Treatment of osteochondral defects of the talus
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Chapter 5

Arthroscopic accessibility of the talus quantified by computed tomography simulation

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Abstract

Background

Anterior ankle arthroscopy is the preferred surgical approach for the treatment of osteochondral defects of the talus (OCDs). However, the ankle is a congruent joint with limited surgical access.

Purpose

The dual purpose of this study was (1) to quantify the anterior arthroscopic reach (defined as the proportion of the talar dome articular surface located anterior to the anterior distal tibial rim) with the ankle in full plantar flexion, and (2) to identify predictive factors of the arthroscopic reach.

Methods

Computed tomography scans were obtained of 59 ankles (57 patients aged 33 ± 11 years) in full plantar flexion in a non-metallic 3-dimensional footplate. The arthroscopic reach of both the medial and lateral talar domes was assessed on sagittal reconstructions using a custom-made software routine. Intraobserver and interobserver reliability were calculated by intraclass correlation coefficients (ICCs). Various predictive factors of the arthroscopic reach were analyzed by multivariate linear regression analysis.

Results

The arthroscopic reach was 48.2% ± 6.7% (range, 26.7% – 60.7%) of the medial talar dome and 47.8% ± 6.5% (range, 31.2% – 65.1%) of the lateral talar dome (p = 0.62). The intraobserver and interobserver reliability of both measurements were excellent (ICC, 0.99). The clinical plantarflexion angle was a statistically significant predictive factor of both the medial and lateral arthroscopic reaches (i.e., increased plantar flexion corresponded to increased area of access), while joint laxity, gender, and age were not predictive.

Conclusions

Almost half of the talar dome is accessible anterior to the anterior distal tibial rim. The plantarflexion angle is an independent predictive factor of the arthroscopic reach both medially and laterally.

Clinical Relevance

These results may facilitate preoperative planning of the surgical approach for OCDs.
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Introduction

Osteochondral defects of the talus (OCDs) typically affect young, active adults. The location of OCDs has been described classically as posteromedial or anterolateral. More recently, a large survey of more than 400 patients showed that these defects are most frequently located on the middle third of the medial or lateral talar dome in a nine-grid scheme. Arthroscopic debridement and bone marrow stimulation is considered the primary surgical treatment. Most OCDs can be reached and treated through anterior ankle arthroscopy. During this procedure, access to the talar dome is restricted by the tibial plafond due to the high congruence of the ankle joint. Therefore, the OCD is treated in the anterior working area with full plantar flexion of the ankle (Figure 1). However, whether the OCD can be reached by anterior ankle arthroscopy may often be unclear preoperatively.

As a rule of thumb, OCDs located in the anterior half, including the anterior part of the posterior half of the talus, can be reached and treated by anterior ankle arthroscopy in patients with unlimited plantar flexion. After identification of the OCD with the ankle in full plantar flexion, the defect is debrided anteriorly to posteriorly, thus gaining further access during arthroscopic treatment. Saxena and Eakin approached OCDs arthroscopically when they were located within the anterior 50% of the talar dome, while an arthrotomy with or without osteotomy was performed for defects located in the posterior half. Similarly, Gobbi et al. withheld patients with far posterior or central lesions from arthroscopic management. Hankemeier et al. converted from arthroscopy to arthrotomy, with or without a medial malleolar osteotomy, in 25 of 45 ankles because of insufficient access to the OCD. Preoperative knowledge of arthroscopic reach of the talus may facilitate the choice of surgical approach for talar OCDs.

For preoperative planning, computed tomography (CT) scans accurately assess the size and extent of the bony lesion. The range of motion of the ankle joint has been successfully analyzed using stress CT with forced extreme positions in healthy individuals. Using a similar scanning technique in patients with an OCD, van Bergen et al. showed that the location of talar OCDs on CT scans of the ankle in full

Figure 1. Schematic drawing showing the effect of plantar flexion on the arthroscopic reach of an osteochondral defect of the talus (OCD). In the neutral (plantigrade) ankle position, the OCD is covered by the tibial plafond (A). In full plantar flexion, the OCD can be accessed in the anterior arthroscopic working area (B).
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Plantar flexion corresponded well with the in situ intraoperative arthroscopic findings of the OCDs. Hence, a CT scan of the ankle in full plantar flexion can be used reliably to determine the reach of OCDs with anterior ankle arthroscopy. However, this scanning technique is not readily available in most places. Normal values of arthroscopic reach could thus be helpful for the planning of treatment. Identifying predictive factors of the arthroscopic reach may further improve the preoperative planning process.

The dual purpose of this study was (1) to simulate and quantify, with the use of CT data, the area of the talar dome that can be accessed anteriorly to the anterior distal tibial rim (i.e., arthroscopic reach) with the ankle in full plantar flexion, and (2) to identify predictive factors of the arthroscopic reach. We hypothesized that (1) 50% of the talar dome articular surface is located anteriorly to the anterior distal tibial rim, and (2) plantarflexion angle and joint laxity (anterior drawer test) are independent predictive factors of the arthroscopic reach.

Materials and methods

A prospective study was undertaken according to a study protocol approved by the local Medical Ethics Committee. Fifty-seven patients, aged 18 years or older (mean age, 33 ± 11 years), with a known or suspected OCD in 59 ankles (32 right, 27 left) were included between May 2008 and June 2010, including 20 patients from a previous validation study. In two patients, both ankles were scanned because of a bilateral OCD.

Figure 2. Computed tomography (CT) scanning of an ankle in full plantar flexion using a 3-dimensional footplate. The patient was positioned on the CT table with the affected lower leg attached to the supporting base platform (1) and the foot attached to the footplate (2). The ankle was forced into full plantar flexion and the footplate secured.
were 44 male and 13 female patients. Informed consent was obtained.

**Computed tomography**

A multislice helical CT scan was acquired of each affected ankle in full plantar flexion (Figure 2). A non-metallic 3-dimensional (3-D) footplate (unpublished data, 2011) compatible with CT scanning was constructed to fit into a commercial CT scanner (Figure 2). The 3-D footplate had six degrees of freedom and allowed unconstrained hindfoot joint motion upon loading to force the foot in an extreme position. The patient lay supine on the CT table, and the affected lower leg was fixed to a base platform of the 3-D footplate with two straps. The base platform was 10 cm above the CT table, allowing slight flexion of the knee and relaxation of the gastrocnemius muscle. The foot was attached to the 3-D footplate, and the ankle was positioned in full plantar flexion and secured by turning the fixation handle.

Analogous to the protocol as described previously, a Philips MX8000 spiral CT scanner (Philips Medical Systems, Eindhoven, the Netherlands) was used with the following settings: tube voltage, 120 kV; tube current, 26 mAs; collimation, 2 × 0.5 mm; slice thickness, 0.6 mm; slice increment, 0.3 mm; voxel size, 0.3 × 0.3 × 0.3 mm; image matrix, 512 × 512 pixels; rotation time, 0.75 s; resolution, ultra high; kernel, D (sharp); and gantry tilt, 0. The examined volume included the distal tibia and the complete talus. The Committee of Radiation of our hospital has estimated the radiation of the scan to be 0.02 mSv, which is categorized as a “trivial” risk for average adults by the International Commission on Radiological Protection.

The original axial images were reformatted into sagittal 1.0-mm slices in two planes: one set of images parallel to the medial talar facet and one set parallel to the lateral talar facet. These planes were defined to correspond with the geometry of the talar dome, which has a divergent anatomic orientation. The reformatted images parallel to the medial talar facet were used for the assessment of the medial talar dome, while the images parallel to the lateral facet were used for the lateral talar dome.

**Outcome analysis**

Arthroscopic reach was defined as the proportion of the talar dome articular surface located anteriorly to the anterior distal tibial rim. This definition was based on the fact that, initially during arthroscopy, only the anterior part of the lesion has to be identified. The OCD is then treated anteriorly to posteriorly, thus gaining further exposure during treatment. Removal of the anterior part of the cartilage lesion creates more space for access to the more posterior defect area. The ankle joint opens up anteriorly by forced plantar flexion, improving access to the complete defect.

To determine the arthroscopic reach, we made the following measurements (Figure 3). The anterior and posterior borders of the talar dome and the anterior distal tibial rim were digitally marked on medial and lateral sagittal reconstructions using the radiology Picture Archiving and Communication System (Impax 5.3.1, Agfa-Gevaert NV, Mortsel, Belgium), providing two measurements for each scan. In case of a clear anterior distal tibial osteophyte (i.e., fully sclerosed relevant extension of the anterior rim), the osteophyte was excluded from analysis because it is usually removed when performing ankle arthroscopy for OCDs. The marked CT images were loaded into a custom-made software routine (Matlab, version 7.5.0.342 (R2007b), The Mathworks, Natick, Massachusetts). Within this routine, two observers independently indicated the talar dome contour with 10 points. Based on these data, two angles, α and β, were...
calculated as follows. A circle was fit through the 10 points on the talar dome using a least squares algorithm, providing the circle's diameter and midpoint coordinates. The latter was used as the imaginary center of rotation of the ankle joint. Subsequently, angle \( \alpha \) was calculated as the arc length of the circle between the line crossing the anterior border of the talar dome and the midpoint, and the line crossing the anterior distal tibial rim and the midpoint, divided by the total circle's circumference (Figure 3). Analogously, angle \( \beta \) was calculated as the arc length of the circle between the line crossing the anterior border of the talar dome and the midpoint, and the line crossing the posterior border of the talar dome and the midpoint, divided by the total circle's circumference. The arthroscopic reach (%) was calculated by dividing angle \( \alpha \) by angle \( \beta \) times 100%.

**Figure 3.** Sagittal computed tomography reconstructions of a fully plantarflexed ankle showing the measurements performed to assess the arthroscopic reach of the medial (A) and lateral (B) talar domes. Using a custom-made software routine, a circle was fit through the talar articular surface. Angle \( \alpha \) (black arrow, i.e., area anterior to the distal tibial rim) was defined by the arc length of the circle between the dashed lines from the midpoint of the circle to the anterior border of the talar dome and to the anterior distal tibial rim, respectively, divided by the total circle's circumference. Angle \( \beta \) (white arrow, i.e., complete talar dome) was defined by the arc length of the circle between the dashed lines from the midpoint to the anterior border of the talar dome and to the posterior border of the talar dome, respectively, divided by the total circle's circumference. The arthroscopic reach (%) was calculated by dividing angle \( \alpha \) by angle \( \beta \) times 100%.

**Predictive factors**

To investigate the hypothesis that increased plantar flexion and joint laxity improve the arthroscopic reach, these factors were assessed prior to CT scanning in 46 ankles. The other predictors investigated were gender and age.

The passive plantarflexion angle was measured from a lateral view with a goniometer, using the anterior side of the lower leg and dorsum of the foot as landmarks (Figure 4). The measured angles were divided into three groups: group 1 (n = 6), plantarflexion angle >180°; group 2 (n = 18), plantarflexion angle 171° - 180°; and group 3 (n = 22), plantarflexion angle ≤170°. These cutoff values were based on our clinical experience that more than 180° indicates increased range of motion, while less than 170° indicates restriction in range of motion.

The anterior drawer test was performed to assess joint laxity. The assessor determined the amount of force and estimated the excursion. A positive test (n = 9) was defined as an anterior drawer of ≥4 mm and/or a difference between left and right of >2 mm.
Statistical analysis

The mean of both observers’ first CT measurements is reported. The continuous data (age, angles α and β, and arthroscopic reach) were normally distributed and are presented as mean ± standard deviation, supplemented with 95% confidence intervals (CIs) and ranges for the arthroscopic reach of the talar dome. The statistical difference between the arthroscopic reach of the medial and lateral talar domes was calculated with the paired t-test. The intraobserver and interobserver reliability of the arthroscopic reach were analyzed using intraclass correlation coefficients (ICCs). According to Fleiss, the reliability is considered excellent if the ICC is >0.75.134

To identify predictive factors of the arthroscopic reach, multivariate linear regression analysis was performed with a backward selection procedure. The dependent variables were the medial and lateral arthroscopic reaches. The investigated independent variables were plantarflexion angle, anterior drawer test, gender, and age. Plantarflexion angle was a categorical variable with three groups. Each independent variable was initially tested by use of univariate analyses. Those variables significantly associated with arthroscopic reach (significance level, 0.10) were entered in the multivariate regression analysis. The unstandardized regression coefficient (B) and standard error (SE) were calculated. A p-value of 0.05 indicated statistical significance.

Results

On the medial talar dome, angle α was 51.2° ± 10.5°, and angle β was 106.2° ± 14.9°, resulting in an arthroscopic reach of 48.2% ± 6.7% (95% CI, 46.4% – 49.9%; range, 26.7% – 60.7%) (Figure 5A). On the lateral talar dome, angle α was 49.3° ± 8.3°, and angle β was 103.1° ± 11.5°, indicating an arthroscopic reach of 47.8% ± 6.5% (95% CI, 46.1% – 49.5%; range, 31.2% – 65.1%) (Figure 5B). The difference between medial and lateral was not statistically significant (p = 0.62). The intraobserver and interobserver reliability of the measured angles on CT were excellent (both ICCs, 0.99; p < 0.001).

On the medial talar dome, the arthroscopic reach was 52.6% ± 6.1% in plantarflexion group 1 (>180°), 50.8% ± 5.7% in group 2 (171° - 180°), and 45.5% ± 4.8% in group 3 (≤170°) (Figure 6). On the lateral talar dome, the arthroscopic reach was 53.7% ± 8.7%, 49.2% ± 3.7%, and 45.4% ± 6.0% in plantarflexion groups 1, 2, and 3, respectively.

With the medial arthroscopic reach as the dependent variable, univariate analysis revealed three significant factors (plantarflexion angle, gender, and age) to be included in
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Figure 5. Histogram showing the distribution of the measured arthroscopic reach of the medial (A) and lateral (B) talar domes in the study population.

Figure 6. Arthroscopic reach (mean and standard deviation) of the medial (continuous line) and lateral (dashed line) talar domes in three patient groups with different plantarflexion angles. The clinical plantarflexion angle was a significant, independent predictor of the arthroscopic reach.
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the multivariate linear regression analysis. Multivariate analysis revealed only the plantarflexion angle as a predictive factor of the medial arthroscopic reach (group 1 vs. group 3: $p = 0.02$, $B = 6.7$, SE = 2.7; group 2 vs. group 3: $p = 0.03$, $B = 4.0$, SE = 1.8).

Univariate analysis showed that two factors (plantarflexion angle and age) were significantly associated with the lateral arthroscopic reach. Multivariate linear regression analysis showed that only the plantarflexion angle was significantly associated with the lateral arthroscopic reach (group 1 vs. group 3: $p = 0.01$, $B = 7.6$, SE = 2.7; group 2 vs. group 3: $p = 0.09$, $B = 3.1$, SE 1.8). The other investigated factors did not reach statistical significance in the multivariate analyses.

Discussion

This study aimed to quantify the anterior arthroscopic reach of the talar dome. It is shown that almost half (48%) of the articular surface of the talar dome is situated anteriorly to the tibial plafond with the ankle joint in full plantar flexion. Thus, on average, an OCD can be reached and treated by anterior ankle arthroscopy if its anterior border is located in the anterior half of the talar dome. The anterior defect border is the landmark for accessibility, since only this part of the defect has to be identified initially during arthroscopy. The defect is then treated anteriorly to posteriorly, thus gaining further exposure during treatment. As the plantarflexion angle is an independent predictor of arthroscopic reach, the preoperative estimation of exposure can be improved by measuring the plantarflexion angle clinically. These findings can serve as a guideline for preoperative planning of the surgical approach.

Exposure of the talus has been quantified in studies with different open surgical approaches. Muir et al. compared seven approaches, including four arthrotomies (anteromedial, anterolateral, posteromedial, and posterolateral) and three osteotomies (anterolateral tibial plafond, distal fibula, and medial malleolus) in nine cadaver specimens. After Kirschner wires had been inserted in the talus through the different approaches, lateral radiographs were used to measure sagittal access. Using an anteromedial arthrotomy, they could access a mean of 47% (range, 41% - 60%) of the medial talar dome in the sagittal plane. The anterolateral arthrotomy provided 43% (range, 37% - 50%) sagittal access of the lateral talar dome. Young et al. have presented data on cadaveric dissections of five ankles to evaluate the accessible region of the medial talar dome through an anteromedial and posteromedial open approach without osteotomy. They found that a median of 50% (range, 44% - 58%) of the anteroposterior medial talar dome length could be reached through the anteromedial approach. The results of our study are in the range of the findings of both cadaveric studies. The added value of the present study is the use of a validated method, specific focus on arthroscopy, the larger and representative study population, and the identification of predictive factors of arthroscopic reach. The results may also be relevant for osteochondral grafting or other methods that require perpendicular access to the OCD. However, in these cases, the posterior border of the OCD (instead of the anterior border) has to be located anteriorly to the anterior distal tibial rim for complete access.

The importance of plantar flexion on the exposure of the talus by anterior ankle arthroscopy can be estimated when comparing the CT angles of this study with radiographic angles of another study. Magerkurth and colleagues published normal values of hindfoot dimensions in a series of 100 radiographs of neutrally positioned ankles. They found that the mean angle of talar coverage by the tibia,
defined by the center of the talus and the borders of the distal tibial joint plane, was 88.1°. In our study, the complete talar dome angle (β) was 104.6° (i.e., mean of medial and lateral). This suggests that only 15.8% (i.e., (104.6° - 88.1°)/104.6° × 100%) of the talar dome articular surface is uncovered by the tibial plafond when the ankle is in a plantigrade position. Our study shows that 48% of the talar dome is uncovered when the ankle is in full plantar flexion, suggesting that this area is increased threefold. However, this calculation should be interpreted with caution because different diagnostic modalities were used (i.e., plain radiographs by Magerkurth et al. vs. CT by us).

Numerous diagnostic methods are in use for talar OCDs, including plain radiographs, CT, magnetic resonance imaging (MRI), and, more recently, single-photon emission computed tomography (SPECT-CT). Verhagen et al. showed that MRI and multislice helical CT have similar diagnostic accuracy that are both superior to plain radiographs. MRI may further show concomitant soft-tissue injury. The diagnostic value of SPECT-CT has not been reported, but its use has led to a treatment decision making change in 48% compared with MRI. The use of either CT or MRI is recommended for the diagnosis of OCD, but as the subchondral bony defect is the main problem in ankle lesions, CT scans are preferred for preoperative planning because they accurately assess the size of the bony fragment or associated cyst.

With anterior ankle arthroscopy, vision of only the anterior part of the OCD is initially required. After identification of the anterior border of the defect, it is debrided anteriorly to posteriorly to further expose the defect, followed by microfracturing. We routinely use a 4.0-mm, 30° angle arthroscope, a 4.5-mm or 5.5-mm bonecutter shaver, and a 45° angle microfracture awl. An angled microfracture awl allows treating a lesion “around the corner.”

If access is insufficient with the standard anterior arthroscopy procedure, there are some alternative arthroscopic approaches. The anterior portals can be combined with a posterolateral portal. Alternatively, a two-portal hindfoot arthroscopic approach with the patient in the prone position is applied to treat OCDs located far posteriorly. However, these procedures require more experience. Furthermore, distraction of the ankle joint can be used to improve exposure in ankle arthroscopy. For example, Kelberine and Frank in 1999 described 48 ankle arthroscopies for the treatment of OCDs. To gain access to the lesions, distraction was used in 11 patients, and an additional posterolateral portal was made in one patient. The maximum joint distraction has been reported to average 1.3 to 4.5 mm. Continuous distraction, however, could possibly lead to more neurovascular complications.

We prefer an anterior arthroscopy technique without continuous distraction, applying dorsiflexion and plantar flexion as indicated and, if necessary, temporary noninvasive distraction. Alternatives to microfracturing or antegrade drilling for hardly accessible lesions are transmalleolar or retrograde drilling. Although good clinical results have been reported, there are disadvantages of both techniques that are not encountered with microfracturing or antegrade drilling. With transmalleolar drilling, healthy tibial cartilage is sacrificed. Retrograde drilling requires intact overlying cartilage of the OCD and is therefore only occasionally applicable.

The present study has limitations. According to the findings of this study, a mean of 48% of the talar articular surface is accessible in the anterior arthroscopic working area. These findings can provide clear clinical guidelines for the optimal surgical approach. However, the percentages reported might be rather strict, as there are different surgical methods to improve exposure, including grooving of the anterior...
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distal tibial rim and using temporary noninvasive distraction.\textsuperscript{135,422} These surgical methods were not assessed in this study. Nevertheless, the data can be regarded as the lower limit of access, which can further be improved in practice, thus being on the safe side. Furthermore, there was a high range of arthroscopic reach, that is, 27\% to 61\% on the medial side and 31\% to 65\% on the lateral side. Because of this range, a CT scan of the ankle in full plantar flexion is advised for doubtful cases to optimize the preoperative planning individually. Another possible limitation is that arthroscopic reach was assessed indirectly with CT scans rather than with arthroscopy. For arthroscopic assessment, cadaveric ankles would have to be used, but these are not representative of the patient population and are scarce. The obtained results can be regarded as reliable because the methods used were validated in a previous study.\textsuperscript{415} Finally, different physicians assessed a subset of ankles (46 of 59) for clinical plantar flexion and joint laxity. These assessments may be subject to interobserver variability. The variability was minimized by providing clear instructions for measurements, and using easily recognizable anatomic landmarks for clinical plantarflexion measurement. The interobserver reliability of plantarflexion measurement in another study was good (ICC, 0.72), although the measurement technique in that study was not specifically described.\textsuperscript{119} Although clinical plantar flexion was an independent predictor of the arthroscopic reach (Figure 6), joint laxity, in contrast to our hypothesis, was not. Therefore, the arthroscopic reach variability cannot be reliably correlated with ankle laxity.

Conclusion

This study quantifies the anterior arthroscopic reach of the talus with CT scans in a representative patient population. With the ankle in full plantar flexion, a mean of 48\% of the talar dome, both medial and lateral, is located anteriorly to the anterior distal tibial rim. The clinical plantarflexion angle is an independent predictor of the arthroscopic reach. These results facilitate preoperative planning of the surgical approach for treatment of OCDs.

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