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SLM Additive Manufacturing of NiTi Porous Implants: A Review of Constitutive Models, Finite Element Simulations, Manufacturing, Heat Treatment, Mechanical, and Biomedical Studies

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Abstract

Nitinol shape memory alloy is a biocompatible material that is suitable for biomedical applications due to its superelasticity, shape memory effect, good corrosion and fatigue resistance, and sound damping properties. With the selective laser melting (SLM) additive manufacturing process, it is possible to produce customized NiTi implants in the form of porous metamaterials with complex geometries. This paper presents a review of modeling, production, and application of NiTi implants. First, the fundamentals of shape memory alloys and the SLM process are summarized. Then, the effects of the SLM process on the transformation temperatures and the impacts of Heat treatments on these temperatures for additive manufactured parts are discussed. Next, a review of recent experimental works on the mechanical properties of NiTi lattice structures are presented regarding the required functional properties of orthopedic implants. Also, in vitro and in vivo biological studies of NiTi implants are reviewed. Finally, constitutive models developed for SMAs are presented and finite element simulations of NiTi lattice structures are discussed.

Keywords NiTi bone implant · SLM additive manufacturing · Heat treatment · Biomedical studies · Constitutive models · Finite element simulation

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Abbreviations

SLM	Selective Laser Melting
SMA	Shape Memory Alloy
SME	Shape Memory Effect
PE	Pseudoelastic
AM	Additive Manufacturing
CAD	Computer-Aided Design
LPBF	Laser Powder Bed Fusion
TTs	Transformation Temperatures
OWSME	One-Way Shape Memory Effect
TWSME	Two-Way Shape Memory Effect
DSC	Differential Scanning Calorimetry
ICP-AES	Inductively Coupled Plasma Atomic Emission Spectroscopy
VED	Volumetric Energy Density
TPMS	Triply Periodic Minimal Surfaces
MVF	Martensite Volume Fraction
TRIP	Transformation-Induced Plasticity
HTSMA	High-Temperature Shape Memory Alloy
FEM	Finite Element Method
UMAT	User-defined Material
FEA	Finite Element Analysis

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