Transportal femoral drilling creates more horizontal ACL graft orientation compared to transtibial drilling : a 3D CT imaging study

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Title page

Title

TRANSPORTAL FEMORAL DRILLING CREATES MORE HORIZONTAL ACL GRAFT ORIENTATION COMPARED TO TRANSTIBIAL DRILLING: A 3D CT IMAGING STUDY

Authors

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Abstract

Introduction

The principle of anatomic anterior cruciate ligament (ACL) reconstruction is to create a femoral and tibial tunnel that resembles the insertion of the native ACL in terms of location, size and apertura. It is assumed that anatomic reconstruction leads to a more horizontal graft orientation which provides more rotational stability. To achieve this, both transportal and transtibial drilling methods are widely used to drill the femoral tunnel.

Purpose/Aim

The aim of this study is to determine the best method to achieve anatomical reconstruction of the femoral insertion of the ACL and thus, a more horizontal orientation of the ACL. We investigated the efficacy of the transportal femoral drilling technique used at AZ Monica Antwerp and compared with the transtibial technique.

Materials and Methods

Thirty one patients were included in this study after giving their informed consent. Post-operative CT scans were obtained and the femur, tibia and ACL tunnels were reconstructed with 3D medical image processing software. The position and orientation of the tibial and femoral tunnels were quantified using the quadrant method described by Forsythe and Bernard respectively. These measurements were analyzed to compare the transportal technique with the transtibial technique.

Results

Transportal drilled femoral tunnels were situated significantly lower than transtibial drilled tunnels ($p<0.0001$), resulting in a significant more vertical oriented ACL in the transtibial group in both coronal ($p<0.0001$) and sagittal plane ($p=0.01$). No differences were observed in the depth of femoral tunnel position ($p=0.44$). There were no differences between both

groups in tibial position considering mediolateral ($p=0.99$) and anteroposterior width ($p=0.23$) measures.

Conclusion

This study indicates that transportal drilling of the femoral tunnel leads to a more horizontal graft orientation of the ACL.

Keywords

anterior cruciate ligament

reconstruction

transportal

transtibial

3D CT

1. Introduction

Anatomic placement of the anterior cruciate ligament (ACL) should result in more physiologic knee kinematics *(Musahl 2005)* compared to non-anatomic ACL reconstruction. The principle of anatomic ACL reconstruction is to create a femoral and tibial tunnel that resembles the footprint of the native ACL in terms of location, size, aperture, resulting in the functional restoration of the ACL to its native dimensions and collagen orientation *(Fu and Karlsson 2010)*. Traditionally, non-anatomic ACL reconstructions were only successful in restoring anteroposterior stability, but not rotational stability, resulting in a positive pivot shift *(Woo 2002)*. Vertical ACL placement provides anteroposterior stability, however, studies indicate that rotational stability can only be assured by a more horizontal graft positioning. It is assumed that anatomic reconstruction leads to a more horizontal graft orientation. Therefore, drilling of the femoral and tibial tunnels at native ACL insertion sites is considered a key factor to establish anteroposterior and rotational stability, and prevents impingement of the graft against the intercondylar notch or posterior cruciate ligament (PCL).

Both transportal (TP) and transtibial (TT) drilling methods are widely used to drill the femoral tunnel. Some authors mention that the transtibial method gives a higher chance for postoperative rotational instability due to a more vertical, and thus less anatomical, graft placement. However, clinical studies are inconclusive regarding this theory: a recent systematic review by Chalmers was not able to clearly demonstrate these differences in tunnel position, nor did they find differences in clinical outcome *(Chalmers 2013)*.

The aim of this study is to determine the best method to achieve anatomical reconstruction of the femoral insertion of the ACL and thus, a more horizontal orientation of the ACL. We investigated the efficacy of the transportal femoral drilling technique used at AZ Monica Antwerp and compared with the transtibial technique for drilling the femoral tunnel using more accurate 3D CT based measurements.

2. Patients & Methods

1.1. Study population

Thirty two patients were included in this study undergoing ACL reconstruction at AZ Monica Hospitals, Antwerp, Belgium and University Hospital of Ghent, Belgium, after giving their informed consent. Sixteen patients underwent a transportal reconstruction (9 males, 7 females, aged 34.4 ± 10.0 years), sixteen patients underwent a transtibial reconstruction (9 males, 7 females, aged 34.3 ± 9.9 years), the ACL reconstructions were performed by 3 surgeons.

1.2. Surgical technique

All patients underwent single bundle ACL reconstructions. An ipsilateral hamstring autograft was harvested prior to arthroscopy. Tibial tunnel was drilled using a tibial guide (Acufex, Smith & Nephew, Mansfield, MA). In the transtibial group, drilling of the femoral tunnel was performed using an offset guide with the knee at 90° flexion. For drilling the femoral tunnel through the anteromedial portal, the knee was flexed at 120° and the positioning was done free handed, based on the synovial fold in the back of the femoral notch, the posterior edge of the notch and the distance to the articular cartilage as anatomic landmarks.

1.3. 3D CT analysis

Post-operative CT scans were obtained and the femur, tibia and ACL tunnels were reconstructed with 3D medical image processing software. The ACL tunnels were represented by the inertia axes of the ACL tunnels and the insertion of the ACL graft was represented by the intersection of these inertia axes and the 3D femur and tibia model (Figure 1 and 2). To quantify the position and orientation of the ACL graft, 2D planes were created on the femur and tibia (Figure 1). The quadrant method described by Forsythe *(Forsythe 2010)* and

Bernard *(Bernard 1996)* were applied to quantify the graft position on the femur and tibia respectively (Figure 2). The angulation of the tunnels was measured in the coronal and sagittal plane (Figure 3). These measurements were analyzed to compare the transportal technique with the transtibial technique.

1.4. Statistical analysis

Transtibial versus transportal groups were compared for all outcome measures using unpaired 2-tailed t test. Statistical significance was assumed at $p<0.05$.

3. Results

Femoral tunnels drilled through the anteromedial portal were situated significantly lower than transtibial drilled tunnels (TP 21.8% SD 7.8 vs TT 6.97% SD 6.2, $p<0.0001$), resulting in a significant more vertical oriented ACL in the transtibial group in both coronal (TT 172.1° SD 5.4 vs 147.5° SD 8.1, $p<0.0001$) and sagittal plane (TT 120.0° SD 14.7 vs 107.4° SD 11.3, $p=0.01$) (Figure 4 and 5). No differences were observed in the depth of femoral tunnel position (TT 31.9% SD 5.7 vs TP 30.5% SD 4.6, $p=0.44$).

There were no differences between both groups in tibial position considering mediolateral (TT 45.3% SD 2.7 vs TP 45.3% SD 1.8, $p=0.99$) and anteroposterior width (TT 45.1% SD 3.2 vs TP 43.2% SD 4.6, $p=0.23$) measures.

4. Discussion

This 3D imaging study of patients undergoing ACL reconstruction confirms the idea that transportal drilling of the femoral tunnel leads to a more horizontal graft orientation of the ACL, as shown by a significantly increased coronal and sagittal angle of the ACL in the transtibial group. Our results indicate that the more vertical positioning may be explained by the height of the femoral tunnel, since the average femoral height was indeed significantly higher in the transtibial group compared to the anteromedial group.

Our results are in line with other recent studies that indicate that with the transtibial technique, there is tendency to place the tunnel more into the roof of the notch, leading to a more vertical position of the graft *(Giron 1999; Yau, Fok 2013, Bird 2011)*. Anteromedial portal drilling allows positioning of the femoral tunnel independent of the tibial tunnel and thus potentially in a more anatomical position. Standard deviations were low in both groups for all measurements, indicating that techniques were performed in a standardized and reproducible way.

Some studies indicate that there is a tendency to position the tibial tunnel more posterior in patients with ACL reconstruction using the transtibial drilling technique, compared to patients with transportal reconstruction *(Kopf, Forsythe 2010; Scanlan, Lai 2012; Chang, Choi 2011; Silva, Sampaio 2012; Amis 1996)* or compared to the native ACL reconstruction. This might be due to the overdrilling in a more posterior direction of the tibial tunnel when preparing the femoral tunnel through the tibial tunnel, as mentioned by Yau et al *(Yau, fok 2013)*. In our study, where there was no difference between both groups in tibial tunnel positioning, which indicates that this technical problem did not occur in our technique.

Although our results are in favor of transportal drilling, it should be noted that literature mentions an increase in blow out fractures and critical short femoral tunnels (Harner 2008, Lubowitz 2009) using the anteromedial technique. Another disadvantage that is mentioned by opponents of this technique, is the need for hyperflexion, with diminishes surgical view and the risk of damaging medial femoral articular cartilage *(Bedi 2010, Lubowitz 2009)*.

The main advantage of our study is that we were able to 3D CT based reconstruction of the tibial tunnel, which are more accurate than MRI based reconstruction or X-ray based measurements. It enables to visualize regions that are difficult to see, such as the medial aspect of the lateral femoral condyle. The major limitation of the study is that it is not a randomized study, and therefore potential bias is unavoidable.

In conclusion, this study supports the use of transportal drilling of the femoral tunnel to achieve a more anatomical position of the ACL.

5. Acknowledgements

The authors would like to thank Dr. L. Swinnen of the Department of Radiology, AZ Monica Hospitals, for his support in obtaining the CT scans.

6. References

7. Figure captions

Figure 1

Conversion of tibia and femur 3D reconstruction into 2D plane for further analysis

Figure 2

2D measurement of tibia and femur based on the quadrant technique described by Forsythe *(Forsythe 2010)* and Bernard *(Bernard 1996)*

Figure 3

Reconstruction of ACL orientation and measurement of coronal and sagittal angle

Figure 4

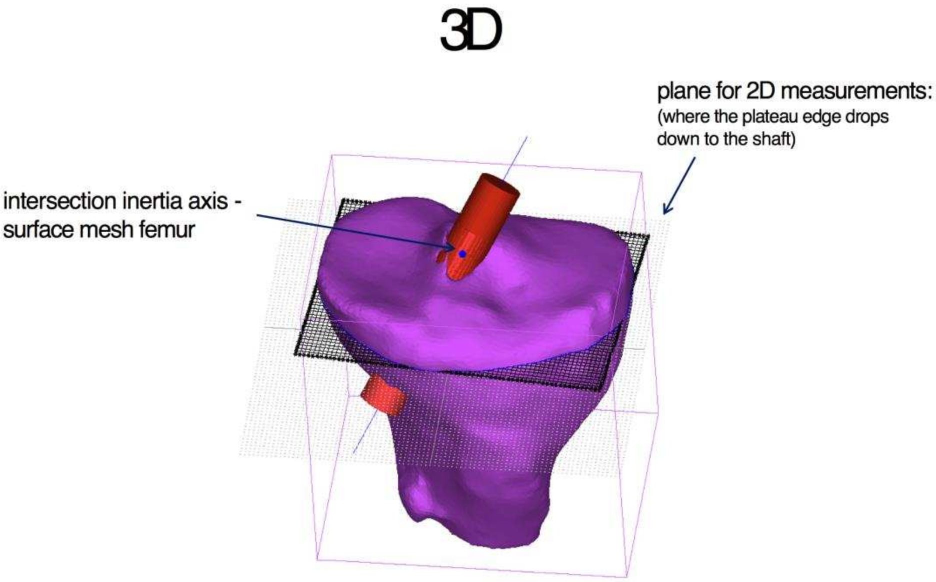
Results shown in boxplots. Statistical analysis was performed using Mann-Whitney-u test. A p value of less than 0.05 was considered significant (indicated by *)

Figure 5

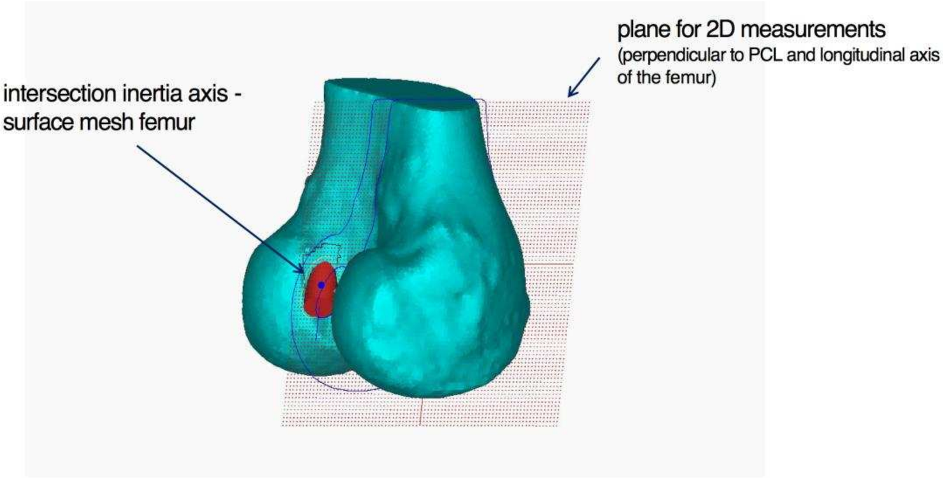
Mapping of tibia and femur tunnel insertion sites for transtibial and transportal drilled tunnels

8. Figures

Figure 1



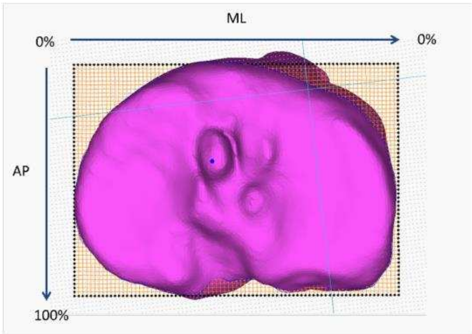
3D



plane for 2D measurements
(perpendicular to PCL and longitudinal axis of the femur)
intersection inertia axis - surface mesh femur

Figure 2

2D measurement tibia



2D measurement femur

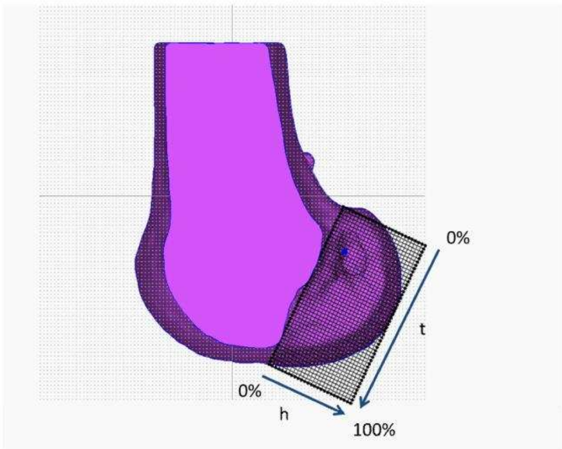
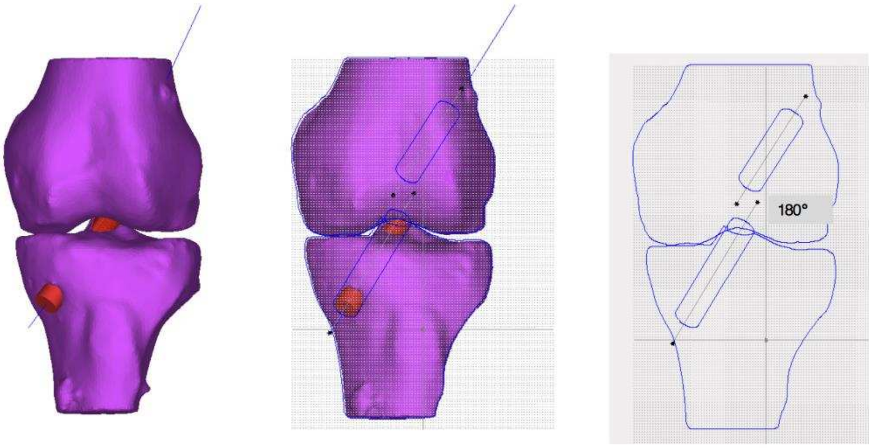


Figure 3

Coronal angle



Sagittal angle

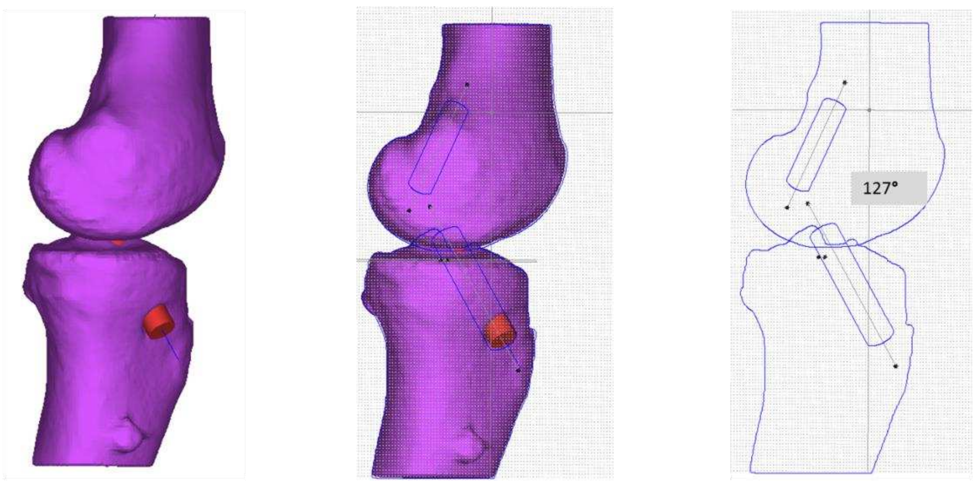
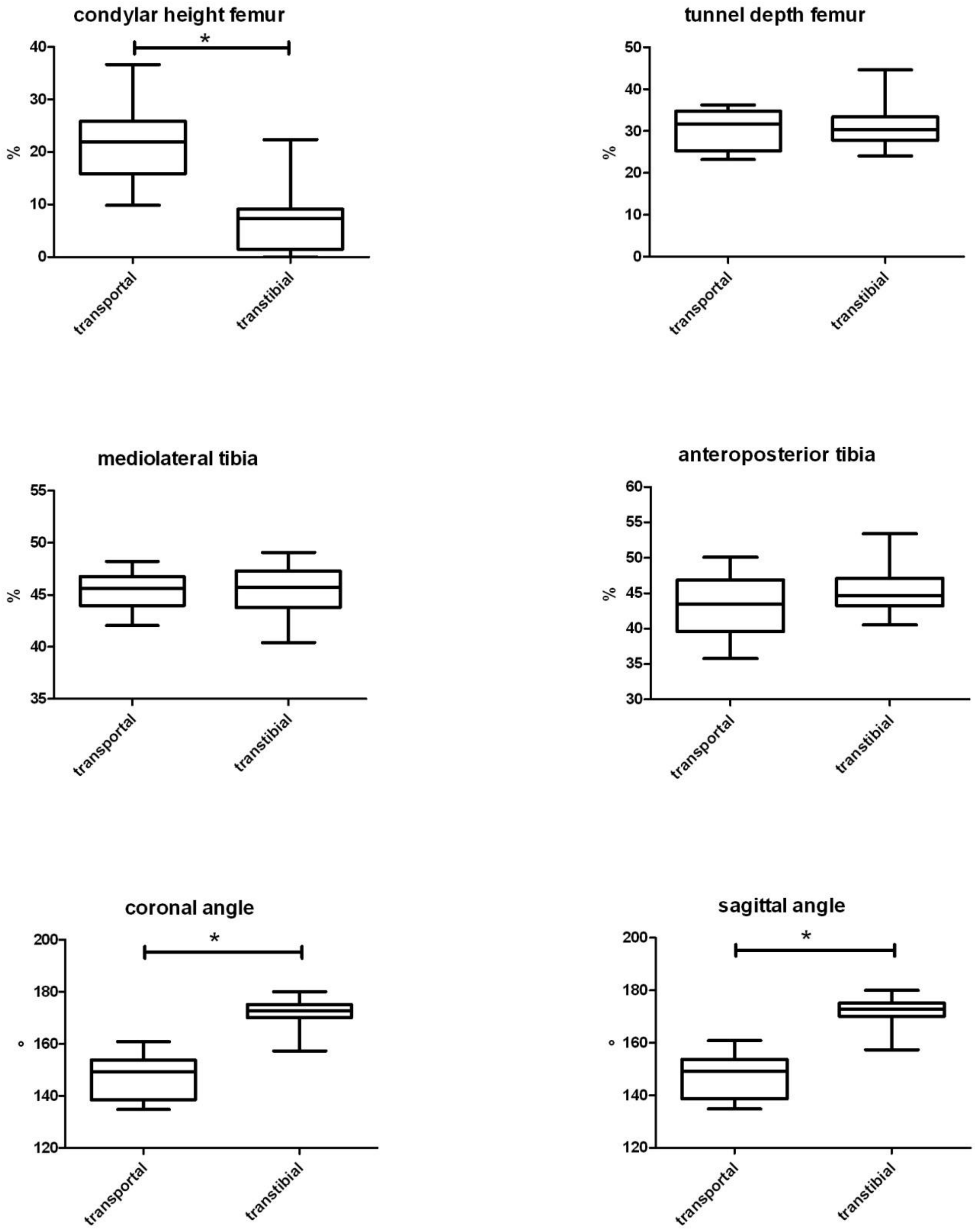


Figure 4


condylar height femur
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*
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transtibial
tunnel depth femur
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transtibial
mediolateral tibia
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transportal
transtibial
anteroposterior tibia
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transportal
transtibial
coronal angle
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transtibial
sagittal angle
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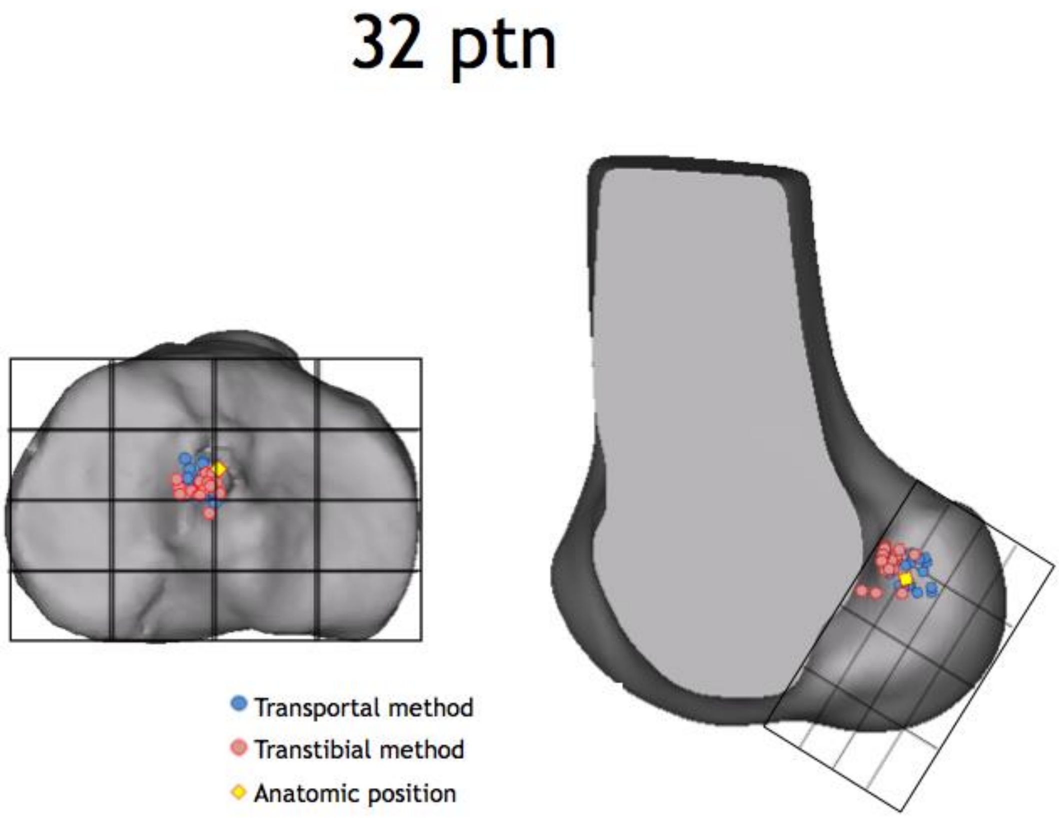
transportal
transtibial

Figure 5


32 ptn
Transportal method
Transtibial method
Anatomic position