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Introduction

Hallux valgus (HV), more commonly known as the bunion, is the most common painful deformity of the big toe and many surgical procedures have been proposed for its correction. Hypermobility or instability of the first metatarsal (MT1) at its tarsometatarsal joint (TMJ1) is associated with greater degrees of deformity and also greater risk of recurrence after surgery. Recent anatomical work has shown the importance of the plantar aponeurosis (PA), and the transverse ‘tie-bar’ system (TTB) comprising the metatarsophalangeal (MPJ) plantar plates and intervening deep transverse intermetatarsal ligaments in the structure and function of the foot. These ligamentous systems are important in MPJ stability, but may also be important at TMJ1. Their disruption may account for deformities such as HV. A greater understanding of factors leading to MT1 instability will allow a rational approach to surgical management of HV deformity. An in vitro model has been developed to study the ranges of movement of the normal MT1 and the effect of these ligamentous systems.

Methods

Ten normal cadaveric feet were dissected to expose the capsules and ligaments of the MPJs and TMTJs and the PA. They were then mounted in plaster of Paris leaving the MT1, MT2, and their articulations free. A loading fixture was constructed so that loads could be applied to MT1 in the transverse plane to produce moments in flexion, abduction or extension. The movements resulting from a load of 40N were measured relative to MT2 using an Isotrak II (Polhemus, US) magnetic measurement system (Fig 1). The tests were performed with the hallux mobile, fixed neutral and fixed dorsiflexed at the MPJ. After an initial test with all structures intact, the PA and the TTB were severed in random order and the test repeated. (A series of photographs for illustrating the specimen preparation procedures is given in Fig 5.) “Movement maps” were produced showing the range of motion available in different directions and with different ligamentous restraints.

Results and Conclusions

Movement maps indicate that the TMJ1 behaves as a ball and socket joint with no preferred axis of motion, as has been previously suggested (Fig 2). The contributions of the PA and TTB to stiffness in the sagittal plane are small (about 1° movement). However, the TTB provides significant control of the abduction of MT1 (Figs 3 & 4). The control afforded by the TTB is particularly important since it can ensure that the PA acts to provide an adduction moment about the TMJ1. The integrity of these ligamentous structures is likely to be important in the success of corrective surgical procedures for HV, where disruption can allow up to 10° increase in MT1-2 angles.

This study has broadened our understanding of the complex nature of structures that control the stability of the first metatarsal. It has provided a theoretical basis on which surgery for hallux valgus can be based. From this study, we hope to develop a more sophisticated computerised model of this complex interaction of muscles and ligaments controlling stability of the first ray. This will help in the theoretical evaluation of biomechanical consequences of corrective surgical procedures.
References


Acknowledgements

This investigation was supported by a research grant from the British Orthopaedic Association Wishbone Trust. The authors express their appreciation to Gavin Smalley, Christine Harkness and Michael Robson for their assistance with experimental data collection.

Fig 1  Schematic diagram of sensors installation and loading applied direction

Fig 2  Movement map showing the angular displacement (in degree) -- Intact Ball & Socket Joint Behaviour under 40N transverse load (Specimen ID : 1197R-CTA)

Fig 3  Movement map showing the angular displacement (in degree) under 40N transverse load Severed TTB First  (Specimen ID : 1197L-CTA)
Fig 4  Movement map showing the angular displacement (in degree) under 40N transverse load
Severed PA First  (Specimen ID : 1197R-CPA)

Legend :
(condition : with fixed dorsiflexed at the MJP1 & Applied Load = 40N)
C4F = Complete Ligament (Intact)
P4F = PA Severed
A4F = All Ligaments Severed

Fig 5  A series of photographs for illustrating the specimen preparation procedures