Open Versus Arthroscopic Mosaicplasty of the Knee: A Cadaveric Assessment of Accuracy of Graft Placement Using Navigation

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Purpose: The purpose of this study was to compare an open freehand mosaicplasty technique with an arthroscopic technique for the treatment of osteochondral lesions by measuring the instrument deviation, quantifying this deviation, and providing numerical information on the difference in the outcomes of these techniques. **Methods:** Four cadaveric knees were used. Reference markers were attached to the femur, tibia, and donor/recipient site guides. A total of 10 osteochondral grafts were harvested and inserted into recipient sites arthroscopically and 10 similar grafts were inserted freehand. The angles of graft removal and placement were calculated for each of the surgical groups compared. Ostensibly, a navigation system was used as an aid, to measure the graft placement parameters. **Results:** Statistical analysis revealed that there was no statistically significant difference between the arthroscopic method and the freehand method regarding the angle of graft removal at the donor site ($P = .162$), recipient site plug removal angle ($P = .731$), and recipient site graft placement angle ($P = .630$). In the freehand group, the mean angle of graft removal at the donor site was 12°, the mean angle of recipient site plug removal was 10.7°, and the mean angle of recipient site plug placement was 10.6°. Using the arthroscopic technique, the mean angle of graft removal at the donor site was 17.14°, the mean angle of recipient site plug removal was 12.0°, and the mean angle of recipient site graft placement was 10.14°. **Conclusions:** Our study revealed there was no statistically significant difference regarding precision and accuracy during harvesting, recipient site preparation, and plug placement between the 2 techniques. **Clinical Relevance:** Controversy exists whether an open or arthroscopic osteoarticular transfer system (OATS) technique provides superior accuracy. According to our results, there is no statistically significant difference regarding better visualization, precision, and accuracy between the freehand and arthroscopic techniques. However, larger number of specimens are required for study.

Although the osteoarticular transfer system (OATS) is a well-established treatment option for osteochondral lesions,[1-4] it remains a technically challenging procedure that relies on accuracy both in harvesting and placement of the osteochondral graft. "Real-time" accuracy assessment in the technique would be very useful regarding the resultant insertion depth, the articular surface congruity, and the articular contact pressures.[5]

Graft harvesting and insertion must be perpendicular to the articular surface.[6] Deviation from this goal may compromise the final result.[7] Precise reproduction of insertion angles for multiple grafts in an open fashion has been reported to be more difficult if the technique is performed arthroscopically with a 30° fiberoptic camera.[8]

Although computer-assisted navigation provides 3-dimensional accuracy and precise control in orthopaedic procedures of the spine, hip, knee, and ankle joint,[9-16] there are few data concerning variability in the angle of graft placement in either open or arthroscopic approaches. The overall accuracy that this technology provides for orthopaedic applications may be

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The authors report that they have no conflicts of interest in the authorship and publication of this article.

Received October 30, 2013; accepted March 13, 2015.

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0749-8063/13770/$36.00

http://dx.doi.org/10.1016/j.arthro.2015.03.016

within 1 mm for every 1°.[17] Koulalis et al.[18] and Di Benedetto et al.[19] previously showed that navigation technology may provide important data about graft placement angles while improving vertical positioning.

The purpose of this study was to compare an open freehand mosaicplasty technique and an arthroscopic technique for the treatment of osteochondral lesions by measuring the instrument deviation, quantifying this deviation, and providing numerical information on the difference in the outcomes of these techniques. It has to be clarified that computer navigation was used as a tool to study the differences between the operating methods. The hypothesis of the current study was that graft insertion angles vary to a greater degree during arthroscopic mosaicplasty than during the open freehand technique, leading the surgeon away from the requisite vertical positioning.

Methods

For both open and arthroscopic techniques, 2 cadaveric fresh-frozen lower limbs (femoral head to toe) were used, with preinspection by the investigators to rule out previous osteochondral injuries or knee surgery. Thus, 4 specimens were used in total. A total of 20 grafts were harvested from the lesser—weight-bearing surface zone of the lateral femoral condyle and placed in the weight-bearing articular surface zone of the medial condyle. A conventional image-free navigation system (there was no need for imaging tools at this stage) (Praxim, La Tronche, France) was used in combination with a conventional system (OATS; Arthrex, Naples, FL) for autologous osteochondral graft transplantation of the knee. The navigation system was used ostensibly to access the measurements as a tool to measure the placement parameters. It was used in combination with the arthroscopic instruments, but only when the first part (the arthroscopic portion) of the procedure was done. The software provided information for the evaluation of the measured angles. The image-free navigation system index process included the hip center and defined tibial and femoral cutaneous landmarks. Through arthroscopic visualization, a bone-morphing algorithm for defined femoral intra-articular landmarks was obtained, including donor and recipient sites of the lateral and medial aspects of the femoral trochlea and the lateral and medial femoral condyles. All stages of the procedure were performed by the senior author (D.K.), a surgeon with a great level of expertise and more than 20 years in orthopaedic practice.

Once the specimens were thawed (at room temperature overnight the night before each procedure), the femoral head was fixed into a customized lower-limb holding device. After rigid fixation of femoral and tibial reference markers with 3.5-mm Schanz screws, the lower limb registration process was performed. This included temporary release of the femoral head to allow for the navigated hip center registration process and cutaneous registration of defined tibial and femoral landmarks. Finally, after conventional medial parapatellar arthrotomy, a bone-morphing algorithm of defined femoral intra-articular landmarks was performed.

The same procedure was performed arthroscopically. Distinct areas of the donor and recipient sites of the lateral and medial femoral condyles were morphed. A customized arthroscopic module allowed for permanent visualization of the guide and measured deviations from the optimal 90° position to the articular surface. This represented the longitudinal axis of the guide during harvesting of the graft.

Using a mallet, the harvesting tool was driven into the bone to a depth of 15 mm (Fig 1). The harvester containing the cylindrical osteochondral graft was then removed by rotating the T-handle sharply 90° twice to score and dislodge the graft.

The recipient site was prepared using the recipient tool. This has a similar T-handle construction but, critically, the instrument forms a cylindrical recipient site with a diameter 1 mm less than that of the donor harvester so that the transplanted graft will fit tightly into the recipient site in press-fit fashion. The osteochondral graft was then advanced into the precored area at an angle of 90° to the articular surface, which was calculated as an angle of 0° for the instrument's longitudinal axis.

All osteochondral grafts had a diameter of 8 mm and were taken from the donor site using the 8-mm donor guide. The donor sites were chosen in accordance with the matching characteristics of the grafts, with attention paid to cartilage thickness and surface curvature. The

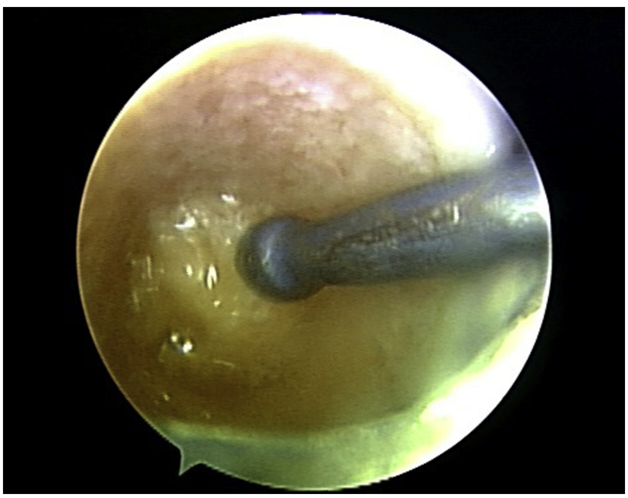

Fig 1. Depth measurement of the recipient site socket with the measurement tool of the navigation system. Arthroscopic view of the probe.

grafts were taken from the proximal articular surfaces of the medial and lateral condyles of the specific knee, with particular avoidance of the trochlear region.

Ten freehand OATS transfers using an open technique were performed in 2 knees and were compared with 10 freehand OATS transfers using an arthroscopic technique. A statistical analysis was performed comparing the 2 methods—arthroscopic freehand and open freehand mosaicplasty—using the Mann-Whitney method because of the small sample size. For all tests, $P < .05$ was considered statistically significant. The analysis was performed with IBM SPSS Statistics, version 20.0 (SPSS, Chicago, IL).

Results

With the freehand open technique, the mean angle of graft removal at the donor site was 12° (range, 5° to 24°; standard deviation [SD], 5.5°), the mean angle of recipient site plug removal was 10.7° (range, 2° to 17°; SD, 4.9°), and the mean angle of recipient site plug placement was 10.6° (range, 3° to 17°; SD, 4.4°).

Using the freehand arthroscopic technique, the mean angle of graft removal at the donor site was 17.14° (range, 6° to 26°; SD, 7.53°), the mean angle of recipient site plug removal was 12.0° (range, 4° to 17°; SD, 3.98°), and the mean angle of recipient site graft placement was 10.4° (range, 5° to 15°; SD, 3.23°).

Statistical analysis revealed no statistically significant differences between the 2 methods regarding the angle of graft removal at the donor site ($P = .162$) (Fig 2). Moreover, there were no statistically significant differences regarding angles of recipient site plug removal ($P = .731$) (Fig 3) and the angle of recipient site graft placement ($P = .630$) (Fig 4).

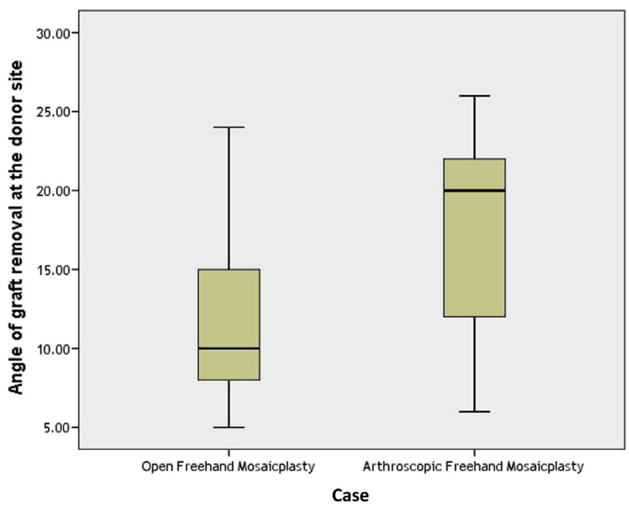

Fig 2. The mean angle of graft removal at the donor site was 12° in the open freehand technique and 17.14° in the arthroscopic technique. No statistically significant difference was noted between the 2 methods.

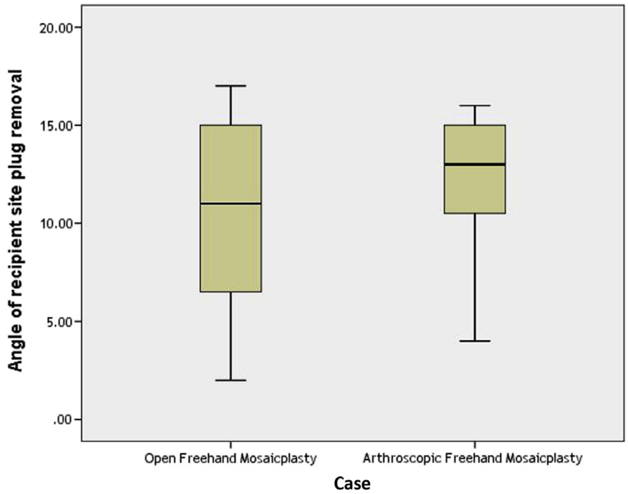

Fig 3. The mean angle of recipient site plug removal was 10.7° for the open method and 12° for the arthroscopic technique. No statistically significant difference was noted.

Discussion

Achieving verticality during recipient site preparation, graft harvest, and graft placement is a challenging task. From a practical point of view, this task should become more difficult when the procedure is performed arthroscopically, leading to increased deviation from the desired vertical position because of the distortion of the arthroscopic lens, the inability to work close to the articular surface (thus having less control of the instrument tip), and the inability to palpate remaining irregularities of the transplanted surface to refine the position of the grafts. Graft positioning is important and demanding even for the most talented and experienced surgeon. In previous studies, the superior reproducibility of the navigated procedures was evinced by means of accuracy of measurements.[18]

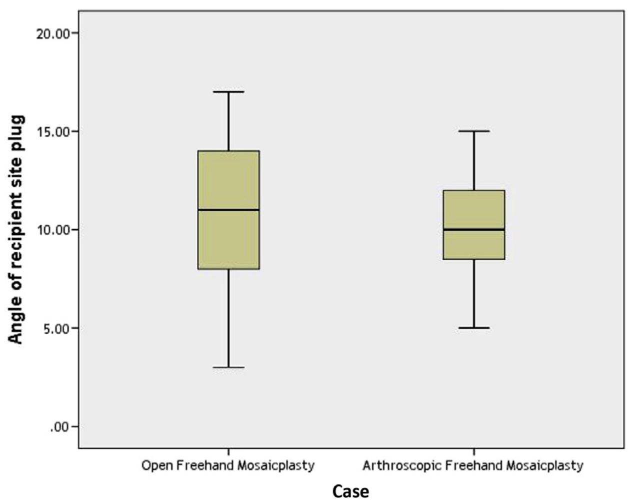

Fig 4. The mean angle of recipient site graft placement was 10.6° for the open method and 10.4° for the arthroscopic technique. No statistically significant difference was seen.

There was no difference between the 2 techniques regarding measuring instrument deviations. Both open and arthroscopic techniques of osteochondral graft transplantation showed similar deviations from the desired angles during insertion as well as extraction. Given the lack of difference between the arthroscopic and open techniques, it appears that concerns regarding arthroscopic placement of plugs may be unwarranted. Future studies are needed to assess the information given by this technology in a clinical setting.

Transplantation of multiple autologous osteochondral grafts aims to prevent further articular surface deterioration and the development of localized chondral defects. Graft harvest and placement should be performed perpendicular to the articular surface; deviations from such an approach could compromise the end result and impair osteointegration and surface matching.[6,20]

Loosening of adjacent grafts and articular surface incongruency resulting from nonvertical insertion and obliquity of the chondral portion of the graft within a range of 5° are 2 important potential sequelae of the procedure that may occur because of inaccurate graft placement.[18]

Placing the graft in a nonvertical manner in the subchondral socket will result in an unsatisfactory final position of the chondral portion of the graft, leading to focal elevation and uneven distribution of joint load.[21] Koh et al.[5] found an increase of up to 50% in contact pressures with grafts elevated by 0.5 to 1 mm.

Graft loosening will lead to instability and synovial fluid penetration of the subchondral bone, leading to cyst formation. According to Whiteside et al.,[22] the initial stability after plug transfer decreases by greater than 50% after 1 week.[16] This emphasizes the need to provide as much stability as possible to the plugs during osteochondral transplantation.[6]

Another problem related to reproduction of the insertion angle concerns the forces exerted on the chondral part of the graft. Inaccurate angulation in graft placement will necessitate greater force to override the forces of friction between the wall of the socket and the graft. This will cause greater injury to the cartilaginous portion of the graft and chondrocyte apoptosis.[23]

Limitations

There are certain limitations in our study, starting with the small number of specimens tested and the lack of power analysis. Concerning its clinical use, it has to be taken into consideration that our study results may differ because of the age and condition of the cadaveric knees used. A final limitation is that in our survey, knee joint cartilage was intact with no additional bone lesions present, whereas in real life and in most cases this is not a common scenario.

Conclusions

Our study revealed there was no statistically significant difference concerning precision and accuracy during harvesting and recipient site preparation and plug placement between the 2 techniques.

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