INTERNATIONAL JOURNAL OF INTEGRATED ENGINEERING
ISSN: 2229-838X e-ISSN: 2600-7916

IJIE

Vol. 17 No. 8 (2025) 54-64
https://publisher.uthm.edu.my/ojs/index.php/ijie

Finite Element Assessment of Short Stem in Hip Arthroplasty Based on Different Activities

Haslina Abdullah[1]*, Norfazillah Talib[1], Mohd Nasrull Abdol Rahman[1], Mohamad Shukri Zakaria[2]

[1] *Department of Mechanical Engineering, Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Johor, MALAYSIA*

[2] *Fakulti Teknologi dan Kejuruteraan Mekanikal, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, MALAYSIA*

*Corresponding Author: haslinaa@uthm.edu.my
DOI: https://doi.org/10.30880/ijie.2025.17.08.006

Article Info

Received: 1 June 2025
Accepted: 20 November 2025
Available online: 31 December 2025

Keywords

Stress shielding, short stem, prosthesis, FEM

Abstract

Stress shielding is a phenomenon that occurs when an implant absorbs too much of the load that would typically be distributed to the surrounding bone, resulting in reduced mechanical stimulation of the bone. In hip arthroplasty, the implant's design plays a crucial part in stress distribution at the interface of the implant and the adjacent bone. This study examines the stress distribution in hip arthroplasty implants using Finite Element Analysis (FEM), comparing conventional stems with short stems. Titanium alloy has been chosen as the material of the implant. Stress analysis has been conducted under five different activities: normal walking, walking upstairs, walking downstairs, standing, and sitting to study the effect of these activities on various lengths of stem. The results show that in the conventional stem, the highest stress concentrations occur at the joint and the tip of the implant, leading to stress shielding in the proximal area of the femur bone, which may result in bone resorption and potential implant complications over time. On the contrary, the short stem exhibits higher stress values at the neck of the implant for all activities. However, the short stem demonstrates a uniform stress distribution pattern compared to the conventional stem. In addition, the analysis found that conventional stem practices had higher stress levels throughout all activities than the short stem practices. Among the activities examined, walking activities generated the highest stress, followed by activities such as upstairs walking, normal walking, standing, and sitting. These findings provide insight into the mechanical performance of hip implants and suggest that short stems offer advantages in reducing stress shielding and enhancing longevity.

1. Introduction

Hip arthroplasty, also known as hip replacement surgery, replaces a damaged or diseased hip joint with a prosthetic implant. This surgery alleviates pain and improves function in patients with dangerous hip arthritis, fractures, or other hip joint disorders. Over the past several decades, hip arthroplasty has become one of the most successful and common orthopedic surgeries, significantly enhancing the quality of life for millions of patients. Modern hip prostheses are designed to mimic the biomechanical conditions of natural anatomy and of the hip joint. They generally consist of a femoral component, which trades the femoral head, and an acetabular component, which replaces the hip socket. These components are made from various materials, including metals, for example, cobalt-chromium alloys, titanium, ceramics, and polyethylene. The choice of materials and design of the prosthesis play a crucial role in the success and longevity of the implant [1] [2]. Despite the advances in prosthetic design and materials, one of the significant challenges in hip arthroplasty is the problem of stress shielding [3][4]. Stress shielding occurs when the prosthetic implant alters the natural distribution of mechanical stress within the bone [5]. In a healthy hip, the bone is subject to various mechanical forces during daily activities, which helps maintain bone density and strength. However, when a rigid prosthesis is implanted, it can take on much of the load the bone would typically bear. This reduction in mechanical stress can lead to bone resorption and weakening, particularly around the implant site, compromising the stability and longevity of the prosthesis [6] [5].

Stress shielding is a crucial factor affecting hip surgery's long-term success. It can lead to complications such as aseptic loosening, where the prosthesis becomes loose without infection, necessitating revision surgery. To mitigate this issue, several research studies focus on optimizing prosthetic design and materials to distribute mechanical loads better and promote bone health. Strategies include using fewer stiff materials, designing implants with better load-sharing characteristics, and developing surface treatments that enhance bone-implant integration. For example, Pal et al. [7] present an implant with integrated lattice structures in conventional hip implants, and conduct a finite element study to determine the effectiveness by comparing the lattice-based implants throughout solid implants. As a result, it was found that two designs of implants, specifically Octet and Diamond, are suitable for implementation as lattice structure implants. A similar study was conducted Rana et al. [8] by designing patient-specific porosity implants. However, the porosity is inhomogeneous. The implant was created by distributing auxetic structure units at separate locations along the stem, along with improved pore spreading, to achieve optimal performance. The finite element (FEM) procedure was implemented to study the effects of porosity and the shielding effect, primarily by observing the stress in Gruen zones. Porous implants generally exhibit reduced stiffness compared to solid implants.

The Finite Element Method (FEM) can be employed to simulate the decrease in elastic modulus resulting from porosity and evaluate its impact on load transfer between the implant and the surrounding bone. By simulating the behavior of porous structures, FEM enables the assessment of force transmission to adjacent bone tissue, allowing the evaluation of whether porosity contributes to more natural bone loading patterns, thereby mitigating stress shielding. Optimizing the existing implant has reduced the average stress shielding by 18% from 56% [8]. It has been proven that porosity behavior enables the remodeling of bone and tissue restoration through the transmission of cells, with implant porosity potentially reduced and enhanced by modifying the size of the pores and volume. Besides promoting bone growth, the use of porosity in implant materials is also significant because it results in implants with reduced weight. Hence, Delinkali et al. [9] designed and analyzed a lightweight implant for total hip arthroplasty (THA) with adequate fatigue performance. By applying a lattice structure to a commonly used THA implant geometry, they achieved a 15–17% reduction in mass compared to a solid implant. The study also found that increasing the diameter of pore on the stem surface, while maintaining the lattice design constant, enhanced the implant's flexibility. The outcome of the fatigue tests and finite element method (FEM) showed acceptable agreement.

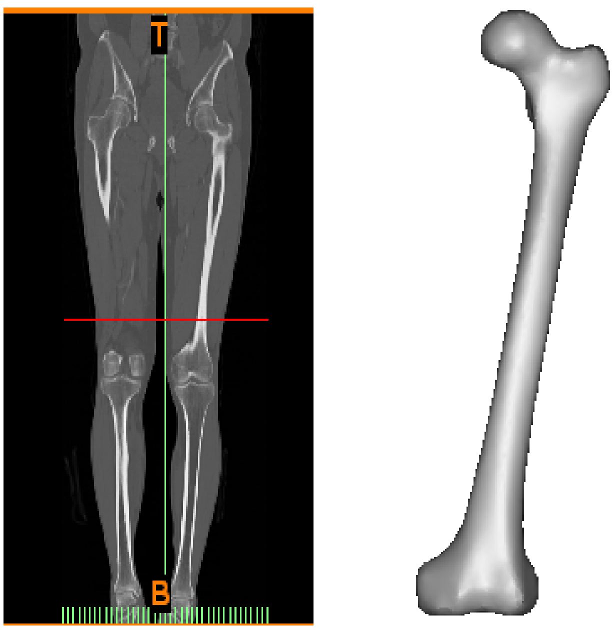
Meanwhile, Jia et al. [10] designed a new cementless femoral hip stem using a low-modulus metastable β Ti-20Zr-3Mo-3Sn alloy, and experimental verification showed that the β alloy has a low modulus. Subsequently, a finite element procedure was conducted on a Ti-20Zr-3Mo-3Sn alloy hip stem to assess the impact of the decreased modulus on stress distribution in both the stem and femur bone, associated with the medical-grade Ti-6Al-4V alloy, which has an elastic modulus of 110 GPa. In addition, the study found that the stem made of Ti-20Zr-3Mo-3Sn can reduce total stress shielding by 45.5% compared to the Ti-6Al-4V prosthesis, due to this material having a low elastic modulus. Additionally, the results proved that material elasticity significantly influences the distribution of stress in the implant, particularly at the interface of the bone and stem. The design of the hip implant also influences stress shielding. Various methods have been employed to construct the component for THA to ensure the mechanical behavior of the bone approximates that of a natural femur. Burchard et al. [11] conducted a study to study the effect of short-stem design-dependent differences on the stress shielding impact after the hip surgery procedure. Then, Burchard et al. [3] extended the study by comparing three types of femoral stems: short and anatomical, short and straight, and standard with straight length. The manufacturer provided details on the descriptions of the three stem prostheses, such as size of implant, maximum depth of the stem body, and type of stem. The study concluded that hip arthroplasty with a short, anatomically designed stem that has lower stiffness offers more biological strain allocation through THA compared to the other two stem types. This means that this stem more closely mimics the native load distribution in the femur, which can be beneficial for the long-term success of the implant. The short, anatomical stem is designed to fit the natural contours of the femur, which helps evenly distribute stress and reduces the risk of complications such as stress shielding and bone resorption.

Additionally, Guzmán et al. [12] examined the effects of different implant designs: circular, elliptical, oval, and trapezoidal, and material types on stress distribution based on static loading conditions. However, in this study, only one type of loading was considered. Besides the geometry of the implant, features also play a role. A study found that using THA implanted with hexagonal chambered internal structures stem can reduce stiffness by approximately 18% and decrease the consequences of stress shielding by 30.4% [13]. Based on the studies conducted by, Burchard et al. [3] and Guzmán et al. [12], the design and material of an implant are crucial in ensuring adequate load transfer and reducing stress shielding. One approach is to develop lighter implants, either by using porous materials or short stems. However, in the studies by Burchard et al. [3] and Guzmán et al. [12], short stems were produced, but the type of activity was not considered. Given that design criteria are critical, this study compares conventional and short stems, considering five types of activities. Two types of stems were designed: conventional and short cylindrical stems.

2. Methodology

2.1 Development of CAD Model

In this study, a finite element method (FEM) simulation has been performed to analyze the performance of hip implants. A three-dimensional (3D) model of femoral bone has been established on a computer tomography (CT) data set, as in Figure 1. A two-dimensional data segmentation has been transformed into a three-dimensional bone using Mimic Software. Then, the refined 3D model is converted into a finite element mesh, dividing the bone into more minor, manageable elements. Mechanical properties, such as Young's modulus and Poisson's ratio, are provided based on the work of Morgan et al. [14]. The size of the implant is customized based on the size of the bone. In this study, two implant designs are examined: standard hip implants and short-stem implants. Both implants have collars at the neck to increase the stability of the implant. Figure 2 displays the relationship between the parameters of the bone and the size and dimensions of the implant. In the design of the implant, several parameters must be considered, including the next shaft angle, head offset length, and the next axis. This process ensures the implant fits the bone. Figure 3 illustrates the conventional and short-stem designs used in this study. The dimension of the hip stem, such as the length of the implant and the neck angle, is defined based on the design in Kaku et al. [15].



(a) **(b)**

Fig. 1 *Three-dimensional bone (a) CT Data set; (b) 3D femoral bone*

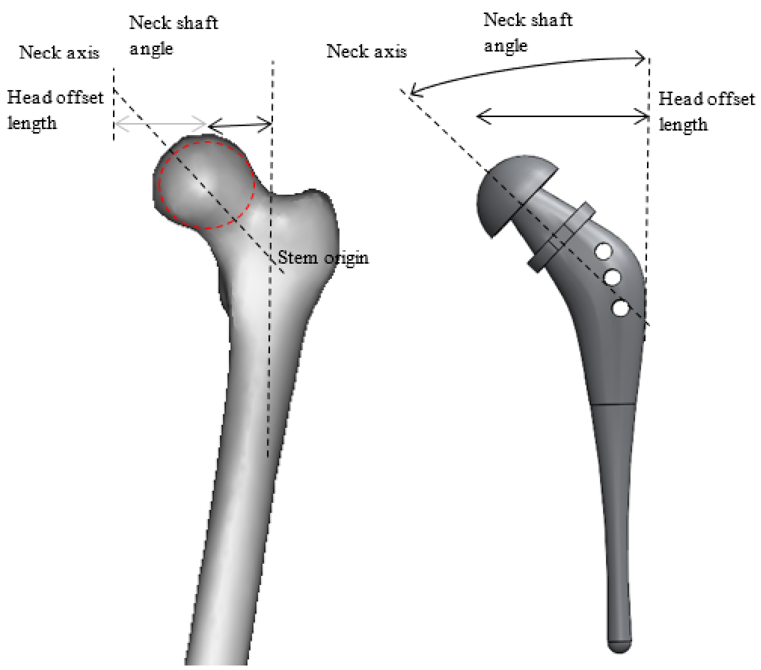
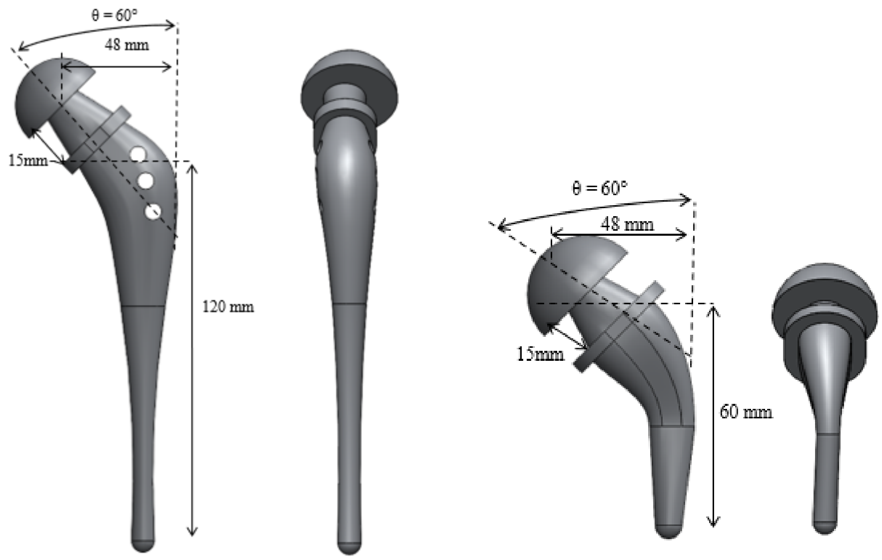


Fig. 2 *Correlation of the hip geometric parameters femoral bone and hip prosthesis*



(a) **(b)**

Fig. 3 *Three-dimensional hip implant (a) conventional; (b) short stem*

2.2 Finite Element Analysis

The Abaqus finite element software was engaged in this research to perform contact analysis using linear tetrahedral elements. Table 1 outlines the mechanical properties utilized in this present study. The value of material's properties used in this study such as Elastic Modulus, Yield strength and Poison ration of the bone and implant defined as suggested by Morgan et al. [14] and Annanto et al. [16]. All materials were presumed to be elastic, homogeneous, and isotropic. For the contact analysis, a frictional interface was defined between the bone and implant, with face-to-face contact elements. The implant surface was designated as the master surface, while the femoral bone surface was designated as the slave surface. As illustrated in Figure 4, a friction coefficient of 0.4 was applied to the interface what was given by Ismail et. al [17]. For loading and boundary conditions, a static analysis has been performed. Joint contact load has been applied at the center of the femoral head, and a fixed boundary condition has been applied at the end of the femur bone. To study the effect of various activities on

Int. Journal of Integrated Engineering Vol. 17 No. 8 (2025) p. 54-64

stress distribution in the implant, five types of activities were applied: normal walking conditions, walking upstairs, walking downstairs, standing up, and sitting—the loading values suggested by Bergmann et al. [18].

Table 1 *Mechanical properties of bone and implant material [14] [16]*

Materials	Elastic Modulus (Gpa)	Yield Strength (Mpa)	Poison ratio (ν)
Cortical bone	17.26	115	0.29
Titanium alloy	110	485	0.34

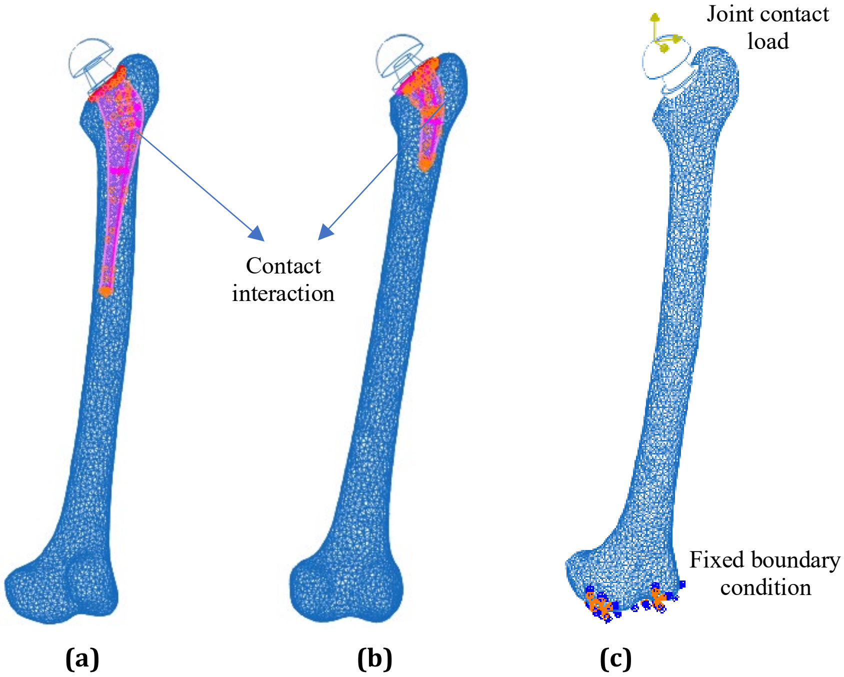
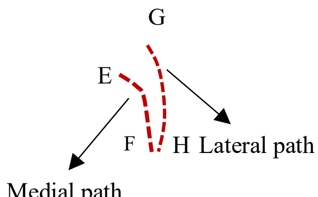


Fig. 4 *(a) Contact interaction conventional stem; (b) contact interaction short stem; (c) Loading and boundary condition*

3. Results and Discussions

3.1 Effect of Implant's Length on the Stress Distribution

Stress values have been assessed in two areas, the medial path, and the lateral path, to examine the effect of implant length on stress distribution. Figure 5 shows the path of the medial and lateral paths along the implant for both conventional and short stem implants. The AB line represents the medial path of the conventional stem. Meanwhile, CD lines show the lateral path of the conventional stem. EF and GH represent the medial and lateral for the short stem, respectively. A graph has been plotted along this path to assess the stress distribution as illustrated in Figure 6 and Figure 7.



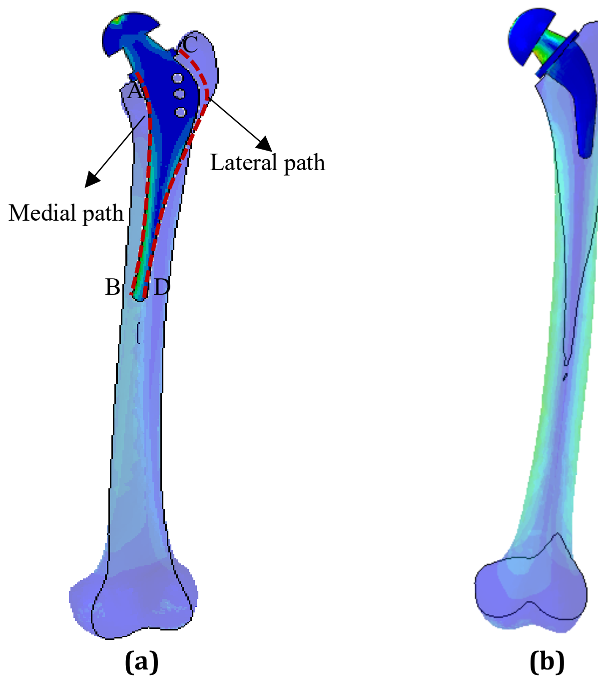


Fig. 5 *Location of path (a) conventional stem; (b) short stem*

The graph compares the Von Mises stress experienced by two different types of implants, which are conventional and short stems along the length of the implant. Overall, the stress is higher for the conventional implant than the short stem along the medial and lateral paths. For the medial path, conventional implants produce low initial stress at the proximal part of the implant (starting from A point). However, as the length increases, the stress rises sharply, reaching a peak of around 140 MPa at approximately 140 mm. In the lateral section, the stress value is higher in the middle of the implant. In contrast, with a short stem, the stress value is higher in the proximal region for both medial and lateral sections. The stress value decreases towards the distal end of the implant. The data suggests that the Conventional Implant experiences much higher stresses along its length compared to the Short Stem Implant, with a sharp increase and peak indicating higher mechanical loads and potential failure points. Meanwhile, the Short Stem Implant's significantly lower and more consistent stress levels suggest better stress distribution and potentially lower risk of mechanical failure along its length. From a design perspective, the short stem might be preferable for reducing stress and avoiding high peak stresses, translating to better performance and longevity in practical applications. Similar results obtained by Kaku et. al [15] implied a short stem in THA could lower the load distribution on the surrounding bone than a conventional implant. However, in their study, short stems produce higher stress at the middle part of the implant.

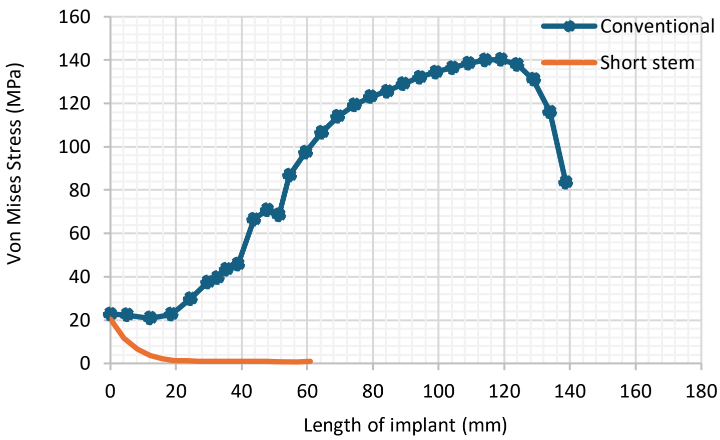


Fig. 6 *Stress distribution along medial path for conventional and short stem*

Int. Journal of Integrated Engineering Vol. 17 No. 8 (2025) p. 54-64

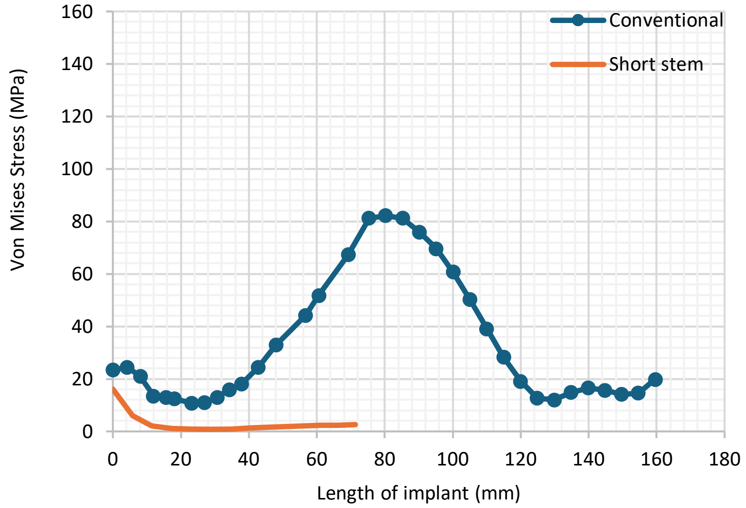
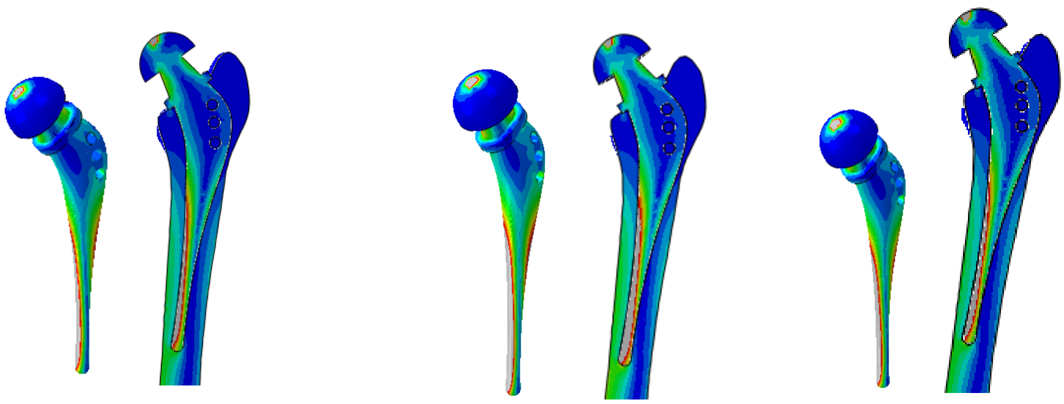


Fig. 7 *Stress distribution along lateral path and for conventional and short stem*

3.2 Effect of Implant's Length on the Stress Distribution Effect of Activities on the Stress Distribution

Figure 8 shows the stress distribution surrounded by the bone and implant for the conventional stem. By observing Figure 8, clearly indicates that the highest stress values occur at the joint and distal end of the implant. This suggests that the implant is experiencing significant stress in these areas. As a result, the bone in the proximal region does not receive adequate stress, which can lead to stress shielding. This can cause bone resorption and potential implant complications over time. Five loading conditions were implemented for the finite element analysis study: normal walking, upstairs, downstairs, standing, and sitting. In all conditions, the stress distribution is less received in the proximal region. However, for walking, upstairs, and downstairs activities, stress is more distributed in the middle of the bone compared to sitting and standing activities. This is because the force and muscle forces involved in walking upstairs and downstairs activities produce higher forces. The joint contact force implemented is also higher than the standing and sitting activities. For Figure 9, which shows the short stem distribution in implant and bone, the highest stress values for all activities occur at the neck of the implant. However, stress distribution in hip surgery is more distributed compared to the stress femur bone with conventional stem. This is because short-stem implants often have a smaller surface area in contact with the bone. This means the load is distributed over a smaller area, increasing the stress at the interface bone-implant. Additionally, the smaller surface contact area leads to higher stress concentrations at the points of contact [19].



(a) **(b)** **(c)**

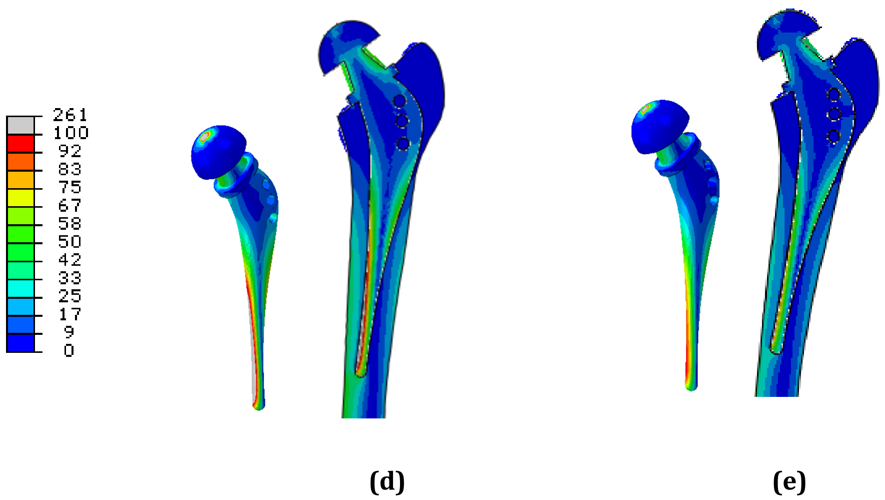


Fig. 8 *Stress distribution in the femur bone and conventional stem for different activities (a) Walking; (b) Upstairs; (c) Downstairs; (d) Standing; (e) Sitting*

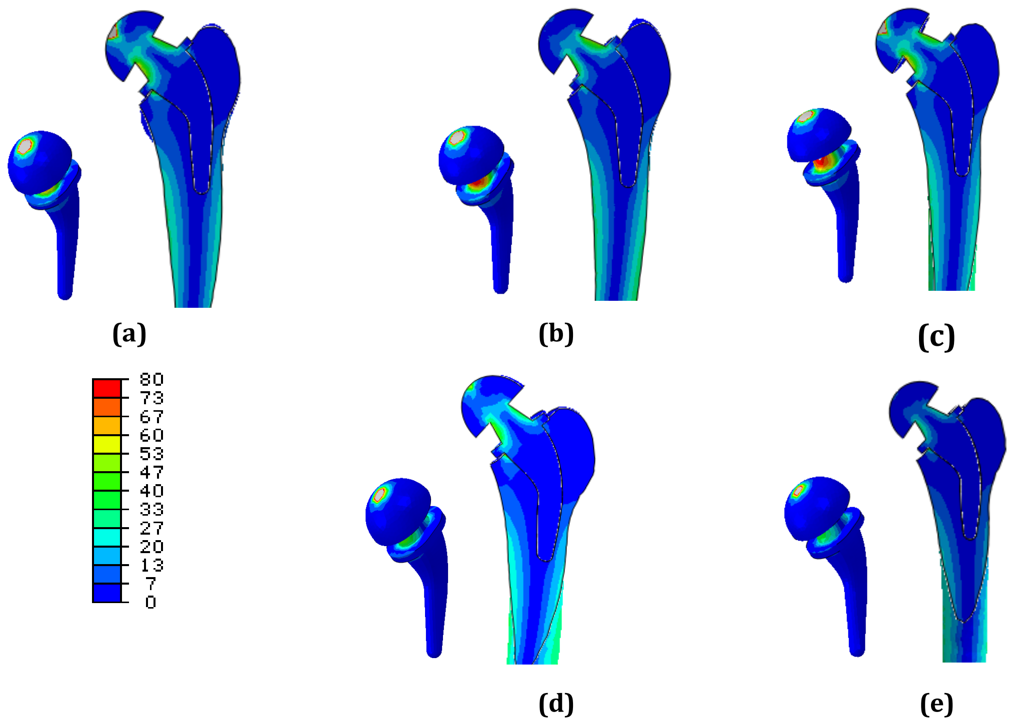


Fig. 9 *Stress distribution in the femur bone and short stem for different activities (a) Walking; (b) Upstairs; (c) Downstairs; (d) Standing; (e) Sitting*

A graph, depicted in Figure 10, was created to compare conventional and short stem implants and better understand the impact of activities on stress values. The short implant shows elevated stress values for all activities compared to the conventional stem. Additionally, it is noted that descending stairs generates the highest stress values, followed by ascending stairs, walking, standing, and sitting. As illustrated in Figures 8 and 9, the peak stress values for the conventional stem occur in the middle of the implant at the medial section. In contrast, for the short stem, the maximum stress is observed at the joint load. During everyday activities, the rotational torque exerted on the stem is minimal during standing and substantial upstairs or downstairs [20] [21].

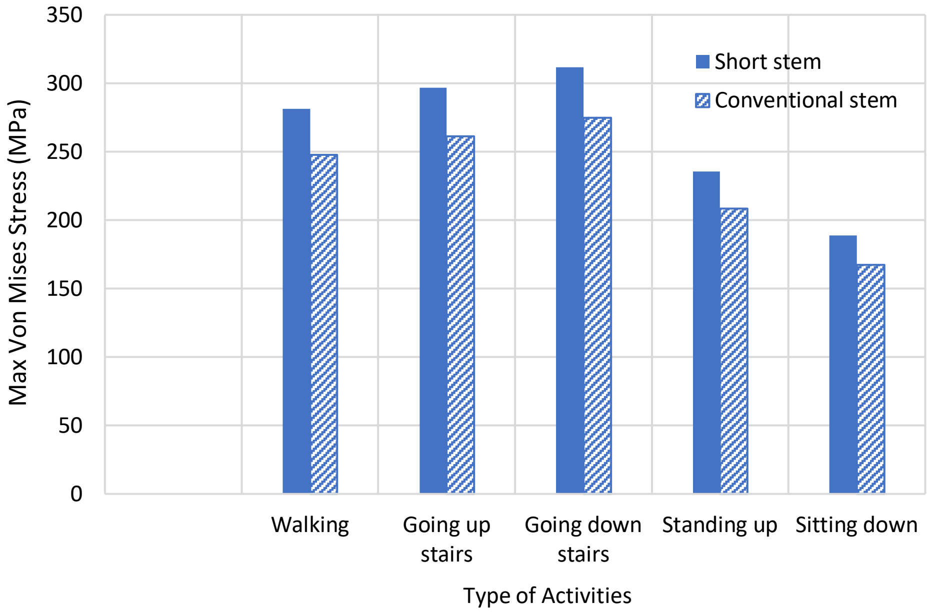


Fig. 10 *Maximum Von mises stress for different activities*

4. Conclusions

This study utilized Finite Element Analysis (FEM) to assess the stress distribution in hip arthroplasty implants between conventional stems and short stems under various daily activities. The findings found that conventional stems exhibited higher stress value at the joint and distal end of the implant, leading to significant stress shielding in the proximal bone. Despite that, the short stems demonstrated higher stress values at the neck of the implant for all activities, demonstrating a more positive stress distribution that reduces stress shielding. The comparative analysis supported that the conventional stem suffered higher overall stress levels in all activities than the short stem. Specifically, downstairs produced the highest stress values, followed by upstairs, normal walking, standing, and sitting. These results indicate that short stems offer advantages over conventional stems in reducing stress shielding and improving the long-term outcomes of hip arthroplasty. In conclusion, understanding the stress distribution is crucial for assessing the durability and reliability of implants, guiding the choice of implant type based on specific conditions

Acknowledgement

This research was supported by University Tun Hussein Onn Malaysia (UTHM) through Tier 1 (vot Q384).

Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***design CAD model and simulation:*** *Haslina Abdullah, Norfazillah Talib;* ***data collection:*** *Haslina Abdullah, Mohamad Shukri Zakaria;* ***analysis and interpretation of results:*** *Haslina Abdullah, Mohamad Shukri Zakaria;* ***draft manuscript preparation:*** *Haslina Abdullah, Mohd Nasrull Abdol Rahman . All authors reviewed the results and approved the final version of the manuscript.*

References

[1] Abdullah Tahir Şensoy, Murat Çolak, Irfan Kaymaz, and Fehim Findik (2019) Optimal material selection for total hip implant: A finite element case study, *Arabian Journal for Science and Engineering,* 44 (12),1-19, https://doi.org/10.1007/s13369-019-04088-y

[2] Liyao Guo, Seyed Ataollah Naghavi, Ziqiang Wang, Swastina Nath Varma, Zhiwu Han, Zhongwen Yao, Ling Wang, Liqiang Wang, & Chaozong Liu (2022) On the design evolution of hip implants: A review, *Materials & Design, 216,* 1-8. https://doi.org/10.1016/j.matdes.2022.110552

[3] Rene Burchard, Jan A. Graw, Christian Soost, & Jan Schmitt (2023) Stress shielding effect after total hip arthroplasty varies between combinations of stem design and stiffness- a comparing biomechanical finite element analysis, *International Orthopaedics,* 47(8), 1981-1987. https://doi.org/10.1007/s00264-023-05825-7

[4] Ridzwan M.I.Z., Solehuddin Shuib, A. Y. Hassan, A. A. Shorki, & M. M. Ibrahim (2007) Problem of stress shielding and improvement to the hip Implat designs: A review, *Journal of Medical Science*, 7(3), 460-467. https://doi.org/10.3923/jms.2007.460.467

[5] Huiskes, R. I. K., Harrie Weinans, & Bert Van Rietbergen (1992) The relationship between stress shielding and bone resorption around total hip stems and the effects of flexible materials, *Clinical Orthopaedics and Related Research*, 274 ,124-134. https://doi.org/10.1097/00003086-199201000-00014

[6] Haslina Abdullah, Mohamad Shukri Zakaria, & Norfazillah Talib (2023, 14 February) Study of Primary Stability of Hip Implant for Semi Hip Replacement by Using Finite Element Analysis, *International Human Engineering Symposium*, Springer Nature Singapore, 133-144, 1- 6, https://doi.org/10.1007/978-981-99-6890-9_11

[7] Ajeet Pal, Jitendra Bhaskar, & Anand Kumar, Design and analysis of hip implant (2023) *Materials Today: Proceedings.* https://doi.org/10.1016/j.matpr.2023.05.701

[8] Masud Rana, Santanu Karmakar, Amit Bandyopadhyay, & Amit Roychowdhury (2023) Design and manufacturing of patient-specific Ti6Al4V implants with inhomogeneous porosity, *Journal of the Mechanical Behavior of Biomedical Materials,* 143, 1-11, https://doi.org/10.1016/j.jmbbm.2023.105925

[9] Yunus E Delikanli, & Mehmet C. Kayacan (2019) Design, manufacture, and fatigue analysis of lightweight hip implants, *Journal of Applied Biomaterials & Functional Materials*, 17(2), 1-8, https://doi.org/10.1177/2280800019836830

[10] Tianyu Jia, Dominique Guines, Doina-Margareta Gordin, Lionel Leotoing, & Thierry Gloriant (2024) Finite element analysis of a low modulus Ti-20Zr-3Mo-3Sn alloy designed to reduce the stress shielding effect of a hip prosthesis, *Journal of the Mechanical Behavior of Biomedical Materials*, 157,1-10, https://doi.org/10.1016/j.jmbbm.2024.106640

[11] Rene Burchard, Sabrina Braas, Christian Soost, Jan Adriaan Graw, & Jan Schmitt (2017) Bone preserving level of osteotomy in short-stem total hip arthroplasty does not influence stress shielding dimensions–a comparing finite elements analysis, *BMC musculoskeletal disorders*,18, 1-7. https://doi.org/10.1186/s12891-017-1702-2

[12] Manuel Guzmán, Emmanuel Durazo, Alejandro Ortiz, Israel Sauceda, Miriam Siqueiros, Luis González, & David Jiménez (2022) Finite Element Assessment of a Hybrid Proposal for Hip Stem, from a Standardized Base and Different Activities, *Applied Sciences* ,12(6),1-23, https://doi.org/10.3390/app12167963

[13] Oliver Bliss, Greg Swadener, Gillian Pierce, & Iham Zidane (2023) Finite element analysis of a stemmed hip prosthesis to reduce stress shielding in the proximal femur, *Journal of Mechanical Engineering and Sciences*, 17(1), 9349-9359, https://doi.org/10.15282/jmes.17.1.2023.5.0739

[14] Elise F Morgan, Ginu U. Unnikrisnan, &Amira I. Hussein (2018) Bone mechanical properties in healthy and diseased states, *Annual review of biomedical engineering*, 20(1), 119-143, https://doi.org/10.1146/annurev-bioeng-062117-121139

[15] Nobuhiro Kaku, Jonas A. Pramudita, Kansei Yamamoto, Tsuguaki Hosoyama, & Hiroshi Tsumura (2022) Stress distributions of the short stem and the tapered wedge stem at different alignments: a finite element analysis study, *Journal of Orthopaedic Surgery and Research*, 17(1),1-12, https://doi.org/10.1186/s13018-022-03425-6

[16] Gilar Pandu Annanto, Eko Saputra, J. Jamari, Athanasius Priharyoto Bayuseno, Rifky Ismail, Mohammad Tauviqirrahman, & Iwan Budiwan Anwar (2018, 14-15 August) Numerical analysis of stress distribution on artificial hip joint due to jump activity, *The 3rd International Conference on Energy, Environmental and Information System (ICENIS 2018),* EDP Sciences, 73, 1-5, https://doi.org/10.1051/e3sconf/20187312005

[17] Nur Faiqa Ismail, Solehuddin Shuib, Muhd Azman Yahaya, Ahmad Zafir Romli, & Amran Ahmed Shokri (2018) Finite element analysis of uncemented total hip replacement: the effect of bone-implant interface, *International Journal of Engineering & Technology*, 7(4), 230-234. https://doi.org/10.14419/ijet.v7i4.26.22173

[18] Bergmann G. F., Graichen, A. Rohlmann, A. Bender, B. Heinlein, G. N. Duda, M. O. Heller, & M. M. Morlock (2010) Realistic loads for testing hip implants, *Bio-medical materials and engineering*, 20(2), 65-75. https://doi.org/10.3233/bme-2010-0616

[19] Nobuhiro Kaku, Jonas A. Pramudita, Kansei Yamamoto, Tsuguaki Hosoyama, & Hiroshi Tsumura (2022), Stress distributions of the short stem and the tapered wedge stem at different alignments: a finite element analysis study, *Journal of Orthopaedic Surgery and Research*, 17(1),1-12, https://doi.org/10.1186/s13018-022-03425-6

[20] Peter Goshulak, Saeid Samiezadeh, Mina SR Aziz, Habiba Bougherara, Radovan Zdero, & Emil H. Schemitsch (2016) The biomechanical effect of anteversion and modular neck offset on stress shielding for short-stem versus conventional long-stem hip implants, *Medical Engineering & Physics*, 38(3), 232-240, https://doi.org/10.1016/j.medengphy.2015.12.005

[21] Arata Kanaizumi, Daisuke Suzuki, Satoshi Nagoya, Atsushi Teramoto, & Toshihiko Yamashita (2022) Patient-specific three-dimensional evaluation of interface micromotion in two different short stem designs in cementless total hip arthroplasty: a finite element analysis, *Journal of Orthopaedic Surgery and Research,* 17(1),1-9 ,https://doi.org/10.1186/s13018-022-03329-5