Single-Bundle Versus Double-Bundle Arthroscopic Anterior Cruciate Ligament Reconstruction: Comparison of Long-Term Functional Outcomes

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Abstract

Objective

To compare long-term functional results of ACL reconstruction with a single bundle (SB) and double bundle (DB).

Methods

Sixty patients who underwent ACL reconstructions from January 2007 to December 2008 were retrospectively evaluated (30 SB and 30 DB ACL reconstructions). Clinical and functional outcomes were measured pre- and postoperatively in terms of anterior drawer test, Lachman’s test, pivot shift test, KT1000 side-to-side difference, range of motion, International Knee Documentation Committee Scoring, Lysholm knee scoring scale (LKS), and Tegner activity level scale. The period of follow-up was 10 years.

Results

Clinical outcome measured showed that anterior drawer test result were equally normal for both groups (93.3%; p > 0.995); however, the Lachman test was 76.7% in the DB group and 56.7% in the SB group (p > 0.100), the pivot shift was 83% in the DB group and 50% in the SB group (p < 0.001), and KT1000 was 76.7% in the DB group and 56.7% in the SB group (p > 0.100). Regarding the functional outcome, it favored the DB group of patients, with the LKS being statistically significant (p < 0.007) and the Tegner activity level scale p-value being <0.001.

Conclusions

DB ACL reconstruction produces better rotational stability and gives superior functional outcome in terms of return to pre-injury activity level in comparison to SB reconstruction. DB ACL reconstruction using hamstring tendon autograft produces better functional results at 10 years follow-up.

Introduction

Anatomical observation has shown that the anterior cruciate ligament (ACL) mainly consists of two distinct bundles, the anteromedial (AM) bundle and the posterolateral (PL) bundle [1]. Conventional single-bundle (SB) ACL reconstruction techniques have focused on the restoration of the AM bundle while giving limited attention to the PL bundle. However, biomechanical studies show increased anterior and rotational stability with double-bundle (DB) compared to SB ACL reconstruction. The controversy remains in which surgery technique and length of the graft should be used [2]. The purpose of this study is to compare the outcomes of ACL reconstruction patients when using either DB or SB technique with similar rehabilitation in both techniques.

Materials And Methods

This was a retrospective non-randomized comparative study that was carried out at the Orthopaedic Arthroscopic Sports Unit, Hospital Kuala Lumpur (HKL). This study included all patients admitted to HKL and underwent either anatomical DB or SB ACL reconstructive surgery from January 2007 to December 2008. The study population was adults over 18 years and below 40, including both genders. Selected patients had pre-operative findings as follows: anterior drawer test > 3 mm, Lachman test > 3 mm, pivot shift test + (glide), KT 1000 > 3 mm, and functional hop test < 90%. Patients who underwent primary unilateral ‘anatomical’ single (AM) bundle or ‘anatomical’ double (AM and PL) bundle reconstructions of the ACL using only hamstring tendon autograft were also included in this study. The surgery was performed by
several qualified Orthopaedic surgeons using the same technique. Furthermore, we also included patients who underwent the same post-ACL reconstruction rehabilitation therapy, which includes pain and swelling control, restoration of the normal range of motion, and development of muscle strength.

Patients who had a revision ACL and those with concomitant ipsilateral ligamentous injury were excluded from this study. Furthermore, patients with contralateral ACL-deficient or reconstructed knee, those who had a history of any ligament injuries in the contralateral knee, and those who underwent subtotal or total meniscectomy or meniscus repair for meniscus injury were also excluded from this study to avoid confounding factors.

All the patients were assessed both clinically and functionally pre- and post-surgery. In terms of clinical assessment, all patients were examined using the anterior drawer test at 90 degrees of flexion, Lachman test at 25 degrees of flexion, pivot shift test, KT1000 (side-to-side differences) at 25 degrees of flexion, and range of motion. The functional outcome was measured from two years of the ACL reconstruction until 10 years follow up and was further evaluated using the International Knee Documentation Committee (IKDC), Lysholm knee scoring scale (LKS), and Tegner activity level scale.

The anterior drawer test and Lachman test were further divided into normal and nearly normal, whereby knee laxity less than 3 mm is normal and knee laxity less than 5 mm is nearly normal for both tests. The study was analyzed by SPSS Version 25.0 (IBM Corp., Armonk, NY, USA) using the chi-square test and t-test method.

Results

There were 60 patients recruited throughout the study. Among them, 49 were males and 11 were females. Equal numbers of patients were treated with both types of the bundle. Among them, 30 received SB treatment and the remaining received DB reconstruction. The mean (SD) of age was 26.62 (6.727) years. All the patients had either normal or nearly normal outcomes. The data are summarized in Table 1.
| Variables                      | N (%)                           |
|--------------------------------|---------------------------------|
| Age, mean (SD)                 | 26.62 (6.727)                   |
| Gender, n (%)                  |                                 |
| Male                           | 49 (23.1)                       |
| Female                         | 14 (35.9)                       |
| Bundle, n (%)                  |                                 |
| Single                         | 30 (50.0)                       |
| Double                         | 30 (50.0)                       |
| Test results, n (%)            |                                 |
| Anterior drawer test           |                                 |
| Normal                         | 56 (93.3)                       |
| Nearly normal                  | 04 (66.7)                       |
| Abnormal                       | 0                               |
| Severe abnormal                | 0                               |
| Lachman test                   |                                 |
| Normal                         | 40 (66.7)                       |
| Nearly normal                  | 20 (33.3)                       |
| Abnormal                       | 0                               |
| Severe abnormal                | 0                               |
| Pivot shift test               |                                 |
| Normal                         | 45 (75.0)                       |
| Nearly normal                  | 15 (25.0)                       |
| Abnormal                       | 0                               |
| Severe abnormal                | 0                               |
| Functional hop test            |                                 |
| Normal                         | 36 (60.0)                       |
| Nearly normal                  | 24 (40.0)                       |
| Abnormal                       | 0                               |
| Severe abnormal                | 0                               |
| KT1000 _n, n (%)               |                                 |
| Normal                         | 40 (66.7)                       |
| Nearly normal                  | 20 (33.3)                       |
| Abnormal                       | 0                               |
| Severe abnormal                | 0                               |

**TABLE 1: Baseline characteristics**

The association between test and type of bundles is shown in Table 2. There was no association between gender (female, male) and the type of bundle (SB and DB). The treatment outcome was not affected by the
gender. There was no association between anterior drawer test and the type of bundles (SB and DB). The number of patients having normal result of SB is the same as that of DB. The same goes with Lachman test between the bundles. No significant association was found.

| Variable                          | Single bundle | Double bundle | X² statistics (df) | p-Value* |
|----------------------------------|---------------|---------------|-------------------|----------|
| Gender, n (%)                    |               |               |                   |          |
| Male                             | 22 (73.3)     | 27 (90.0)     |                   | 0.095    |
| Female                           | 8 (26.7)      | 3 (10.0)      |                   |          |
| Anterior drawer test, n (%)      |               |               |                   |          |
| Normal                           | 28 (93.3)     | 28 (93.3)     |                   | >0.995b  |
| Nearly normal                    | 2 (06.7)      | 2 (06.7)      |                   |          |
| Lachman, n (%)                   |               |               |                   |          |
| Normal                           | 17 (56.7)     | 23 (76.7)     |                   | 0.100    |
| Nearly normal                    | 13 (43.4)     | 7 (23.3)      |                   |          |
| Pivot shift, n (%)               |               |               |                   |          |
| Normal                           | 15 (50.0)     | 25 (83.0)     |                   | <0.001b  |
| Nearly normal                    | 15 (50.0)     | 5 (17.0)      |                   |          |
| Functional hop test, n (%)       |               |               |                   |          |
| Normal                           | 12 (40.0)     | 24 (80.0)     |                   | 0.002    |
| Nearly normal                    | 18 (60.0)     | 6 (20.0)      |                   |          |
| KT 1000_n, n (%)                 |               |               |                   |          |
| Normal                           | 17 (56.7)     | 23 (76.7)     |                   | 0.100    |
| Nearly normal                    | 13 (43.4)     | 7 (23.3)      |                   |          |

**TABLE 2: Association between test and type of bundles**

*Pearson's chi-square test for independence.

bFisher's exact test.

Comparison means of knee range of motion and LKS_n between types of bundles is shown in Table 3. There was no statistically significant difference in knee range of motion between SB and DB. However, in LKS_n, there was a statistically significant difference (p = 0.007) between SB and DB. The LKS_n mean and standard deviation in DB was a bit higher (93.50 and 4.26, respectively) than that in SB (89.0 and 2.58, respectively).
| Variable               | Single Bundle | Double Bundle | Mean difference (95% CI) | t statistics (df) | p-Value<sup>a</sup> |
|------------------------|---------------|---------------|--------------------------|-------------------|---------------------|
| Knee ROM, mean (SD)    | 135.17 (4.82) | 136.50 (4.58) | 1.50 (-1.99, 4.99)       | 0.862 (58)        | 0.392               |
| LKS_n, mean (SD)       | 89.0 (2.58)   | 93.50 (4.26)  | 3.70 (1.07, 6.33)        | 2.814 (58)        | 0.007               |

TABLE 3: Comparing means of knee ROM and Lysholm Knee Scoring Scale (LKS_n) between types of bundles

<sup>a</sup>Independent t-test

ROM, range of motion

Both pre-Tegner and post-Tegner scores show a statistically significant in SB and DB treatment, with a p-value of < 0.001. Both bundles show a decrease in the post-Tegner score. SB has mean (standard deviation) of 5.15 (1.28) post-Tegner scoring, whereas the mean (standard deviation) of DB post-Tegner scoring was 16.46 (2.96), as shown in Table 4.

| Variable               | Pre-Tegner score | Post-Tegner score | Mean difference (95% CI) | t statistics (df) | p-Value<sup>a</sup> |
|------------------------|-------------------|-------------------|--------------------------|-------------------|---------------------|
| Bundle, mean (SD)      |                   |                   |                          |                   |                     |
| Single                 | 6.30 (1.29)       | 5.13 (1.28)       | 1.17 (0.87, 1.46)        | 8.074 (29)        | <0.001              |
| Double                 | 18.53 (2.59)      | 16.46 (2.96)      | 0.80 (0.59, 1.01)        | 7.954 (29)        | <0.001              |

TABLE 4: Change of Tegner measurement within the type of bundle

<sup>a</sup>Paired t-test

Discussion

Currently, there are many studies focusing on determining if DB ACL reconstruction is superior to SB reconstruction, but only a minority of them present a high level of evidence. Systematic reviews of appropriate studies are often the best form of evidence-based data, and reviews of level I and II studies constitute the highest level of evidence. However, results and conclusions from a randomized controlled trial are not always reliable, as such a trial can be performed and reported with methodical errors in current orthopedic and sports traumatology literature.

In this study, SB and DB surgical techniques were compared to determine differences in both the clinical assessment and functional outcome in patients with isolated rupture of the ACL before and after reconstructive surgery. The goals of anatomical ACL reconstruction are to restore 80-90% of the native ACL anatomy and to maintain long-term knee health [3]. Experience with SB ACL reconstruction has shown that it is as successful as DB but inadequately restoring anterior-posterior (A-P) stability [4].

As in our study, at the end of 10 years of follow-up, the results showed that the DB procedure did not yield better anterior drawer stability in patients undergoing the SB procedure in terms of statistical significance (p > 0.995); nevertheless, both procedures did produce a clinical significance when compared to pre- and post-operative ACL reconstruction (SB: 28 normal and 2 near normal; DB: 28 normal and 2 near normal). In regards to the Lachman test, both groups did provide better clinical outcomes in terms of patient number (SB: 17 normal and 15 near normal; DB: 23 normal and 7 near normal); however, the statistical differences were insignificant (p < 0.100).

We also found that side-to-side KT1000 arthrometer measurements were not statistically significant (p > 0.100) when compared between SB ACL reconstruction and DB ACL reconstruction. Our interpretation of lack of clinical significance is based on the following considerations: (1) the KT1000 arthrometer measures anterior knee laxity in 1-mm (as opposed to smaller) increments of precision, (2) the original description of instrumented measurement of anterior knee laxity using the KT1000 arthrometer reports a mean of 0.8 mm, standard deviation of 0.7 mm, and normal knee side-to-side laxity of greater than 0.52 mm, and (3) the IKDC
Functional outcomes, in the long run, is yet to be determined. Studies have shown a clinical advantage of the DB technique over the SB technique, but whether this will result in better outcomes, these may be negated by the added complexity of the surgical procedure. Current studies have accumulated substantially in this field.

The two main goals of DB ACL reconstruction are to restore the native biomechanics and anatomical parameters of the knee and to maintain long-term knee health. While DB ACL reconstruction has theoretical advantages, these may be negated by the added complexity of the surgical procedure. Recent studies have shown a clinical advantage of the DB technique over the SB technique, but whether this will result in better functional outcomes, in the long run, is yet to be determined.
Nevertheless, DB literature has given ACL surgery a 'rebirth,' which has allowed us to critically analyze ACL anatomy and our surgical techniques, either through SB or DB reconstruction. Therefore, more long-term studies are necessary to determine whether the restoration of knee kinematics to a more physiological state is accompanied by any improvement in the development of osteoarthritis and improved knee functions.

**Additional Information**

**Disclosures**

**Human subjects:** Consent was obtained by all participants in this study. National Medical Research Register issued approval 10999. **Animal subjects:** All authors have confirmed that this study did not involve animal subjects or tissue. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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