Osteochondral talar lesions and ankle biomechanics

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Arthroscopic accessibility of the proximal talar surface as derived from tibio-talar coverage

Maartje Zengerink
Mahyar Foumani
Gabriëlle J.M. Tuijthof
Leendert Blankevoort

Submitted
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Abstract

Purpose
To quantify the coverage of the proximal talar surface by the distal tibia (i.e. tibio-talar coverage) for different extreme foot positions to optimize preoperative planning of anterior and posterior ankle arthroscopy.

Methods
Computed tomography scans of the ankles of 20 healthy subjects were acquired, in neutral and eight forced extreme foot positions, i.e. combinations of dorsal-plantar flexion and eversion-inversion. After segmentation of the talus and the tibia, the distances between the bone surfaces were calculated and represented as distance maps. From these, tibio-talar coverage was calculated for each extreme foot position.

Results
Plantar flexion results in a median of 52% covered area (range 39 to 61) of the proximal talar surface, thus revealing 48% on the anterior side. Dorsal flexion results in a median of 57% covered area (range 51 to 66), revealing 43% on the posterior side. A median of 11.1% (range 0 to 29) and 128 mm² (range 0 to 314) of the proximal talar surface always remains covered by the distal tibia in any of the extreme foot positions. Plantar flexion combined with eversion or inversion did not increase the area that was not covered on the medial or lateral talar shoulder, respectively.

Conclusion
Nearly the entire talar dome is accessible through either anterior or posterior arthroscopy, depending on the individual’s range of motion. There is no gain of adding an eversion or inversion stress to plantar flexion during arthroscopy. On average, part of the postero-central dome, located approximately between 10 and 11 o’clock (viewed from lateral, where the anterior border of the talar dome is 3 o’clock), always remains covered in any position. Osteochondral lesions in this area may be hard to approach arthroscopically.

Clinical relevance
Knowledge of arthroscopic access to the ankle aids orthopaedic surgeons in preoperative planning.
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Introduction
Osteochondral lesions of the talus mostly occur after a sprain or fracture [30]. Because of the nature of the trauma, most lesions are located on the medial or lateral shoulder of the talus [10]. About 80% of the lesions are located in the mid-portion of the talus. Approximately 14% are located in the posterior third [10]. For the initial diagnosis radiographs may be used, but MRI and computed tomography (CT) scanning have a higher accuracy in detecting osteochondral lesions [41]. CT scanning can accurately assess the size and location of the bony lesion [15]. Symptomatic osteochondral lesions require treatment. If arthroscopy is used to address a primary osteochondral talar lesion, then in most cases excision, curettage and bone marrow stimulation are performed [28, 44]. With small instruments like a curette and an angled chondral pick the proximal talar surface is perpendicularly accessed to treat the defect. A 4.5 mm full radius shaver may also be used. For most lesions in the anterior half of the proximal talar surface, anterior arthroscopy is performed [25]. However, for lesions located more posteriorly, it may be unclear whether they can be reached from anterior, from posterior, or not at all by arthroscopy [14, 17]. Whether the osteochondral lesion can be arthroscopically reached is dependent on several factors. Besides the location of the lesion, ankle range of motion, the use of distraction and the type and size of instruments used, determine the feasibility of a successful arthroscopic procedure. The development of better arthroscopic instruments, like the steerable punch [34], improves the procedure.

Access to the talar dome has been a surgical challenge due to the high congruency of the tibio-talar joint and its soft tissue restraints. This is supported by many publications describing access by means of arthrotomy or osteotomy (medial malleolar, tibial, or fibular) [8, 12, 13, 16, 19, 22-24, 31, 43]. However, there are relatively few studies describing arthroscopic talar dome access.

Previous work on this topic was done by Van Bergen et al., who determined the anterior arthroscopic accessibility using computed tomography simulation [36]. The anterior arthroscopic access, with the ankle in full plantar flexion was determined for both the medial and the lateral talar dome, and reported to be 48.2 en 47.8% respectively. In another study it proved to be a reliable method for preoperative planning of arthroscopic treatment of osteochondral lesions in the anterior part of the talus [35].

The above referenced studies have given useful information, but the complete map of arthroscopic accessibility anteriorly and posteriorly is lacking. Furthermore, the dependence of the area of the talar dome that remains covered by the distal tibia on joint range of motion has not been addressed. Finally, it is unknown what the effect is on anterior arthroscopic access when adding an additional eversion or inversion stress to the fully plantar flexed foot. The latter is important since the divergent anatomical orientation of the talus allows plantar flexion movement combined with inversion and eversion [18], in which inversion is larger than eversion [33].

The primary purpose of this study is to quantify full arthroscopic talar dome access by measuring the tibio-talar coverage in various extreme foot positions. Additionally, the secondary purposes are to determine the value of adding an eversion or inversion stress to plantar flexion, and the
Materials and methods
For this study, data from our historical control group were used [5, 33]. The group consisted of twenty healthy volunteers, involving 10 males and 10 females, with a median age of 26 years (range 22 to 35). None of the volunteers had reported ankle or foot complaints or substantial ankle or foot trauma in the past. Of each volunteer, the ankle and hindfoot were physically examined for any abnormalities. The original study was approved by the medical ethics committee. Informed consent was obtained from each individual.

Bone geometric and kinematic data were acquired of the right ankle by our validated 3D stress CT technique [32]. Computer segmentation of the distal tibia and talus was performed with the first series of CT images of each ankle, which was acquired with the foot in a neutral position relative to the lower leg. Following the CT scan in neutral position, CT scans of eight extreme foot positions were performed, i.e. dorsal flexion (DF), combined dorsal flexion and eversion (DF-EV), eversion (EV), combined plantar flexion and eversion (PF-EV), plantar flexion (PF), combined plantar flexion and inversion (PF-IN), inversion (IN), and combined dorsal flexion and inversion (DF-IN) (Fig. 1).

Geometry data of the talus and distal part of the tibia were acquired with a voxel-size of 0.3x0.3x0.3 mm³. Each bone that is segmented from the CT scan in neutral foot position is represented by points on the segmented bony surface. From the matching of the bone geometry to the CT-scan data in the subsequent loaded conditions, the kinematic data were derived. In this fashion the translations and rotations of the tibia and talus for the foot forced in eight extreme positions was determined relative to the neutral unloaded position.

All data processing was performed by using custom-made software based on Matlab (Version 8.2, The Mathworks, Natick, Massachusetts, U.S.A). The full voxel-spaced data set was reduced by a factor 16. The remaining surface data points were used to construct triangulated surfaces of the talus and tibia. The raw triangulated surfaces were smoothed using the implicit fairing method as presented by Desbrun et al. [7]. The amount of smoothing was set such that the root-mean-square (RMS) difference between the triangulated surface points and the original voxel points was close to the voxel size of 0.3 mm, as not to delete any relevant anatomic features. A parameter analysis was performed to evaluate the effect of the data reduction and the amount of smoothing on study outcome.

This study exclusively addressed the proximal talar surface. The medial and lateral articular surfaces of the talus are not part of the proximal talar surface. To limit the analysis of the access of the talar dome to its proximal surface, the opposing medial malleolus of the tibia had to be removed for correct application of the method used in the subsequent analysis. This was done by a virtual osteotomy of the medial malleolus of the tibia. The osteotomy angle was 30 degrees relative to the vertical axis as defined by the CT-scanner [37]. The virtual osteotomy was performed interactively using a custom-made Matlab-program.
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The effect of the patient's range of motion on the tibio-talar coverage. Ultimately, these results lead to optimized preoperative planning for osteochondral lesions in the ankle joint.

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**Figure 1** Images of the ankle of subject 5 in the nine foot positions, i.e. (a) dorsal flexion combined with inversion (DF-IN), (b) dorsal flexion (DF), (c) combined dorsal flexion and eversion (DF-EV), (d) inversion (IN), (e) neutral (NEU), (f) eversion (EV), (g) plantar flexion combined with inversion (PF-IN), (h) plantar flexion (PF) and (i) plantar flexion combined with eversion (PF-EV).

The effect of variations in the interactively performed osteotomies was evaluated by repeating the osteotomies of subjects 1 to 3. First, it was repeated in a similar fashion as the original osteotomy. Secondly, to determine the effect of an intentional deviation, the osteotomy was repeated 2 mm...
wider, i.e. more medial, than the original osteotomy. With these variations the calculations were repeated.
Subsequently, a distance map [20] was determined for each joint position by calculating the distance from every point on the talus to the tibia surface along the line perpendicular to the talus in the talus point.

**Table 1** Definition of terminology used in this study.

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tibio-talar coverage</td>
<td>Coverage of the proximal talar surface by the distal tibia</td>
</tr>
<tr>
<td>Complete tibio-talar coverage</td>
<td>Coverage of the proximal talar surface by the distal tibia for all ankle positions combined</td>
</tr>
<tr>
<td>Covered area</td>
<td>Area of the proximal talar surface covered by the distal tibia</td>
</tr>
<tr>
<td>Area that is not covered</td>
<td>Area of the proximal talar surface that is not covered by the distal tibia</td>
</tr>
<tr>
<td>Area that always remains covered</td>
<td>Area of the proximal talar surface that is not uncovered in any of the ankle positions</td>
</tr>
</tbody>
</table>

**Figure 2** Schematic drawing of the coverage of the proximal talar surface by the distal tibia. (a) Coverage of the proximal talar surface by the distal tibia in the one position. (b) Coverage of the proximal talar surface by the distal tibia in different positions.

To facilitate understanding of this study, the main terminology concerning coverage is listed and defined in Table 1, and schematically represented in Figure 2.

For the analysis of the tibio-talar coverage, the cut-off point for joint space thickness was set at 6 mm, because the estimated cartilage thickness of both the distal tibia and proximal talar surface summed with the diameter of typical arthroscopic instruments was calculated to be this value. In literature, the mean cartilage thickness of the distal tibia is described between 1.06 and 1.63 mm,
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average 1.3 mm [4, 6, 21, 26]. For the proximal talar surface this is between 0.89 and 1.68 mm, average 1.2 mm [1-4, 6, 21, 26, 29, 42] (Table 2). These average cartilage thicknesses add up to approximately 2.5 mm. The largest instrument used for treatment of osteochondral talar lesions is a shaver, which has a diameter of 4.5 mm. A bony distance of 6 mm represents approximately a cartilage-to-cartilage distance of 3.5 mm. This is 1 mm smaller than the diameter of a shaver. Therefore, the proximal talar surface that is covered by the tibia with a maximum bone-to-bone distance of 6 mm is most likely not accessible by a shaver.

Table 2 Cartilage thickness data of the proximal talus and distal tibia as described in literature. Maximum thickness of tibial cartilage was not reported.

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>Journal</th>
<th>Subjects</th>
<th>Method</th>
<th>Average thickness talus (mm)</th>
<th>Maximal thickness talus (mm)</th>
<th>Average thickness tibia (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Athanasiou et al.</td>
<td>1995</td>
<td>Ann Biomech Engin</td>
<td>cadavers</td>
<td>anatomic dissection</td>
<td>1.24 range 1.01-1.45</td>
<td>1.23 range 1.20-1.30</td>
<td></td>
</tr>
<tr>
<td>Adam et al.</td>
<td>1998</td>
<td>J Anat</td>
<td>elderly cadavers</td>
<td>ultrasound</td>
<td>0.95 ± 0.17</td>
<td>1.68 ± 0.27</td>
<td></td>
</tr>
<tr>
<td>Shepherd et al.</td>
<td>1999</td>
<td>An Rheum Dis</td>
<td>healthy 65</td>
<td>in vitro needle probing</td>
<td>1.16 ± 0.30 range 0.94-1.62</td>
<td>-</td>
<td>1.06-1.63</td>
</tr>
<tr>
<td>Al-Ali et al.</td>
<td>2002</td>
<td>J Orthop Res</td>
<td>22-27 years</td>
<td>in vivo MRI</td>
<td>0.89 ± 0.19</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sugimoto et al.</td>
<td>2005</td>
<td>Arthroscopy</td>
<td>cadavers</td>
<td>in vivo radiographs</td>
<td>men 1.35 ± 0.22 women 1.11 ± 0.28</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Millington et al.</td>
<td>2007</td>
<td>Osteoarthritis Cartilage</td>
<td>healthy cadavers</td>
<td>in vitro stereophotographic</td>
<td>1.10 ± 0.18</td>
<td>2.38 ± 0.4</td>
<td>1.16 ± 0.14</td>
</tr>
<tr>
<td>Wan et al.</td>
<td>2008</td>
<td>J Orthop Res</td>
<td>22-24 years</td>
<td>in vivo MRI</td>
<td>1.42 ± 0.18</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Akiyama et al.</td>
<td>2012</td>
<td>Osteoarthritis Cartilage</td>
<td>elderly cadavers</td>
<td>anatomic dissection</td>
<td>1.02 range 0.50-1.58</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Buettner et al.</td>
<td>2013</td>
<td>Foot Ankle Int</td>
<td>cadavers</td>
<td>histomorphometric</td>
<td>1.29</td>
<td>0.96 ± 1.68</td>
<td>1.24-1.46</td>
</tr>
</tbody>
</table>

The relative coverage for each joint position was calculated as the ratio between the covered area of the proximal talar surface associated with the joint position and the complete tibio-talar coverage as derived from the minimum distance map. The exposure of the anterior and posterior talar dome was determined by subtracting the covered area from the complete tibio-talar covered area. Furthermore, from the covered areas in each joint position, the area that always remained covered was calculated as the percentage of the complete tibio-talar covered area. This represents the inaccessible area. Results of all 20 subjects were combined and median complete tibio-talar coverage and the median of the area that always remains covered were calculated.
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The percentage of the proximal talar surface that always remains covered as function of the full dorsal-to-plantar flexion range of motion of the tibio-talar joint was calculated using the Pearson Correlation test. For all 20 subjects combined, tibio-talar coverage for the neutral and the 8 extreme foot positions was calculated. Calculations were performed to determine how the selection of a lower or a higher value (0 to 8 mm) for the maximum joint space thickness would decrease, respectively increase, the size of the tibio-talar covered area. The graphic representations were visually analyzed to see if adding an eversion (PF-EV) or inversion (PF-IN) stress to the plantar flexed ankle increased the area that is not covered on the medial or lateral talar shoulder, respectively.

Results

A typical example of the 3D graphic representations of the ankle in the nine positions is shown in Figure 1 (subject 5). The tibio-talar coverage for all nine positions was determined from the associated distance maps (Fig. 3, example of subject 5). For the chosen maximum joint space thickness of 6 mm, maximum plantar flexion reveals a median of 48% (median 52% covered, range 39 to 61) of the proximal talar surface on the anterior side. Maximum dorsal flexion reveals a median of 43% on the posterior side (median 57% covered, range 51 to 66). An example of the minimum distance map and the area that always remains covered is shown in Figure 4 (subject 5). This is the surface of the talus between 10 and 11 o'clock as viewed from lateral, where the anterior border of the talar dome is defined as 3 o'clock. In any position, the area that always remains covered was median 11.1% (range 0 to 29.3), representing 128 mm² (range 0 to 314).

A larger dorsal-to-plantar flexion range of motion leads to less covered area in a maximum position. Therefore, a smaller percentage of the proximal talar surface always remains covered. A nearly linear inverse relationship was found between dorsal-to-plantar flexion range of motion and the percentage of the area that always remains covered (Pearson Correlation coefficient R=0.96; p=0.0000) (Fig. 5).

From analyzing the graphic representations, it was found that adding an eversion (PF-EV) or inversion (PF-IN) stress to the plantar flexed ankle joint did not increase the area that is not covered on the medial or lateral talar shoulder, respectively. Only maximum plantar flexion and maximum dorsal flexion were defining the area of the proximal talar surface that can be reached. The median size of the complete tibio-talar coverage for the neutral and 8 extreme foot positions of all 20 subjects was 1343 mm² (range 1023 to 2102).
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Figure 3 Images of the distance maps of subject 5 associated with the bone positions presented in Figure 1, showing the covered area of the proximal talar surface by the distal tibia, for a distance of 6 mm in a superior view. The nine foot positions are (a) dorsiflexion combined with inversion (DF-IN), (b) dorsal flexion (DF), (c) combined dorsal flexion and eversion (DF-EV), (d) inversion (IN), (e) neutral (NEU), (f) eversion (EV), (g) plantar flexion combined with inversion (PF-IN), (h) plantar flexion (PF) and (i) plantar flexion combined with eversion (PF-EV).
Figure 4 Images of subject 5 of (a) the complete tibio-talar coverage (1248 mm²), and (b) area that always remains covered (12.7%), for a maximum joint space thickness of 6 mm.

Figure 5 The proportion of the talar dome that always remains covered as function of the full dorsal-to-plantar flexion range of motion of the tibio-talar joint. (R = Pearson's correlation coefficient)
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Fig. 4 Images of subject 5 of (a) the complete tibio-talar coverage (1248 mm$^2$), and (b) area that always remains covered (12.7%), for a maximum joint space thickness of 6 mm.

Fig. 5 The proportion of the talar dome that always remains covered as function of the full dorsal-to-plantar flexion range of motion of the tibio-talar joint. (R = Pearson’s correlation coefficient)

$R = -0.955; p<0.0005$

Fig. 6 Boxplot for all 20 subjects combined of the surface area of the proximal talar surface that is covered by the distal tibia for the neutral (NEU) and 8 extreme foot positions, i.e. dorsal flexion (DF), combined dorsal flexion and eversion (DF-EV), eversion (EV), plantar flexion combined with eversion (PF-EV), plantar flexion (PF), plantar flexion combined with inversion (PF-IN), inversion (IN), and dorsal flexion combined with inversion (DF-IN).

The median tibio-talar coverage in all 20 subjects depends on foot position and varies between 51 and 57% (Fig. 6). The variation in median tibio-talar coverage between the twenty subjects is illustrated by the minimum values ranging between 39 and 51% and maximum values ranging between 61 and 66%.

Minimum distance maps showed that the median minimum distance between talus and tibia was 1.41 mm (range 0.97 to 2.87), This can be interpreted as an estimate of the cartilage thickness of tibia and talus combined for the loaded joint, assuming there is cartilage-to-cartilage contact.

Variations around the selected value for the cut-off point for joint space thickness of 6 mm had a small effect on the calculated tibio-talar coverage for the nine joint positions (Fig. 7). Between 4 and 8 mm joint space thickness, tibio-talar coverage changed little. As calculated from subject 5, the effect on the percentage of covered area was between 0.03 and 1.08% (minimum and maximum absolute effect) for 1 mm increase or decrease of the cut-off point.

The evaluations of the effect of the interactively performed osteotomies showed that repeating the original osteotomy on the first three tibias led to variations in covered area smaller than 1%.

When repeating the osteotomies in a wider fashion, it was found that the area (in mm$^2$) that always remains covered increased, but as a percentage of the complete tibio-talar covered area the effect was small.

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![Graph](image)

**Figure 7** Coverage of the proximal talar surface by the distal tibia (i.e. tibio-talar coverage) of subject 5 as function of the set maximum joint space thickness calculated from the minimal distance map (min) and the nine foot positions, i.e. neutral (NEU), dorsal flexion (DF), combined dorsal flexion and eversion (DF-EV), eversion (EV), plantar flexion combined with eversion (PF-EV), plantar flexion (PF), plantar flexion combined with inversion (PF-IN), inversion (IN), and dorsal flexion combined with inversion (DF-IN).

The parameter analysis performed to evaluate the effect of data reduction on study outcome showed that a 16-fold reduction of number of points had a maximum relevant effect of -1.1% compared to a 9-fold reduction, and a relative effect of maximum 3.0% compared to a 25-fold reduction, respectively. Similarly, a smoothing factor of 0.3 had no relevant effect on outcome, since the RMS difference between the triangulated surface points and the original voxel point was close to the voxel size of 0.3 mm. A smoothing parameter of 0.2 had a maximum relevant effect on outcome of 1.2%, for a smoothing factor of 0.4 this effect was 0.7%.

**Discussion**

This study aimed to quantify anterior and posterior arthroscopic access, by determining the area of the proximal talar surface that is not covered in any of eight extreme foot positions for a set bone-to-bone distance of 6 mm. Corresponding with the results of Van Bergen et al, 48% of the anterior proximal talar surface is revealed in maximum plantar flexion, and lesions localised here may be reached through anterior arthroscopy [36]. This study adds the new result that in maximum dorsal flexion 43% of the posterior proximal talar surface is revealed from underneath the distal tibia, which may be reached by posterior arthroscopy [38, 39]. Secondary, the aim was to determine the effect of adding an eversion or inversion stress to maximum plantar flexion. In the present study no increased exposure resulted from adding these stresses, i.e. there was no increase in the area that was not covered. Eversion or inversion does not
add to additional area on the proximal talar surface that is not covered, since the additional motion is not sufficient to affect the covered area. Another explanation is that it may be the result of our set-up protocol, since the stresses added to the footplate may be different from the manual stress that can be applied to the foot per-operatively.

Finally, it was shown that a median 11.1% of the proximal talar surface remains covered by the distal tibia in any position (range 0 to 29), which is the area that is not accessible with the current arthroscopic techniques. This area is located just posterior of the top of the talar dome. As a clinical guideline, using the clock face where the talus is viewed from lateral and the anterior border of the talar dome is defined as 3 o’clock, one can conclude that the area between 10 and 11 o’clock may be hard to reach arthroscopically. Subjects with the highest dorsal to plantar flexion range of motion (75 to 85°) had almost no area that always remains covered, whereas subjects with the lowest range of motion, i.e. 40 to 50°, had the largest area that always remains covered, i.e. 20 to 30%. This calls for a good preoperative evaluation of range of motion.

Feiwell and Frey were among the first to study arthroscopic access of the ankle [11]. They found the complete talar dome could be accessed for arthroscopic debridement by using a curette. However, in our study we were interested in reaching a defected area on the talar dome such that the opposite intact articular cartilage is not interfering with the surgical procedure. Therefore, we defined possible arthroscopic access as a distance of 6 mm or larger between the two bones and no arthroscopic access as a distance smaller than 6 mm between the two bones.

Van Bergen et al. evaluated anterior arthroscopic access by using a medial and a lateral sagittal plane analysis of computed tomography scans of the ankle in forced plantar flexion. They determined anterior arthroscopic access and proved their method was reliable for preoperative planning of osteochondral lesions of the talus [35]. Our findings of 48% anterior reach are in accordance with their findings, although we used a different measurement method, i.e. surface area as opposed to measurements in two sagittal planes on the medial or lateral talar rim, and a different data set. Their method is easier to use in a clinical setting.

This study has limitations. It is well known that articular cartilage thickness is not uniform [27]. Several studies have reported articular cartilage thickness and its distribution for the talar dome, showing varying results [1, 2, 4, 6, 29, 42]. This might be caused by the different methodologies used, as well as the variance among subjects. The talar cartilage is thinner anteriorly than posteriorly [1, 2, 4, 6, 42], and medially thicker than laterally [6, 29]. It is thicker in men than in women [29]. These differences often lie within 0.5 mm. The standard mean cartilage thickness chosen in this study is based on the minimal distance maps of the 20 subjects. The effect of the current assumption for cartilage thickness is so small that it does not affect the conclusions.

Another limitation is that we did not investigate the value of distraction. During arthroscopy non-invasive intermittent distraction may be used to further increase access to the talar dome [40]. It was shown by Dowdy et al. that in healthy young subjects 225 N force resulted in an additional joint space on average of 1.1 mm (standard deviation 0.3 mm) [9]. During arthroscopy small instruments are used and 1 mm of extra joint space may lead to a larger working area. However,
the value of distraction is limited as is shown in Figure 7: the tibio-talar coverage changes little (i.e. 1.08% maximum absolute effect for 1 mm increase or decrease of the cut-off point) between 6 and 8 mm of maximum joint space thickness. One can debate whether the maximum joint space thickness, which was set at 6 mm, was chosen correctly. A bone-to-bone joint space thickness of 7 mm subtracted by a mean cartilage thickness of distal tibia and proximal talus of 2.5 mm still only leads to 4.5 mm of true (cartilage-to-cartilage) joint space. Concerning the curvature of the tibio-talar joint in the sagittal plane, this space will also be hard to reach with a straight and rigid 4.5 mm shaver.

Notice that the measurements of the tibio-talar covered areas are not true representations of the talar articular surface, since the complete tibio-talar coverage that was measured extends beyond the cartilage covered talar dome. An additional limitation of the interpretation of the data is that the arthroscopically inaccessible area is influenced by the location of the portals and the curvature of the talus combined with the use of rigid instruments.

Variations in minimum distance between the bones and in talar geometry among subjects were found. Size of the tali, the presence or absence of a prominent posterior talar process and talar neck angle varied, as did individual range of motion. These individual talar features and range of motion explain the wide variation that was found in complete tibio-talar covered area (range 1023 to 2102 mm²) and the area that always remains covered (range 0 to 29%), for a joint space thickness of 6 mm. Because of these variations we recommend to examine each patient carefully to determine individual patient characteristics like ankle range of motion and joint laxity that influence access to the talar dome. Taking into account individual range of motion, and if necessary, making a CT-scan in plantar flexion to visualize this as was advocated by Van Bergen et al. [36], will result in optimal care for the patient.

The additional value of this study lies in the graphic representations that were made, which give a complete image of the proximal talar surface that may be reached through anterior or posterior arthroscopy and the area that cannot easily be reached by arthroscopy. An accurate assessment of the complete tibio-talar covered area and sagittal and coronal plane access to the talar dome for arthroscopic treatment of primary osteochondral lesions, while making use of the maximum range of ankle motion, has not been reported before. Understanding what parts of the talar dome can be reached through either anterior or posterior arthroscopy requires a true understanding of 3D anatomy.

**Conclusion**

Nearly the entire talar dome is accessible through either anterior or posterior arthroscopy, dependent of the diameter of the instrument that is used. Adding an eversion or inversion stress to plantar flexion does not reveal a greater surface area of the medial or lateral talar shoulder than plantar flexion alone. Because of their location, most osteochondral lesions can be arthroscopically reached, without the need for arthrotomy or osteotomy. However, lesions
between 10 and 11 o’clock (viewed from laterally, where the anterior border of the talar dome is 3 o’clock) may require open surgery.

**References**

Arthroscopic accessibility