3D Analysis of Uniplanar and Biplanar Opening-Wedge High Tibial Osteotomies

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Introduction: Opening wedge high tibial osteotomy is an attractive surgical option for physically active patients with early osteoarthritis and varus malalignment. A recent study has indicated that a biplanar technique, which spares the tibial tubercle, is preferable to the traditional uniplanar technique given that it (a) affords a greater surface area of cut bone to facilitate healing, (b) results in a smaller wedge volume, and (c) permits rapid contact healing between the ascending frontal planes of the biplanar cut (1). However, the study was limited by small numbers (five in each group), and its use of a standardized saw-bone model which might not reflect the natural variation in proximal tibial morphology. It also overlooked the inevitable change in contact area between the frontal planes of the biplanar cut as the osteotomy is hinged open.

The purpose of this study was to determine whether the increased surface area seen using a biplanar osteotomy in a saw-bone model applies to 3D bone models produced from patients’ CT scans, and to describe how the contact area between the frontal planes of the biplanar cut change with increasing angular correction.

Methods: CT scans of 53 patients’ knees with an Ahlbäck grade ≤1 (mean age 58, standard deviation (sd) 11) were acquired according to a standardized protocol (2). The CT scans were manually segmented using Mimics software (Materialise, Belgium) to obtain 3D models of the bones which were then aligned using established frames of reference (3). A virtual medial opening-wedge osteotomy was performed on each bone, starting 35mm below the medial joint line and ending 12mm below the lateral joint line, 10mm from the lateral cortex (1). In all cases the biplanar cut was planned at 110 degrees to the transverse cut, 7mm from the anterior cortex. Rhino software (McNeel, Seattle) was used to calculate the area of the distal cut bone surface, with and without the biplanar cut. Virtual opening of the osteotomies was then performed at 1 degree intervals up to 15 degrees, and the area of the biplanar cuts in contact calculated at each stage [Figure 1]. Wedge volume was calculated for each group at 5, 10 and 15 degrees opening. Statistical analysis was performed with SPSS version 21 (SPSS Inc., Chicago, Illinois); a paired t-test was used to compare surface area between the uniplanar and biplanar groups, and to compare differences in wedge volume with a Bonferroni correction. Statistical significance was set at a p-value <0.05.

Results: The surface area in the biplanar group was significantly higher than in the uniplanar group (mean difference 238 mm², 95% confidence interval (CI) 211 to 265 mm², p<0.001). This represents a mean 10% increase in surface area (2691 mm² (sd 469) biplanar, versus 2453 mm² (sd 469) uniplanar) [Figure 2]. The wedge volume was significantly lower in the biplanar group at 5, 10, and 15 degrees of opening (25 mm³, 95% CI 9-41, 50 mm³, 95% CI 18-81, and 74 mm³, CI 27-121 respectively, p=0.009) The mean contact area of the frontal planes of the biplanar cut was 343 mm² (sd106) prior to opening the osteotomy. This contact area was reduced on average by 26% at 5 degrees of angular correction, 51% at 10 degrees, and 72% at 15 degrees [Figure 2].
**Discussion:** This study, based on patients’ CT scans, confirms that a biplanar opening wedge high tibial osteotomy results in a significantly smaller wedge volume, and a significantly larger area of bone available for healing, compared to a uniplanar technique. However, it also highlights that the contact area available for rapid healing between the ascending frontal planes of the biplanar cut decreases in a linear fashion as the osteotomy is hinged open, which may limit its intended usefulness in conferring early stability to the osteotomy site. Further research is needed to elucidate the minimum contact area required to be of benefit. Additionally, 3D planning to customize the position, angle, and depth of the biplanar cut would permit optimization of the contact area. It should be noted that the 3D bone models were segmented from the CT data of patients without osteoarthritis or constitutional varus, and the bone morphology in this region may be different in these patient groups.

**Significance:** Arguably, a biplanar rather than a uniplanar medial opening wedge osteotomy is preferable on the basis that it provides a smaller wedge volume together with a greater surface area of cut bone for healing. The ability of the ascending frontal planes of the biplanar cut to provide early stability through rapid healing is questionable with larger angular corrections; these patients may benefit from a customized 3D osteotomy plan, and a more cautious approach to rehabilitation.

**Figure 3**
Figure 2

Box and Whisker Plots of Surface Area in Uniplanar and Biplanar Osteotomies

* Significant difference between groups p<0.001 (mean difference 238 mm², 95% confidence interval 211 to 256)