Materials and Design 32 (2011) 4471–4477

Contents lists available at ScienceDirect

Materials and Design

journal homepage: www.elsevier.com/locate/matdes

Material selection for femoral component of total knee replacement using comprehensive VIKOR

Marjan Bahraminasab *, Ali Jahan

Faculty of Engineering, Semnan branch, Islamic Azad University, Semnan, Iran

ARTICLE INFO

Article history:
Received 8 January 2011
Accepted 19 March 2011
Available online 23 March 2011

Keywords:
H. Selection of components
H. Weighting and ranking factors
H. Selection for material properties

ABSTRACT

The increasing trend of total knee replacement (TKR) revision surgery, which is associated with aseptic loosening, makes it a challenging research subject. The concern of loosening can be partially improved by selecting the optimal materials for TKR components. Therefore, this paper considers selection of the best material among the set of alternatives for femoral component of TKR through the multi-criteria decision making approach. The comprehensive VIKOR method was used to select the optimum material, and a systematic technique for sensitivity analysis of weights was introduced to find more reliable results. The obtained ranking order suggested the use of new materials over the existing ones. Porous and dense NiTi shape memory alloys were ranked first and second respectively.

1. Introduction

In recent years, biomaterial development and selection have been two challenging issues due to the essential biological and mechanical requirements [1–3]. Among different biomedical applications, total knee replacement (TKR) has become one of the most critical debates as a result of the simultaneous growing number of replacement [4–7] and revision [4,8] surgeries. The most severe problem associated with revision surgery is aseptic loosening caused by excessive wear between articular surfaces, stress-shielding of the bone by prosthesis, and development of a soft tissue at the interface of bone and implant. Applying the optimal material either for femoral component or the tibial insert can reduce the wear debris and risk of implant loosening. Furthermore, stress-shielding effect is mainly attributed to the material property (elastic modulus) of the components interfacing the bone [9] which are the femoral component on the upper part and the tibial tray in the lower part. Considering this issue for a given design geometry of knee prosthesis, selection of the optimum or best material for femoral part appears to play a significant role in aseptic loosening of the prosthetic joint.

A set of materials is now available which might be suitable to use for femoral component of the knee joint prostheses. However, materials selection of this component has been surrounded by many constraints. To deal with such a difficult problem, one would need to utilize appropriate tools. Traditionally, choosing a new material or replacing an existing one with another whose characteristics provide better performance, was usually carried out by applying trial and error methods or by following of previous experimentation experiences. While it can be dealt with by adopting multiple criteria decision making (MCDM) models [10] to avoid misuse of materials [11] which is associated with huge cost [12]. MCDM provides a foundation for selecting, sorting, and prioritizing materials and helps in the overall assessment. Hence, selection of materials not only requires information about mechanical, physical, biological, electrical, chemical, and manufacturing properties, etc., but also knowledge on MCDM. However, MCDM methods have been widely used in material selection for engineering designs [13–18], and the trend is in growth [10]. In biomedical engineering, most of material selection studies have used finite element analysis as a computer simulation tool [19–21]. Although some have utilized MCDM-based techniques in material selection of hip joint prosthesis [22], and compliant-layer artificial hip joints [23].

This paper discusses a strategy to select suitable material for femoral component of knee prosthesis based on a recently proposed MCDM method, namely comprehensive VIKOR [24], in order to improve the longevity and quality of human life. The scenario starts in Section 2 with theoretical considerations of comprehensive VIKOR approach and a proposed technique for sensitivity analysis of subjective weights, followed by a case study in Section 3. This case study includes a general introduction to TKR components and the required properties of implant materials for femoral component. After good appreciation of the method in Section 2 and the requirements in Section 3, Section 4 offers the solution procedure and discusses selection of the best biomaterials. Section 5 ends the paper with conclusions and remarks.

* Corresponding author. Tel.: +98 2313322034.
E-mail addresses: m.bahraminasab@yahoo.com, m.bahraminasab@semnaniau.ac.ir (M. Bahraminasab).

0261-3069/$ - see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.matdes.2011.03.046