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ORIGINAL RESEARCH

Flexible Reamers Provide Similar Length and Safer ACL Tunnels Without the Need for Knee Hyperflexion: A Cadaveric Assessment of Flexible and Rigid Reamers

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ABSTRACT

Introduction: The purpose of this study was to compare femoral anterior cruciate ligament (ACL) tunnel placement and orientation with flexible and rigid reamers using a simulated anteromedial (AM) portal drilling technique.
Methods: In nine matched pairs of cadaver femora, anatomic ACL tunnels were drilled using rigid (n=9) and flexible (n=9) reamers. Specimens prepared with rigid reamers were fixed in a position simulating 115 degrees of knee flexion, whereas specimens prepared with flexible reamers were fixed in a position simulating 90 degrees of knee flexion. The specimens were imaged with computed tomography and the coronal and axial obliquity to the epicondylar axis, tunnel length, and distance from the posterior cortex were measured.
Results: The average tunnel length was not different for flexible and rigid reamers (36.6 mm vs 36.7 mm, p=0.82). The average distance from the posterior cortex of the femur was greater for specimens prepared with flexible reamers (5.9 mm vs 3.0 mm, p<0.001). Flexible reamers produced more horizontal tunnels in the coronal plane (36.6 degrees vs 53.8 degrees, p<0.00001) and more obliquity in the axial plane (30.2 degrees vs 47.8 degrees, p<0.0005).
Discussion: Flexible reamers reproducibly created femoral ACL tunnels with greater obliquity and were farther from the posterior cortex of the femur compared to rigid reamers using a simulated AM portal drilling technique. Knee flexion of 90 degrees in the flexible group did not produce shorter tunnels.
Keywords: ACL reconstruction; Flexible reamers; ACL tunnel.

INTRODUCTION

Accurate femoral tunnel placement is critical for successful anterior cruciate ligament (ACL) reconstruction (1-5). Improper tunnel placement leads to a nonanatomic graft that may result in recurrent instability, earlier graft failure, and earlier onset of degenerative radiological changes (1,3). Analysis of tunnel placement in failed ACL reconstruction

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has demonstrated that improper tunnel placement is one of the most common indications for revision surgery (6,7).

Previous studies have demonstrated that in order to achieve anatomic graft placement, the femoral tunnel must be obliquely oriented in both the coronal and sagittal planes (5). Although anterior-posterior stability may be restored, vertically oriented femoral tunnels in the axial plane result in decreased rotational stability (1,2,4,5). Furthermore, it has been suggested that femoral tunnels oriented 60 degrees from vertical in the axial plane result in optimal knee kinematics and rotational stability (5).

In an effort to reproducibly create more anatomic graft placement, attention has been directed away from the transtibial technique to an anteromedial (AM) portal drilling technique for ACL reconstruction (8-12). Multiple reports have documented favorable results using the AM portal technique for anatomic graft placement (13,14). Moreover, authors have suggested that truly anatomic graft placement may not be possible using the transtibial drilling technique (9).

However, the AM portal drilling technique has pitfalls. These challenges include shorter tunnel lengths, difficulty with femoral guide placement, damage to the articular cartilage on the medial femoral condyle, maintaining the knee in a hyperflexed position during tunnel preparation, and violation of the posterior femoral cortex (15). Flexible guide pins and reamers have been developed to help mitigate these technical difficulties. Previous studies have suggested that flexible reamers produce longer tunnels and have a decreased risk of "blowing out" the posterior cortex of the femur (16-18).

The purpose of this study was to compare femoral ACL tunnel placement and orientation using flexible and rigid reamers in paired cadaveric specimens using a simulated AM portal drilling technique. The hypothesis was that specimens prepared with flexible reamers in 90 degrees of knee flexion would be no different than specimens prepared with rigid reamers with the knee flexed 115 degrees.

MATERIALS & METHODS

Nine matched pairs of embalmed cadaver femora were used for drilling of ACL tunnels. There were 5 male and 4 female specimens, and the average age was 72 years (range 64 to 81 years). None of the specimens had more than mild degenerative changes and none had evidence of previous surgical intervention. A minimum of 15 cm of the distal femur was preserved on each specimen, and all of the soft tissues were removed. All of the specimens were drilled using a simulated anteromedial portal technique.

The right femur from each specimen was designated to have a tunnel drilled using a rigid reamer. The femur was rigidly fixed at an angle of 25 degrees to the horizontal axis to simulate a knee flexion angle of 115 degrees. The anatomic footprint of the ACL was visually identified and a cannulated femoral footprint guide (ConMed Linvatec, Largo, FL) was seated flush with the footprint and a 2.4-mm diameter guide pin was drilled through the lateral cortex of the femur. A 10-mm diameter rigid, cannulated reamer was inserted over the guide pin (ConMed Linvatec), and the femoral tunnel was drilled to exit the lateral cortex of the femur.

The left femur from each specimen was designated to have a tunnel drilled using a flexible reamer. The femur was rigidly fixed parallel to the horizontal axis to simulate a knee flexion angle of 90 degrees. The anatomic footprint of the ACL was identified and a 7-mm offset femoral guide with a 45-degree curvature (Stryker, Mahwah, NJ) was used to identify the portion of the footprint 7 mm from the posterior aspect of the lateral femoral condyle. A flexible, 2.4-mm diameter nitinol guide pin was inserted through the cannulated guide and drilled through the lateral cortex of the femur. A 10-mm diameter flexible reamer (Stryker) was inserted over the guide pin and the femoral tunnel was drilled through the lateral cortex of the femur.

The length of each tunnel was measured using a digital caliper. The specimens were then imaged using computed tomography (CT). Two-dimensional images were used to measure the obliquity of the tunnel from the epicondylar axis (EA) in the axial and coronal planes; the shortest distance to the posterior cortex of the femur was also measured on the sagittal images.

Statistical analysis was performed using Excel (Microsoft, Redmond, WA). Differences between groups were assessed using the paired t-test. A p-value of less than 0.05 was considered statistically significant.

RESULTS

All tunnels were drilled at the anatomic footprint of the ACL on the lateral femoral condyle. The average tunnel length of the specimens prepared with the flexible reamers was 36.6 mm (range 32.95 mm to 41.9 mm), and was not different than for those prepared with the rigid reamers (36.7 mm; range 32.4 mm to 42.3 mm; $p=0.82$). Among specimens prepared with the flexible reamers, there were a total of 4 specimens with tunnel length less than 35 mm, and none less than 30 mm. Coronal obliquity was greater in specimens prepared with flexible reamers (36.6 degrees vs 53.8 degrees, $p<0.00001$). Axial obliquity was also greater in specimens prepared with flexible reamers (30.2 degrees vs 47.8 degrees, $p<0.0005$). The average distance to the posterior cortex of the femur was 5.9 mm (range 2.6 mm to 9.7 mm) in the specimens prepared with flexible reamers. This was greater than the distance in the specimens prepared with rigid reamers (3.0 mm; range 1.4 mm to 5.2 mm, $p<0.001$) (Table 1).

Table 1. Femoral ACL tunnel measurements for flexible and rigid reaming techniques.

	Flexible Reamer	Rigid Reamer	P Value
Tunnel length (mm)	36.6 (3.33)	36.7 (3.45)	0.82
Angle to EA in axial plane (degrees)	30.2 (5.8)	47.8 (5.1)	0.00034
Angle to EA in coronal plane (degrees)	36.6 (4.45)	53.8 (3.9)	0.0000088
Shortest distance to the posterior femoral cortex (mm)	5.9 (2.3)	3.0 (1.4)	0.00085

Values given are averages with standard deviation in parenthesis.

DISCUSSION

This study demonstrated that femoral ACL tunnel drilling using flexible reamers allows for more obliquely oriented femoral tunnels in the coronal and axial planes and tunnels that were farther from the posterior cortex of the femur. There was no difference in the length of tunnels, regardless of the type of reamer used.

Previous studies have compared flexible and rigid reamers for femoral ACL tunnel drilling. Larson et al. performed a similar cadaveric study using four different drilling techniques including transtibial with a rigid reamer, AM portal with both rigid and flexible reamer, and outside-in technique (18). That study reported that AM portal drilling with a flexible reamer produced femoral tunnels only 28.92 mm in length, which was significantly less than those in the transtibial group. Although not statistically significant, AM portal drilling with rigid reamers created tunnels that were longer than the tunnels created using the flexible reamers. Two other studies comparing flexible to rigid reamers both found that flexible reamers produce longer femoral tunnels than rigid reamers (16,17). Both of these studies performed drilling with the knee in hyperflexion in both groups (Table 2).

It has been demonstrated that shorter femoral tunnel lengths are created with the knee in lesser degrees of flexion (19). This may explain why the results of our study showed no difference in tunnel length between flexible reamers with the knee flexed 90 degrees and rigid reamers with the knee flexed 115 degrees. Tunnel length is an important determinant of graft fixation potential. It is recommended to have a minimum femoral tunnel length of 25 mm when using an interference screw and 35 mm when using suspensory-type fixation (19). Although there were 4 tunnels in the flexible group and 3 tunnels in the rigid group that were less than 35 mm, no tunnel was less than 30 mm in this study.

Distance of the femoral tunnel from the posterior cortex has also been shown to decrease in lower angles of knee flexion. Basdekis et al. reported that rigid guide pins may routinely result in violation of the posterior femoral cortex if placed in 90 degrees of knee flexion (19). Similarly, Steiner et al. reported 3 of 6 (50%) of rigid guide pins in a position that would result in violation of the posterior cortex of the femur compared to none in the flexible group (16). In this study,

Table 2. Comparison of studies measuring femoral ACL tunnel lengths after drilling with flexible and rigid reamers.

Study	Knee Flexion (degrees)	Flexible (mm)	Rigid (mm)	P Value
Steiner et al. 2012 (n=6)	110	42.0	32.5	<0.01
Silver et al. 2010 (n=10)	120	43.5	37.1	0.01
Larson et al. 2012 (n=5)	110	28.92	37.73	NS
This study (n=9)	Flexible 90; Rigid 115	36.6	36.7	NS

NS, not significant

there were no cases of posterior wall "blowout"; however, tunnels drilled with rigid reamers were significantly closer to the posterior cortex of the femur.

Obliquely oriented femoral tunnels provide more rotational stability than vertical tunnels (1-5,13,19). Scopp et al. demonstrated that oblique tunnels oriented 60 degrees to vertical in the axial plane restored tibial internal rotation in 30 degrees of knee flexion to the same value as for knees with intact ACLs, whereas less oblique tunnels (30 degrees to vertical) had significantly more tibial internal rotation (5). In this study, flexible reamers were superior to rigid reamers in producing obliquely oriented tunnels. Similar to our study, Larson et al. found that the use of flexible reamers through the AM portal produced tunnels of greater obliquity than rigid reamers. The method of measuring this angle was slightly different, but the flexible reamers produced tunnels that were approximately 10 degrees more oblique (18). The difference in our study was approximately 17 degrees.

Limitations of this study include the technique of tunnel placement, which was not identical to that performed in the operating room. With soft tissues dissected removed, visualization and guide placement is much simpler. We assessed only tunnel position and orientation and did not perform actual reconstructions with subsequent biomechanical analysis that may demonstrate clinically relevant differences for ACL reconstructions performed with flexible reamers.

CONCLUSIONS

Femoral ACL tunnel placement using flexible reamers produced tunnels with greater obliquity. The tunnels were farther from the posterior cortex of the femur and there was no difference in length of tunnels compared to those created with rigid reamers. The use of flexible reamers for femoral ACL tunnels produced acceptable tunnels without requiring excessive knee flexion.

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