches.



Result

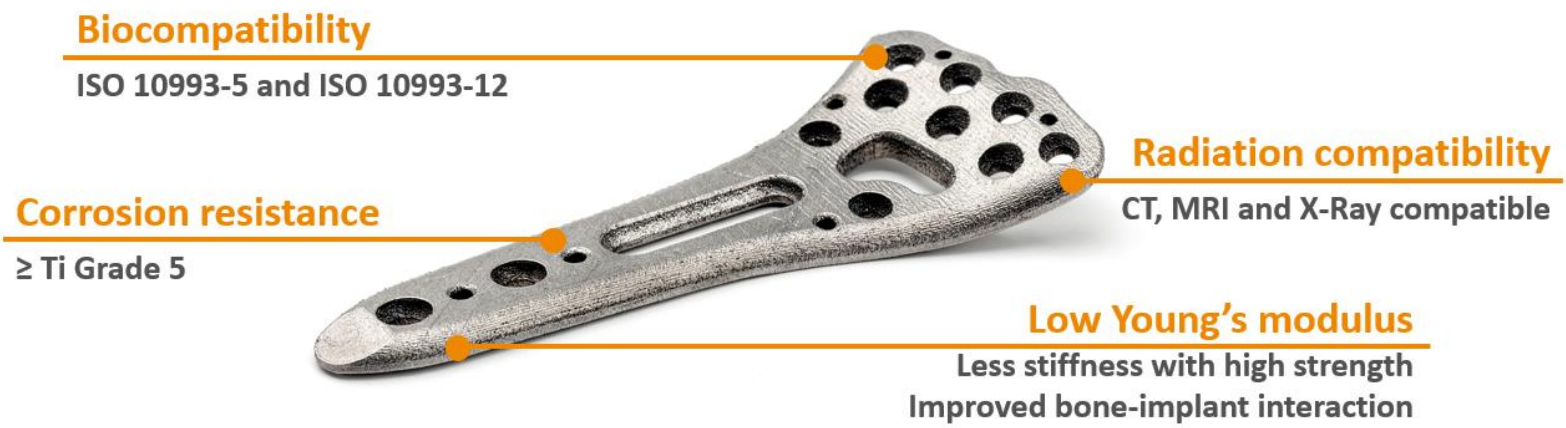
The **optimized design of medical implants using amorphous metals** offers a number of advantages over conventional titanium materials in addition to a **high degree of design freedom**:

- Despite the higher density of AMLOY-ZR01, **material and weight can be saved** due to its mechanical properties.
- At the same time, the material **stabilizes** the bone with **flexural strengths of 2,300 MPa.**
- The **modulus of elasticity of 87 GPa** is also **closer to human bone** than common titanium materials or stainless steel.
- Due to the absence of grain and phase boundaries, no **corrosive reaction occurs.**
- The corrosion resistance and the associated **biocompatibility** open up **completely new possibilities for medical implants.**

The practical results of the CAMed studies underline the innovative way in which amorphous metals are expanding the range of materials used in surgical implants.

Dr. Eugen Milke
Innovation Manager - Heraeus Amloy Technologies GmbH

„3D printing of amorphous metals can streamline the value chain in medical care, facilitate the implantation process for surgeons and, most importantly, sustainably improve the recovery process for patients.“



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