INTRODUCTION

Hallux valgus is a common orthopaedic condition. There are currently many corrective surgical procedures described in the literature, including a variety of first metatarsal osteotomies. These are designed to reduce the first intermetatarsal angle thereby correcting the deformity.

For the treatment of mild and moderate deformities, the Z (or Scarf) and Chevron osteotomies are used. The distal Chevron is an L shaped cut through the head of the first metatarsal. The distal osteotomy is a simpler procedure than the Z osteotomy but there are restrictions on the amount of deformity that can be corrected. There has been recent interest in the Z osteotomy originally described by Burutan popularized by Barouk in France as a result of its versatility. This osteotomy is a three dimensional Z cut orientated along the longitudinal axis of the bone, enabling displacement in the transverse plane reducing the intermetatarsal angle. It also enables rotational correction of the hallux and adjustment of metatarsal length. The technique of the Z osteotomy and the method of fixation have evolved only through the personal experience of the surgeons. Barouk’s early experience revealed that there were complications with fracture through the proximal dorsal fragment (personal communication). Biomechanical tests have more specifically identified the site of fracture at the level of the proximal Z bend extending through the proximal dorsal fragment. De reymaeker (1) states that good correction of moderate hallux valgus can be obtained with the Z osteotomy compared with distal chevron.

The aim of this study was two-fold. Firstly, a Finite Element Analysis (FEA) model of the Z osteotomy was developed. This was to gain an insight into the range of cuts and degree of displacement. A comparison of the stress levels in each of the fragments of the first metatarsal could then be made. Secondly, sawbone models of the first metatarsal were used in a materials testing machine to compare the strengths of the intact metatarsal, the Z and chevron osteotomies. Then different cuts for the Z and chevron osteotomies were compared for their load to failure.

METHOD

A Z osteotomy was carried out on a cadaveric foot. It was then CT scanned at 1mm sections. The data was analysed in CTM (Materialise N.V., Belgium) to determine the outer and inner profiles of the capital and dorsal fragments of the first metatarsal. CTM software was able to determine the extent of cortical and cancellous bone and this data was incorporated in the finite element model. The outer and inner profiles of the first metatarsal were exported as iges files and these were then incorporated in the finite element model. The model consisted of 32306 eight-noded hexahedral elements and 39988 nodes. The proximal part of the first metatarsal was then hand oriented along the longitudinal axis of the bone, enabling displacement in the transverse plane reducing the intermetatarsal angle. It also enables rotational correction of the hallux and adjustment of metatarsal length. The technique of the Z osteotomy and the method of fixation have evolved only through the personal experience of the surgeons. Barouk’s early experience revealed that there were complications with fracture through the proximal dorsal fragment (personal communication). Biomechanical tests have more specifically identified the site of fracture at the level of the proximal Z bend extending through the proximal dorsal fragment. De reymaeker (1) states that good correction of moderate hallux valgus can be obtained with the Z osteotomy compared with distal chevron.

Sawbone models of the first metatarsal were used in a materials testing machine to compare the strengths of the intact metatarsal, the Z and chevron osteotomies. Then different cuts for the Z and chevron osteotomies were compared for their load to failure.

RESULTS

The findings from this study are presented in Table 1. The FEA results show that raising the resection level of the longitudinal cut increased the stresses at the proximal Z bend (from 33.1MPa for a low cut to 49.3MPa for a high cut). The sawbone study showed a similar pattern with a lower load to failure the higher the cut was made with fracture occurring at the proximal Z bend. The minimum distance the apex of the distal cut could be made from the articular cartilage without fracture of the metatarsal head was 3mm. There was no significant difference in peak stress at the proximal Z bend if this distance was increased to 10mm. Decreasing the length of longitudinal cut from the distal end was found to decrease peak stresses at the proximal Z bend once the cut was made way from the head. Decreasing the length of the longitudinal cut from the proximal end resulted in an increase in stress at the proximal Z bend. The saw bone study showed a similar pattern with a decrease in load to failure as the cut was decreased from the proximal end. Altering the degree of bony displacement reduced stress where there was maximal contact between the two cortices. The sawbone study showed that the load to failure increased as the contact between the cortices increased. Comparison of the sawbone study for the Z and the Chevron osteotomies showed higher loads to failure for the Chevron than the Z osteotomy. The short Chevron osteotomies had higher loads to failure than longer cuts.

![Table 1](attachment:image.png)

CONCLUSION

For the Z osteotomy, this study has shown that optimum positions for increased strength of the osteotomy are where the resection level is low thereby increasing the lateral face. Although maximal contact between the cortices has been shown to beneficial this is highly dependent on the amount of correction required for the deformity. Increasing the length of the osteotomy, and where the cut is more proximal increases strength. Steck and Ringstrom (2) reported that a long Z osteotomy had superior strength. Although the Chevron is not as versatile as the Z osteotomy, this study has shown that the Chevron osteotomy is stronger than the Z with the short chevron being the strongest. With this regard, in mild degrees of hallux valgus the Chevron cut is a suitable method of correction and early weight-bearing.

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REFERENCES

2. Steck, JK; Ringstrom, JB. Foot Ankle Surg, 40, 305-310, 2001

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