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The Influence of peg designs on glenoid component: A finite element study

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ABSTRACT – Glenoid loosening was associated with stress at the implant and cement. The purpose of this study was to determine the effect of pegs and its distribution on stress transfer to the implant and cement. Six commercially available implant designs were simulated via finite element analysis with different peg distributions. Maximum stress at the implant and cement and stress critical area (SCA) at the cement were obtained. Partially cemented implants had the ability to reduce the stress at the implant and cement by adding more fins at the central peg.

1. INTRODUCTION

Glenoid component loosening is a common complications in shoulder replacement. Peg fixation is known to provide better seating than keel, but loosening of the glenoid still remained a concern which led to a new design with an anchor peg aimed to extend the durability of the implant. Besides, the rocking motion that normally takes position in the superior-inferior plane causes high stress to the implant. The phenomenon is also associated with high stress at the cement interface [1]. There has been numerous works analysing implant failure via finite element method. However, from our literature search, there have been no reports reporting on the effect of pegs with different orientation on stability and stress transfer to the cement. Thus, the aim of this study was to analyse six types of glenoid implants with different peg designs using finite element method with regards to predicting potential loosening of the component in vivo.

2. METHODOLOGY

2.1 Component Designs

Six glenoid implant designs with different number of pegs were used in this study. Four fully cemented implant designs were developed; an implant with two pegs (2P) located at superior-inferior, a vertically inline three pegs (3P) implant, a four pegs (4P) implant with inverse “T” orientation, and a five pegs (5P) implant down arrow orientation. Two partially cemented implant designs had three cemented pegs at superior-inferior direction and one non-cemented central peg with four fins (4Fins) and six fins (6Fins). The orientation of the pegs in partially cemented implant designs were similar to the four pegs fully cemented implant.

2.2 Finite Element Modelling

The three dimensional (3D) model of scapula cortical bone was constructed using commercial software (Mimics 15). Implants and cements were constructed from CAD modeler (Solidworks 2010). All models were meshed using 4-nodes tetrahedral elements with the total number of elements between 113,804 and 126,353 depending on the type of implants. The cortical bones were isotropic with Young’s modulus of 16GPa and Poisson’s ratio of 0.3. The glenoid implant was made of ultra-high molecular weight polyethylene (UHMWPE) with Young’s modulus of 965MPa and Poisson’s ratio 0.34. While the cement was made of polymethylmethacrylate (PMMA) with Young’s modulus of 2GPa and Poisson’s ratio of 0.23 [2]. The medial border of the scapula was fixed. The 750N load was applied specifically at the inferior location where the pegs were distributed representing the daily activities done by elderly people [3].

3. RESULTS AND DISCUSSION

The maximum stress at the cement increased as the number of peg increase from two to five pegs in inferior load as shown in figure 1. Partially cemented implants showed no significant difference between 4Fins (6.19 MPa) and 6Fins (6.15 MPa). The stress at the cement which exceeded 5MPa was defined as stress critical area (SCA) and it shown as percentage (table 1). The highest SCA was in 5P implant, which was almost 10% of cement mantle. Meanwhile, SCA in partially cemented implant was 3% lower than 5P implant. In inferior load, the 2P implant showed highest maximum stress at the implant than other designs which was 11.11 MPa. Small difference in stresses were seen at 3P (8.98 MPa), 4P (8.73 MPa), and 6Fins (8.60 MPa), while, at 5P implant, it had the lowest maximum stress, 6.14 MPa. In partially

cemented implant, 4Fins implant had higher stress compared to 6Fins implant, 9.61 MPa.

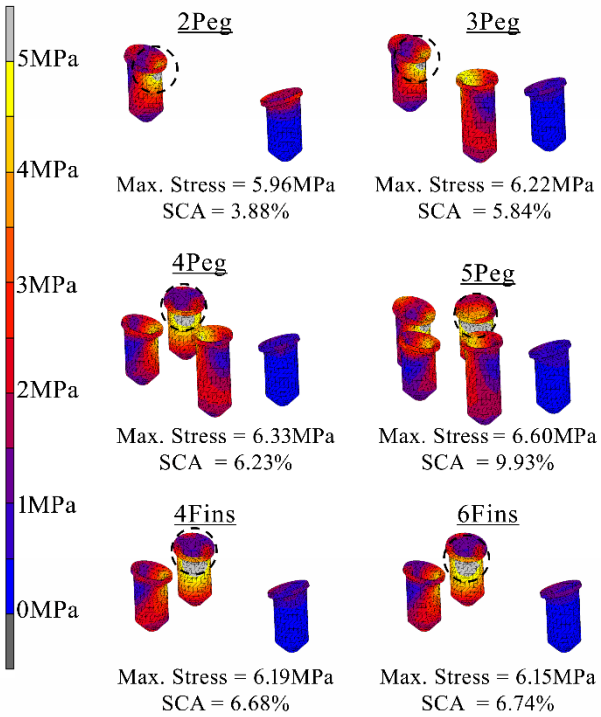

Figure 1 Stress at cement and SCA (in circle).

High stress of glenoid implant had been associated with glenoid loosening and it also could cause implant failure. This high stress could lead to implant micro-movement at the opposite site of load applied. Repetition of this micro-movement, later, lead to glenoid loosening and it commonly known as Rocking Horse Phenomena. Our study showed that, by adding more pegs, stress exerted to the implant can be reduced. Higher peg numbers distribute the stresses to all pegs available instead of focusing on one peg for lesser peg implants. Thus, the 2P implant had higher potential of glenoid loosening due to high stress than the 5P implant.

Table 1 Stress at cement and implant for all designs.

	Cement		Implant
Designs	Max. Stress (MPa)	SCA (%)	Max. Stress (MPa)
2P	5.96	3.88	11.11
3P	6.22	5.84	8.98
4P	6.33	6.23	8.73
5P	6.60	9.93	6.14
4fins	6.19	6.68	9.61
6fins	6.15	6.74	8.60

Under physiologic conditions, cement micro-cracks were initiated when stress at the cement exceeded 5 – 7MPa [1]. In our study, maximum stress at the cement for all designs exceeded the micro-cracks limit, 5MPa, and it increased as the increase of peg numbers (table 1). Besides, SCA also increased in higher peg implant. Patel et al. [4] reported that after total shoulder arthroplasty, the load carried by cement reached up to 24% while, for polyethylene implant, 11%. Thus, by increasing the peg numbers, the load carried by the cement would increase because higher cement usage make it stiffer than lesser peg implant.

There are no significant difference of stress at the implant for 6Fins and 4P implants, however, at cement, 6Fins had lower maximum stress. Currently, the advantages of partially cemented implants compared to conventional fully cemented implants are, they provide long term stability and reduce the usage of PMMA cement, which could lead to bone necrosis due to exothermic reaction. Our study showed that partially cemented implants also maintained the maximum stress at the implant, reduced maximum stress at the cement and reduced SCA at the cement. The high usage of cement could have high possibility of cement micro-cracks which produce cement debris and later on lead to bone osteolysis.

4. CONCLUSION

The durability is the most important criteria to prolong the survival of the glenoid implant in total shoulder arthroplasty. Increasing the peg number has the ability to reduce the stress at the implant. However, it reduces the glenoid bone stock and increases the usage of the cement which could expose it to exothermic reaction from PMMA cement. In addition, high cement usage produces more cement debris due to cement micro-cracks leading to osteolysis. Thus, partially cemented implants with extra fins could provide better solution as it reduces the stress at the implant and cement.

5. ACKNOWLEDGEMENT

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6. REFERENCES

[1] D. Lacroix, L. A. Murphy, and P. J. Prendergast, "Three-dimensional finite element analysis of glenoid replacement prostheses: a comparison of keeled and pegged anchorage systems," *J Biomech Eng*, vol. 122, pp. 430-6, Aug 2000.

[2] P. Mansat, J. Briot, M. Mansat, and P. Swider, "Evaluation of the glenoid implant survival using a biomechanical finite element analysis: Influence of the implant design, bone properties, and loading location," *Journal of Shoulder and Elbow Surgery*, vol. 16, pp. S79-S83, 2007.

[3] C. Anglin, U. P. Wyss, R. W. Nyffeler, and C. Gerber, "Loosening performance of cemented glenoid prosthesis design pairs," *Clinical Biomechanics*, vol. 16, pp. 144-150, 2001.

[4] R. J. Patel, T. M. Wright, and Y. Gao, "Load transfer after cemented total shoulder arthroplasty," *Journal of Shoulder and Elbow Surgery*. vol. 23, pp. 1553-1562, 2014.