

Topography optimisation and experimental validation of an external circular fixator

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ABSTRACT: The use of external fixation devices for the treatment of bone fractures is a very common method of fracture treatment. Also, the topography optimisation using toscan has shown a reduction in the device weight by 40%. Although this study has presented satisfactory results, there is still a need for further studies regarding the structure and type of materials used for the medical device.

1 INTRODUCTION

External fixation device systems are widely used to treat unstable fractures, limb lengthening, and the correction of pathological orthopaedic deformities, among other things. [1,2].

This study aimed to perform biomechanical topography optimisation of a continuous dynamic compression system on the fracture surfaces to satisfy the demand by reducing materials and cost.

2 METHODOLOGY

Dassault Systems' ABAQUS finite element analysis software was used to create the Ilizarov external frame, model. The model was analysed based on the American Society for Testing and Materials (ASTM) F1541 – Standard Specification and Test Methods for External Skeletal Fixation Devices (See Figure 1). The femur bone is attached via a four-pin connector to a cylinder in the design frame. The lower and upper halves of the femur have been separated by 2cm to replicate a real-life bone fracture (See Figure 1).

A wide range of mesh sizes has been investigated (see Table 1). In this study, the linear tetrahedron (C3D10) was considered. The external cage, bone, and pin bar were all 6mm in mesh size.

The pin bar mesh size had to be steadily reduced until the change in findings for von mises stress was less than 1% to obtain the appropriate mesh size. Element size 0.5mm is recommended because it reduces Von Mises Stress by 0.23 per cent compared to mesh size 2mm, which is smaller than the difference between the two values.

The experimental research has been conducted using Instron 5966 Series Dual Column Table Frames with 10kN as the maximum load applied.

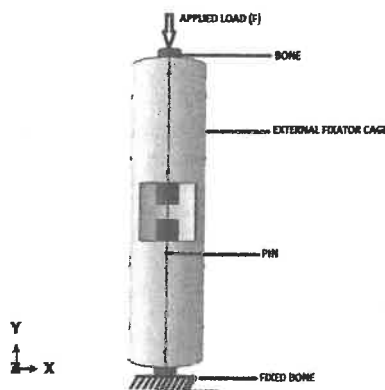


Figure 1. 3D simplified model of an Ilizarov frame fixator.

Table 1. Mesh convergence study of the external circular fixator device.

Mesh size(mm)	Number of elements	Von-mises stress (MPa)	Change in results (%)
6	72710	1799	N/A
3	74341	1726	4
2	77411	1732	0.36
1	87714	1755	1.33
0.5	104698	1751	0.23
0.25	136180	1771	1.14

3 RESULTS

3.1 Finite element analysis for external circular fixator

The 3D external fixator device simulation was conducted using ABAQUS finite element analysis software. 770N load was applied to simulate the patient's posture standing on both legs, where the total load was distributed equally to each leg.

3.2 Experimental analysis results

Table 2. Experimental analysis of the external fixator device.

Sample	Maximum Stress (MPa)	Maximum Deflection (mm)	Time For Experiment(s)
1	1742	12.45764	106.841
2	1729	12.03899	103.27
3	1703	11.74254	100.706
4	1714	11.97014	102.67
5	1726	12.02455	103.121

Table 2 shows the experimental analysis of the external fixator device using the Instron 5966 Series Dual Column Table Frames with 10kN as the maximum load applied Universal Testing machine. The test was done by applying a load at the top femur's top until the deflection reached 10mm. This process has been repeated for the 5 samples.

3.3 Design optimisation

The topology task was created by selecting the external fixator cover to be optimised. Then a design response was created to specify the objective function (strain energy) and the constrain function (volume) with 25 cycles See Figure 2.

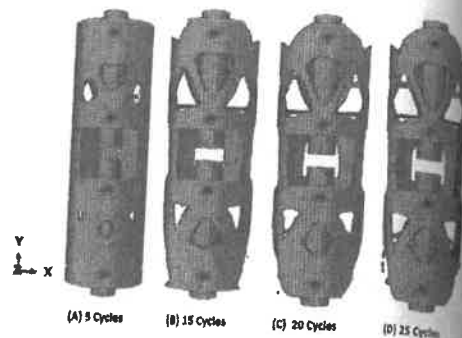


Figure 2. Topography optimisation cycles.

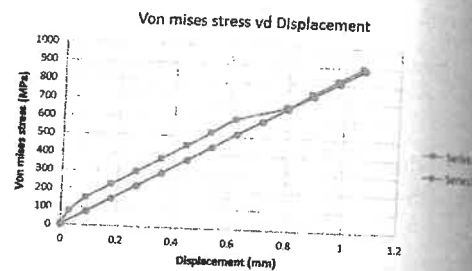


Figure 3. Comparison of von mises stress obtained before and after the optimisation process.

4 DISCUSSION

During the Optimisation phase, the job task was configured to run for 25 cycles to obtain the high quality of the design shape after optimisation by reducing the weight by 40%.

5 CONCLUSION

Manual and topological optimisation strategies were considered for weight loss, and 40% weight loss was successfully achieved.

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- [2] Dichio, G., et al. (2020). *Engineering and manufacturing of a dynamizable fracture fixation device system*. *Applied Sciences*, 10(19): p. 6844.