Jahan, J Biotechnol Biomater 2022, 12:10

Journal of Biotechnology & Biomaterials

Case Report Open Access

Behavior of Porous Biomaterials Produced by Selective Laser Melting with Regard to Fatigues

Amin Jahan*

Department of Orthopaedics, Erasmus University, Netherlands

Introduction

The biomaterials that replace bone should be biocompatible and have mechanical properties that are comparable to those of bone. The majority of metallic biomaterials used today are substantially stiffer than the bone they replace, which leads to stress shielding. In the case of orthopaedic prostheses, unloading of the bone as a result of stress shielding will cause bone resorption (Wolff's law) or may prevent full bone regeneration in the case of bone substitute biomaterials. Stress shielding is thought to trigger bone resorption, which can lead to extremely undesirable outcomes including aseptic implant loosening. Utilizing porous metallic biomaterials is one method for lowering stress shielding. The range of stiffness values for bone is much more closely matched by the overall stiffness of porous biomaterials. Using space-holder technique as manufacturing technique Porous biomaterials with mechanical characteristics (stiffness) similar to bone have been created using additive manufacturing technology [1].

When compared to porous biomaterials manufactured using traditional manufacturing methods, additive manufacturing offers three significant advantages. First, it is possible to carefully manipulate the microarchitecture of porous biomaterial. This is a significant benefit since the microarchitecture of porous biomaterials affects their mechanical properties. Therefore, altering the micro-architecture of porous biomaterials will change their mechanical properties. The ability to combine porous materials with varied micro-architectures or solid materials with porous materials in a single construction is the second benefit. Every micro-architecture results in a specific range of mechanical properties, so it is possible to optimise the distribution of mechanical properties inside the implant to reduce stress shielding. Thirdly, utilising additive manufacturing techniques, patient-specific implants can be created [2].

There are two key benefits to porous metallic biomaterials having more porosity. The metallic biomaterial's stiffness first decreases to a level comparable to the stiffness values commonly measured for bone. Furthermore, highly porous biomaterials offer plenty of room for bone regrowth and implant anchoring. High degrees of porosity, however, may negatively impact the fatigue properties of extremely porous biomaterials. In a recent in vivo experiment, we demonstrated how highly porous titanium alloys created through selective laser melting may regenerate significant amounts of bone in severely sized bone lesions [3-5]. But several of the implanted porous biomaterials displayed fatigue failure symptoms. Understanding the fatigue behaviour of bone replacement biomaterials is crucial since they frequently undergo cyclic loading. Porous metallic biomaterials produced using traditional methods have a fatigue characteristic. Research on the fatigue behaviour of porous metallic biomaterials produced using additive manufacturing techniques are scarce, and the most of them are concentrated on selective electron beam melting, the use of sacrificial wax templates, and laser designed net shape (LENS).

In the current investigation, we examine the wear behaviour of a porous titanium alloy produced using selective laser melting. Prior to using compression-compression fatigue tests to ascertain the examined materials' fatigue behaviour, we measure the static mechanical properties of the materials under study. Studies are also conducted on the impact of porosity, stress level, and other variables on the fatigue behaviour of the examined biomaterials. Utilizing data on strain and strain increments, the mechanisms underlying failure and fatigue are explored, and the many stages of fatigue failure are discovered and described [6].

Materials and Methods

Utilizing the selective laser melting approach, porous structures were created [7]. The specifics of the laser processing techniques matched those described in earlier investigations. Dodecahedrons were always used as the basic building block for the microarchitecture of these porous structures. The biomedical titanium alloy Ti6Al4V ELI was used to create four distinct structures. As per ASTM B348, grade 23 spherical pre-alloyed Ti6Al4V ELI powder was employed. The samples were constructed on a solid titanium substrate, and the fabrication was carried out in an inert environment. Following manufacture, wire electro discharge machining was used to separate the samples from the substrate. There were differences in the four separate porous constructions' parameters, such as the pore size and strut thickness, which led to in four distinct porosity levels. For static and dynamic testing, cylindrical specimens having a diameter of roughly 10 mm and a length of 15 mm were produced. On five distinct samples from each series, the overall open porosity was assessed using dry weighing and Archimedes measurements [8].

Dry weighing was done under standard atmospheric circumstances, and total porosity was determined by dividing the measured weight by the macrovolume's theoretical weight, which was 4.42 g/cm3 for Ti6Al4V ELI. The measures used by Archimedes are based on a combination of dry and pure ethanol weighing. The final step was to calculate overall porosity by dividing actual volume by macro volume. A Pioneer OHAUS balance was used for all weighing measurements. Using Computer Tomographic data obtained with a Skyscan 1172 micro-CT system pores and struts were measured. One sample from each series was scanned.

utilising an 11.8 m resolution protocol over a total height of 6 mm (100 kV, 100, Al + Cu filter, 0.4 degree rotation step, 5° frame averaging). With automatic misalignment compensation, smoothing

***Corresponding author:** Amin Jahan, Department of Orthopaedics, Erasmus University, Netherlands, Email: Jahan.amin@gmail.com

Received: 02-Sep-2022, Manuscript No. jbtbm-22-80826; **Editor assigned:** 05-Sep-2022, Pre-QC No. jbtbm-22-80826 (PQ); **Reviewed:** 24-Sep-2022, QC No. jbtbm-22-80826; **Revised:** 29-Sep-2022, Manuscript No. jbtbm-22-80826 (R); **Published:** 07-Oct-2022, DOI: 10.4172/2155-952X.1000299

Citation: Jahan A (2022) Behavior of Porous Biomaterials Produced by Selective Laser Melting with Regard to Fatigues. J Biotechnol Biomater, 12: 299.

set to 4, ring artefacts reduction to 8, and beam hardening correction to 70%, CT images were rebuilt using the Sky scan NRecon programme. In CTAn software, the size of the pores and the struts were calculated As a result, a global threshold was used to extract a binary dataset from the reconstructed dataset. Following the measurement of pore size and strut size, global threshold values were established for each sample based on the theoretical volume of the titanium structure that had been scanned. To learn more about the micro-structure and the micro-hardness, one sample from each series was prepared following compression static mechanical testing. After being etched, polished samples were examined using a Leica DMILM 12 V/100 W microscope after being submerged in a solution of 50 ml H2O, 25 ml HNO3, and 5 ml HF. Vickers hardness was measured using a Leitz micro-hardness tester with a 50 g load. Seven indentations were produced on each sample [9, 10].

The majority overlap of normalised S-N curves has significant practical ramifications. The power law that fits all of the data points has a very high R2 = 0.94 coefficient of determination. As a result, this power law may be useful for approximating the S-N curves of porous titanium structures produced using the same manufacturing process, selective laser melting, for which no data from fatigue tests are available. The ability to quickly estimate normalised S-N curves using the given power law is a welcome possibility because fatigue testing are time- and money-consuming. Therefore, using quick and inexpensive static mechanical tests, one can determine the yield stress of any identical porous material and translate the normalised S-N curve. with absolute stress levels, to an S-N curve. Although the power-law presented in this study is based on in-depth testing of four different porosities, additional fatigue tests for other structures with different porosities are required to ensure that the deduced power law is valid also for porous titanium structures with porosities that are very different from those tested here.

The specimens of all porous constructions that are taken into consideration fail before 106 loading cycles, even for stress values as low as 0.2 y. The allowable stress limit is 0.25 y for 105 loading cycles, based on the fitted power-law. The predicted allowable stress level, calculated by extrapolating the power law to 106 loading cycles, is 0.12 y. This is significantly less than the solid's normalised endurance limit. Even a little bit less than the normalised endurance limitations of porous-coated Ti6Al4V and electron beam melted Ti6Al4V. Similar to porous titanium alloys melted by electron beam, there are three main factors that may have contributed to the selective laser melting of porous titanium having a lower fatigue life than solid Ti6Al4V. First, manufactured porous structures have a rather rough surface [10].

Conclusion

In combination with Ti6Al4v's high notch sensitivity, the high amount of surface roughness could lead to early fracture initiation and growth from a number of sites inside the porous structure. Second, a lot of the struts are low-thickness due to intrinsic manufacturing restrictions. The porous structure's weakest link is this low-thickness strut, which is susceptible to significant plastic deformation even when other struts.

References

1. J Bobyn A, Glassman H, Goto J, Krygier J, Miller C (1990) The effect of stem stiffness on femoral bone resorption after canine porous-coated total hip arthroplasty. Clin Orthop Relat Res 196.
2. Huiskes R, Weinans H, Rietbergen B (1992) the relationship between stress shielding and bone resorption around total hip stems and the effects of flexible materials. Clin Orthop Relat Res 124-134.
3. Burg KJL, Porter S, Kellam JF, Bauer W J, Schils Skelet (2000) Biomaterials. Radiol 28: 483-497.
4. Sharma S, Srivastava D, Grover S, Sharma V (2011) Biomaterials in tooth tissue engineering: a review.
5. Biplab Das (2014) Porous biomaterial makes for better heart valves scaffolds.
6. Canham L (2011) Porous silicon as a therapeutic biomaterial. J clin adv 12-14.
7. Anna Knaislova, Pavel Novak (2018) Preparation of Porous Biomaterial Based on Ti-Si Alloys.
8. Douglas Rangel Goulart (2015) Considerations on the Use of Lumina-Porous? Biomaterial in Maxillary Sinus Floor.
9. Tapas Mitra G, Sailakshmi A, Gnanamani AB (2013) Manda Exploring the dual role of α,ω-di-carboxylic acids in the preparation of collagen based biomaterial.
10. Kajal K, Mallick (2009) Development, Synthesis and Characterization of Porous Biomaterial Scaffolds for Tissue Engineering. 115-128.