Introduction: Double-bundle (DB) anterior cruciate ligament (ACL) reconstruction is becoming increasingly common. However, no definitive data on the superiority of DB reconstruction have been shown when compared with single-bundle (SB) ACL reconstruction.

Sources of data: We performed a comprehensive search of PubMed, Medline, Cochrane, CINAHL and Embase databases using various combinations of keywords such as ‘ACL’, ‘reconstruction’, ‘DB’ and ‘SB’. Only articles published in peer-reviewed journals were included in this systematic review.

Areas of agreement: Several new techniques are available for ACL reconstruction. DB ACL reconstruction could provide better outcome for patients in terms of closer restoration of normal knee biomechanics and improving the rotatory laxity of the knee.

Areas of controversy: Data are lacking to allow definitive conclusions on the use of DB reconstruction techniques for routine management of patients with ACL tear.

Growing points: Given the limitations of the current studies, it is not possible to recommend systematic use of DB ACL reconstruction. Even though biomechanical results are encouraging, subjective patient evaluation is similar for SB and DB reconstruction.

Areas timely for developing research: Studies of higher levels of evidence, for instances large adequately powered randomized trials, should be conducted to bring new insight in this field. With the current evidence available, a simple SB
ACL reconstruction is a suitable technique, and it should be not abandoned until stronger scientific evidence in favour of DB ACL reconstruction will be produced.

Keywords: single-bundle/double-bundle/anterior cruciate ligament/sports/knee/arthroscopy

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Introduction

Reconstruction of the anterior cruciate ligament (ACL) is one of the most common orthopaedic procedures,\textsuperscript{1–4} with reported clinical success ranging from 80 to 95\%.\textsuperscript{5} Approximately 75 000–100 000 ACL reconstructions are performed annually in the USA, but 85\% of orthopaedic ‘surgeons’ perform <10 ACL reconstruction procedures per year.\textsuperscript{5}

The double-bundle (DB) anatomy of the ACL was firstly described by Weber \textit{et al.}\textsuperscript{6} and was remarked upon by Norwood and Cross.\textsuperscript{7,8} The ACL consists of two functional bundles: the antero-medial bundle (AMB) and postero-lateral bundle (PLB).\textsuperscript{9,10} The AMB originates more proximally on the femoral site, and inserts antero-medially on the tibia. The PLB originates more distally on the femoral site, and inserts postero-laterally on the tibia.\textsuperscript{9–11} The AMB and PLB are oriented nearly parallel with the knee extended, and twist around each other as the knee flexes.\textsuperscript{5} Sakane \textit{et al.}\textsuperscript{12} reported that an anterior drawer force to the tibia is distributed to the PLB to a greater degree than to the AMB in the nearly extended position, whereas it is distributed to the AMB to a greater degree than to the PLB in the flexed position. Despite this complex anatomy, a single-bundle (SB) construct is most commonly used: this does not reconstitute normal anatomy.\textsuperscript{13}

A large number of ACL reconstruction techniques has been described.\textsuperscript{14–21} At present, a definite consensus for optimal positioning of the femoral tunnel or determining the anatomical landmarks that best identify the correct insertion of the ACL does not exist.\textsuperscript{22,23}

A SB reconstruction is performed by producing one single femoral tunnel and one single tibial tunnel. Several SB techniques are commonly used.\textsuperscript{14,18,24–28} Some authors hypothesize that it is crucial to re-establish the DB anatomy of the ACL to obtain a closer restoration of normal knee biomechanics, and to improve the rotatory laxity of the knee.\textsuperscript{17,18,29,30} Furthermore, in recent years it has been hypothesized that after ACL reconstruction some failures occur because SB ACL provides insufficient control of combined internal
and valgus torques applied to the knee. DB techniques therefore aim to reconstruct both the AMB and PLB, and, theoretically, should provide a superior construct that would reduce failure rates and improve functional outcome. ACL DB reconstruction should theoretically improve rotatory laxity compared with ACL SB reconstruction. Biomechanical in vitro testing of DB ACL constructs showed rotational stability closer to anatomical behaviour than ACL SB, but it has not been shown to correlate with an improved functional outcome within a follow-up period of 2 years.

To assess the success of ACL reconstruction, quantitative measurements of the pivot-shift phenomenon, transverse plane rotational knee laxity and patient satisfaction must be considered. In addition, the long-term outcome of the reconstruction in terms of preventing or slowing down the progression of degenerative joint disease should be taken into account.

We performed a systematic review of the published literature on SB and DB ACL reconstruction, and analysed the reported outcomes.

**Materials and methods**

*Literature search and data extraction*

Two reviewers (U.G.L. and E.F.) independently identified studies, in any language, by a systematic search of CINAHL, Embase, Medline, HealthSTAR and the Cochrane Central Registry of Controlled Trials, from inception of the database to February 15, 2011, using various combinations of keywords such as ‘ACL’, ‘reconstruction’, ‘DB’ and ‘SB’.

All articles relevant to the subject were retrieved and their bibliographies hand searched for further references in the context of ACL reconstruction.

We considered publications in any language. Reviewers scanned the bibliographies of all retrieved studies and other relevant publications, including reviews and meta-analyses, for additional relevant articles.

Two reviewers (U.G.L. and E.F.) screened the titles and abstracts of the identified citations independently and in duplicate and acquired the full text of any article that either judged potentially eligible. These reviewers independently applied eligibility criteria to the methods section of potentially eligible trials. Eligible studies had to report on patients with single versus DB ACL reconstruction. Only articles published in peer-reviewed journals were included in this systematic review. We resolved disagreements by discussion.
From each article, two investigators (U.G.L. and E.F.) independently extracted the year of publication, type of study (i.e. randomized controlled trial, prospective study or retrospective case series), number of patients, length of follow-up, method of managements (i.e. SB versus DB) and the type of outcome measures.

Methodological quality assessment

The Coleman methodology score (CMS), which was originally developed for and used to grade clinical studies on patellar and Achilles tendinopathy, and subsequently used in several other systematic reviews, was adapted to evaluate studies reporting on ACL reconstruction.

This scoring system assesses methodology using 10 criteria, giving a total score between 0 and 100. A score approaching 100 indicates that the study has a robust design and largely avoids chance, various biases or confounding factors. A score >85 is considered excellent; 70–84, good; 50–69, moderate; and <50, poor.

The subsections that compose the CMS are based on the subsections of the CONSORT statement (for randomized controlled trials, RCTs), but are modified to allow for other trial designs. Two investigators (U.G.L. and E.F.) independently scored the quality of the studies. Each investigator scored the quality of the studies twice, with a time interval of 3 weeks between each scoring session to minimize intraobserver error. Intra and interobserver reliability was examined. Where differences were encountered, agreement was achieved by consensus.

Results

Studies

Given the earlier criteria, we included 17 articles, published from May 2004 to September 2010, which examined SB versus DB technique for ACL reconstruction (Fig. 1). To our knowledge, while many authors have described DB techniques, and several have reported DB outcome studies at 2 years in level IV evidence investigations, only 9 RCTs, 4 quasi-RCTs and 4 prospective comparative cohort studies (non-randomized clinical trials) compared SB and DB reconstruction of the ACL, and all these studies have been included. All showed comparable clinical outcome between the two techniques. It is remarkable that
no study has detected any statistically significant differences between SB and DB when using patient-based outcome measures (Tables 1 and 2).

**Demographics details**

Included in this systematic review are 17 studies (Tables 1 and 2) reported on 833 SB ACL reconstructions and 774 DB ACL reconstruction, in 1017 men and 590 women. The mean number of patients included in each study was $90.8 \pm 69.9$ SD. The mean age of subjects in the SB group was $26.5 \pm 3.8$ SD years, whereas the mean age in DB group was $27.5 \pm 3.1$ SD years.

The median duration of follow-up was $24.1 \pm 9.1$ months in SB group and $25.2 \pm 8.7$ months in DB group.

**Quality assessment**

The detailed results of the CMS for each criterion are given in Table 3.

**Length of operation**

Operating time was reported in three studies.\textsuperscript{21,61,62} Yasuda et al. showed no significant differences concerning the time for operation.
### Table 1 Demographics details of included studies.

<table>
<thead>
<tr>
<th>Reference</th>
<th>Number of patients</th>
<th>Method of management</th>
<th>Gender (M/F)</th>
<th>Mean age (years)</th>
<th>Mean follow-up (months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adachi(^{17})</td>
<td>108</td>
<td>SB = 55, DB = 53</td>
<td>32/23</td>
<td>29.5</td>
<td>33</td>
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<tr>
<td>Yasuda(^{21})</td>
<td>72</td>
<td>SB = 24, ADB = 24, NADB = 24</td>
<td>13/11, 14/10, 15/9</td>
<td>25.7, 26.6, 25.5</td>
<td>24</td>
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<tr>
<td>Aglietti(^{18})</td>
<td>75</td>
<td>SB = 25, DB single incision transtibial = 25</td>
<td>12/13, 10/20</td>
<td>28, 30</td>
<td>24</td>
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<tr>
<td>Yagi(^{30})</td>
<td>60</td>
<td>SB = 20, SB posterolateral = 20</td>
<td>6/14, 5/15</td>
<td>22.9, 22</td>
<td>12</td>
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<tr>
<td>Muneta(^{29})</td>
<td>68</td>
<td>SB = 34, DB = 34</td>
<td>14/20, 20/14</td>
<td>23.4, 24.0</td>
<td>24.4, 25.2</td>
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<tr>
<td>Jarvela(^{70})</td>
<td>65</td>
<td>SB = 30, DB = 35</td>
<td>–, –</td>
<td>33.0, 33.0</td>
<td>14</td>
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<tr>
<td>Streich(^{71})</td>
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<td>SB = 25, DB = 25</td>
<td>25/0, 25/0</td>
<td>30, 29.2</td>
<td>24</td>
</tr>
<tr>
<td>Jarvela(^{69})</td>
<td>77</td>
<td>SBB = 27, SBM = 25</td>
<td>51/26</td>
<td>33</td>
<td>24</td>
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<tr>
<td>Kondo(^{62})</td>
<td>328</td>
<td>SB = 157, DB = 171</td>
<td>85/72, 101/70</td>
<td>25, 27</td>
<td>24</td>
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<tr>
<td>Zaffagnini(^{66})</td>
<td>72</td>
<td>SB + Lateral Plasty = 35</td>
<td>20/15, 20/17</td>
<td>26, 27</td>
<td>46.9</td>
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<tr>
<td>Siebold(^{64})</td>
<td>70</td>
<td>SB = 35, DB = 35</td>
<td>31/4, 32/3</td>
<td>29, 38</td>
<td>19</td>
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<tr>
<td>Wang(^{61})</td>
<td>64</td>
<td>SB = 32, DB = 32</td>
<td>20/12, 29/3</td>
<td>23.3, 23.6</td>
<td>17.7, 14.4</td>
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<tr>
<td>Tsuda(^{63})</td>
<td>144</td>
<td>LSBP-F = 27, LSBP-M = 35, DBH-F = 50, DBH-M = 32</td>
<td>35/27, 32/50, 32/50</td>
<td>21, 23, 23</td>
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<td>Sastre(^{68})</td>
<td>40</td>
<td>SB = 20, DB = 20</td>
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<td>Aglietti(^{67})</td>
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<td>SB = 35, DB = 35</td>
<td>25/10, 28/7</td>
<td>28, 28</td>
<td>24</td>
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<tr>
<td>Ibrahim(^{65})</td>
<td>200</td>
<td>SB (=50), SB endobutton (=48), SB rigid fix (=52), SB trans fix II (=50), DB (=50), DB (=22)</td>
<td>48/0, 52/0, 50/0</td>
<td>28, 28</td>
<td>29</td>
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<tr>
<td>Misonoo(^{72})</td>
<td>66</td>
<td>DB (=22), SB (=22)</td>
<td>11/11, 11/11</td>
<td>22, 22</td>
<td>12</td>
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<tr>
<td>Total</td>
<td>1607</td>
<td>SB = 833, DB = 775</td>
<td>1017/590, 27.5 ± 3.1 SD</td>
<td>26.5 ± 3.8 SD, 27.5 ± 3.1 SD</td>
<td>24.1 ± 9.1, 25.2 ± 8.7</td>
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<td>Reference</td>
<td>Number of patients</td>
<td>Type of study</td>
<td>Follow-up</td>
<td>Method of management</td>
<td>Physician centred Outcome measures</td>
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<tr>
<td>Adachi et al.</td>
<td>108</td>
<td>RCT</td>
<td>2 years</td>
<td>SB (n = 55), DB (n = 53)</td>
<td>Side-to-side ATT (KT-2000) NS (P-value not reported in the study) Proprioception (Cybex II)</td>
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<tr>
<td>Yasuda et al.</td>
<td>72</td>
<td>Prospective Comparative Cohort Study</td>
<td>2 years</td>
<td>SB (n = 24), N-AD (n = 24), AD (n = 24)</td>
<td>Side-to-side ATT (KT-2000) SB and AD (P = 0.002) N-AD and AD NS (P = 0.072) Peak torque (Cybex II) NS (P-value not reported in the study) Pivot-shift (manual) NS (P = 0.025) IKDC score NS (P-value not reported in the study)</td>
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<tr>
<td>Aglietti et al.</td>
<td>75</td>
<td>Prospective Comparative Cohort Study</td>
<td>2 years</td>
<td>Single incision SB (n = 25), Single incision DB (n = 25), Double incision DB (n = 25)</td>
<td>Side-to-side ATT (KT-2000) Single incision SB and Double incision DB P &lt; 0.05 Pivot-shift (manual) IKDC score</td>
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<td>Yagi et al.</td>
<td>60</td>
<td>Quasi-RCT</td>
<td>1 year</td>
<td>Anteromedial SB (n = 24), Posterolateral SB (n = 24), DB (n = 24)</td>
<td>Side-to-side ATT (KT-1000) NS (P-value not reported in the study) Peak torque (Cybex II) NS (P-value not reported in the study) Pivot-shift (instrumented) P &lt; 0.05 (P-value not reported in the study) IKDC score</td>
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<table>
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<tr>
<th>Reference</th>
<th>Number of patients</th>
<th>Type of study</th>
<th>Follow-up</th>
<th>Method of management</th>
<th>Physician centred Outcome measures</th>
<th>Patient centred Outcome measures</th>
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</thead>
<tbody>
<tr>
<td>Muneta et al.</td>
<td>68</td>
<td>Quasi-RCT</td>
<td>2 years</td>
<td>SB (n = 34), DB (n = 34)</td>
<td>Side-to-side ATT (KT-1000) ( P &lt; 0.05 ) (( P )-value not reported in the study) ( )</td>
<td>Lysholm knee score, IKDC score, Tegner knee score ( P )-value not reported in the study</td>
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<tr>
<td>Jarvela</td>
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<td>RCT</td>
<td>1 year</td>
<td>SB (n = 30), DB (n = 35)</td>
<td>Side-to-side ATT (KT-1000) ( P )-value not reported in the study</td>
<td>Lysholm knee score, IKDC subjective score ( P )-value not reported in the study</td>
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<td>IKDC score ( P )-value not reported in the study</td>
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<tr>
<td>Streich et al.</td>
<td>50</td>
<td>RCT</td>
<td>2 years</td>
<td>SB (n = 25), DB (n = 25)</td>
<td>Pivot-shift test ( P = 0.002 ) ( ) Side-to-side ATT (KT-1000) ( P = 0.798 ) ( )</td>
<td>Lysholm knee score, Tegner activity score ( P )-value not reported in the study</td>
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<td>Pivot-shift ( P = 0.098 ) ( )</td>
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<td>Siebold et al.</td>
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<td>RCT</td>
<td>19 months</td>
<td>SB (n = 35), DB (n = 35)</td>
<td>Side-to-side ATT (KT-1000) ( P = 0.054 ) ( )</td>
<td>Lysholm knee score ( P = 0.22 )</td>
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<td>IKDC score ( P &lt; 0.000 ) ( )</td>
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<td>Pivot-shift test ( P = 0.01 ) ( )</td>
<td>IKDC 200 subjective score ( P = 0.42 )</td>
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<tr>
<td>Jarvela et al.</td>
<td>77</td>
<td>RCT</td>
<td>2 years</td>
<td>DB (n = 25), SB with bioabsorbable screw fixation (( n = 27 )), SB with metallic screw fixation (( n = 25 ))</td>
<td>Side-to-side ATT (KT-1000) ( P &lt; 0.001 ) ( )</td>
<td>Lysholm knee score ( P = 0.460 )</td>
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<td>Study</td>
<td>Design</td>
<td>Follow-up</td>
<td>SB, DB</td>
<td>Side-to-side ATT</td>
<td>Lysholm knee score</td>
<td>IKDC score</td>
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<tr>
<td>Kondo et al.</td>
<td>Prospective</td>
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<td>157, 171</td>
<td>KT-2000</td>
<td>NS (P-value not reported in the study)</td>
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<td>Aglietti et al.</td>
<td>RCT</td>
<td>2 years</td>
<td>35, 35</td>
<td>KT-1000</td>
<td>KS (P = 0.08)</td>
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<td>Sastre et al.</td>
<td>RCT</td>
<td>2 years</td>
<td>20, 20</td>
<td>KT-1000</td>
<td>NS (P-value not reported in the study)</td>
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<td>Tsuda et al.</td>
<td>Prospective</td>
<td>2 years</td>
<td>62, 82</td>
<td>KT-1000</td>
<td>NS (P-value not exactly reported in the study)</td>
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<td>Wang et al.</td>
<td>RCT</td>
<td>10 Months</td>
<td>32, 32</td>
<td>KT-2000</td>
<td>NS (P = 0.6)</td>
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<td>Quasi-RCT</td>
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<td>35, 37</td>
<td>KT-2000</td>
<td>NS (P = 0.05)</td>
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Continued.
Table 2  Continued

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<tr>
<th>Reference</th>
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<th>Method of management</th>
<th>Physician centred Outcome measures</th>
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<td>Outcome measures</td>
<td>Statistical significance of results</td>
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<td>Outcome measures</td>
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<tr>
<td>Ibrahim et al.\textsuperscript{65}</td>
<td>200</td>
<td>RCT</td>
<td>29 months</td>
<td>DB(=50), SBendobatton (=48), SB rigid fix (=52), SB trans fixII (=50)</td>
<td>IKDC score Side-to-side ATT (KT-1000)</td>
<td>P = 0.04</td>
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<td>Three-dimensional motion analysis</td>
<td>NS</td>
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<tr>
<td>Misonoo et al.\textsuperscript{72}</td>
<td>66</td>
<td>Quasi RCT</td>
<td>12 months</td>
<td>DB (=22), SB (=22), Control Healthy Group (=22)</td>
<td>Side-to-side ATT (KT-1000)</td>
<td>NS</td>
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<td>Lysholm knee score</td>
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</table>

RCT, Randomized controlled trial; SB, Single-bundle; DB, Double-bundle; ATT, Anterior Tuberosity Translation; IKDC, International Knee Documentation Committee; NS, Non-significant. Significance was set at P < 0.05.
Table 3 Methodological quality assessment with Coleman methodology score.

<table>
<thead>
<tr>
<th>Section score (maximum score)</th>
<th>Adachi17</th>
<th>Yasuda21</th>
<th>Aglietti18</th>
<th>Yagi30</th>
<th>Muneta25</th>
<th>Jarvela20</th>
<th>Streich11</th>
<th>Jarvela19</th>
<th>Kondo12</th>
<th>Zaffagnini16</th>
<th>Siebold34</th>
<th>Wang61</th>
<th>Tsuda53</th>
<th>Sastre68</th>
<th>Aglietti67</th>
<th>Ibrahim65</th>
<th>Misonoo72</th>
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<td>Study size (10)</td>
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<td>Mean duration of follow-up (5)</td>
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between the DB and SB groups.\textsuperscript{21} The operation time of DB ACL reconstruction was longer than the SB ACL reconstruction in the other two studies.\textsuperscript{61,62}

**Range of motion**

The range of motion of the knee improved significantly in the post-operative period in both groups in comparison with preoperative values. Tsuda \textit{et al.}\textsuperscript{63} found that the patients with SB recovered knee extension better at 1 month compared with the patients with DB, but extension was similar after 3 months. Some studies\textsuperscript{21,29,64,65} found that the range of motion was comparable for both DB and SB technique. Zaffagnini \textit{et al.}\textsuperscript{56} found that the DB group showed significantly better results regarding the range of motion.

**Knee stability**

Most of the studies included report the results of rotational stability and side-to-side anterior stability in post-operative DB and SB ACL reconstruction. In most of the studies included, rotational stability has been evaluated with pivot-shift test, whereas the side-to-side anterior stability has been evaluated either with KT arthrometer or with anterior drawer and Lachman test.

Concerning the anterior stability of the knee in eight of the included studies\textsuperscript{18,21,29,62,64,66,67} there was a statistically significant decrease in the anterior tibial translation in patients undergoing DB when compared with patients undergoing SB. Eight studies\textsuperscript{17,30,61,63,68–71} showed that there was no significant difference between SB and DB techniques.

Most of the included studies shown significantly better results in the DB technique than in the SB techniques concerning rotational stability\textsuperscript{18,21,29,62,64,65,67,69,70} whereas other studies\textsuperscript{30,61,63,68,71} Misonoo\textsuperscript{72} showed no significant difference between SB and DB techniques.

**Knee outcome score**

Most comparative studies reporting on knee outcome score did not show any statistical difference for one or the other technique.\textsuperscript{17,18,21,29,30,61–63,68–72} Aglietti \textit{et al.}\textsuperscript{67} found a statistically significant difference in favour of the DB technique in the results of visual analogue scale and subjective International Knee Documentation Committee (IKDC) and Knee Injury and Osteoarthritis Outcome Score (KOOS) evaluations and objective IKDC. Sastre \textit{et al.}\textsuperscript{68} found a
statistically significant difference in favour of the DB technique in the results of objective IKDC. In the study of Zaffagnini et al., the DB group showed significantly better IKDC results.

Complications

Concerning minor intraoperative problems, there were no significant differences between the SB and DB groups. There were no serious postoperative complications including fractures, deep vein thrombosis and infections in either groups.

Siebold et al. reported only one patient for each group with an early postoperative infection that required arthroscopic lavage and antibiotic treatment. In each group, one patient developed a cyclops lesion to the intact ACL reconstruction; the lesion required arthroscopic debridement. Another minor intraoperative problem was the fact that an EndoButton was flipped within the lateral vastus muscle in five and nine knees of SB and DB groups, respectively. Of the nine buttons in DB group, seven and two buttons were used to fix the PLB and AMB, respectively. Two patients (one from each group) who showed recurrence of knee instability were diagnosed as complete disruption of the graft at second-look arthroscopy.

Sastre et al. found two patients in the SB group with leftover metal pieces in the control radiograph that had no clinical repercussions. This might have resulted from the forced position of the guide with respect to the drill when the PL femoral tunnel was placed.

Discussion

The DB ACL reconstruction was introduced to replicate the native two bundles (anteromedial and posterolateral) of the ACL. The different behaviour of the two bundles should affect knee kinematics, and it has been hypothesized that the AMB bundle, which is closer to the line of knee axial rotation, controls mainly anterior laxity while the PL bundle, which is more divergent to the axis, should better control rotation. The latter should also be involved in controlling the pivot-shift phenomenon, which is a combination of abnormal rotation and translation.

In in vitro laboratory studies, the DB technique is more effective than the SB technique in controlling anterior tibial translation, internal rotation and simulated pivot shift. Conversely, in vivo comparative studies have led to different and sometimes conflicting results.
The *in vivo* measurement of rotational knee stability remains technically demanding. Ishibashi *et al.* measured superior rotational stability for DB reconstruction during intraoperative navigation, but this technique only evaluates primary knee stability and is due to the bone pins an invasive method.30 For pivot-shift testing in a clinical follow-up situation, techniques with electromagnetic sensors or a mechanized pivot shifter are described but they are not used in a standardized manner yet.79,80

An original non-invasive methodology used to quantify pivot-shift test was recently described.81 The method was validated on 66 consecutive unilateral ACL-injured patients. A commercial triaxial accelerometer was non-invasively mounted on patient’s tibia, the corresponding 3D acceleration was acquired during PS test execution and a set of specific parameters were automatically identified on the signal to quantify the test. PS test was repeated three times on both injured and contralateral limbs. Reliability of the method was found to be good (mean intra-rater intraclass correlation coefficient was 0.79); moreover, ACL-deficient knees presented statistically higher values for the identified parameters than the contralateral healthy limbs, averagely reporting also large effect size.81

Recently, with the enthusiasm for the DB technique, the ACL attachment anatomy, particularly for the femur, has been revisited.33,82,83 On the femur, the ACL fibres attach exclusively on the wall and not on the roof of the notch. From an arthroscopic point of view, it is useful to remember that all the femoral ACL attachment lies along the posterior articular cartilage border and is vertical with the knee in extension and assumes a horizontal direction with the knee at 100° of flexion.84 At 90° of flexion, the AMB attachment is deep and high just below the over-the-top position. The PL bundle attachment is shallow, 5 mm from the cartilage contour.78

A few clinical studies reported that there were no significant differences in the quantified knee laxity between their SB and DB ACL reconstruction procedures.17 However, they described that the tunnel for PL bundle reconstruction was produced at the 2 to 3 o’clock position. In addition, they drilled only one tunnel in the tibia. From our current anatomic knowledge, there is a strong possibility that these femoral tunnel positions were not at the attachment of the normal AM or PL bundles.62

Five prospective clinical trials did not show any statistical difference between DB technique and SB technique concerning post-operative knee laxity.61,68,70,71

Misonoo *et al.*72 showed no difference in restoring rotational stability during high-demand activities between DB ACL reconstruction and SB ACL reconstruction with the femoral tunnel placed at the center of the
ACL footprint. They also showed significant differences between the intact and ACL reconstructed sides in both reconstruction groups. This result further indicates that modern SB and DB ACL reconstructions fail to restore normal 3D rotational motion of the knee under dynamic, high-demand stressful loading. Although further studies are required, these abnormal motions may contribute to long-term joint degeneration associated with ACL reconstruction.

Eight prospective clinical trials show that the DB technique is better than SB technique for what concerns post-operative knee laxity. Aglietti et al., Siebold et al. and Jarvela et al. reported that their anatomic DB reconstruction procedures were better in both the pivot-shift test and the quantified anterior laxity than their SB reconstruction procedures. Yagi et al. reported that their anatomic DB reconstruction procedures were better in the pivot-shift test measured with magnetic sensors than their SB reconstruction procedures but shows no difference in side to side anterior laxity. Zaffagnini et al. and Yasuda et al. showed that their anatomic DB reconstruction procedures were better in reduction of the anterior laxity than their SB reconstruction procedures.

However, in these eight studies, the number of patients was not high enough (20–35 patients in each compared group) to generalize clinical conclusions.

Most of these prospective studies did not show a statistical difference between DB or SB technique in clinical outcome. Only a few studies found a statistically significant difference in favour of the DB technique in the results of clinical outcome. Aglietti et al. found a statistically significant difference in favour of the DB technique in the results of Visual Analogue Scale and subjective IKDC and KOOS evaluations and objective IKDC. Sastre et al. found a statistically significant difference in favour of the DB technique in the results of objective IKDC. In the study of Zaffagnini et al. DB group showed significantly better results regarding IKDC.

One of the great limitations of the studies on single versus DB is that several studies compared different SB techniques. A true consensus does not exist for optimal positioning of the femoral tunnel in ACL reconstruction or for determining the landmarks that best identify its true location. To restore knee function in response to both externally applied anterior tibial and combined rotatory loads in a SB reconstruction, positioning of the graft at the 10 o’clock position has been proposed to be better than the 11 o’clock position. To our knowledge, however, there are no RCTs testing the difference in clinical and mechanical outcome between positioning the graft at the 10 o’clock position or at the 11 o’clock position.
In summary, these results demonstrate a statistically significant but clinically insignificant difference in KT arthrometer results and no statistically significant difference in pivot-shift results when comparing SB versus DB ACL reconstruction clinical outcomes. These results are in agreement with recently published evidence.2,86

Since their introduction, DB techniques have been intensively marketed. Clearly, the modern era’s communications technology and sophisticated marketing techniques have markedly influenced the speed with which new techniques are recognized, popularized, and thus demanded by an easily influenced public. However, despite the available literature on DB technique, it is important to critically review the strength of evidence before new techniques are added to the surgeon’s armamentarium. Additionally, the risk of complications in DB techniques is theoretically higher as four drill holes and four fixation devices are required, and further possible pitfalls are possible.87 However, in a small group of patients, Snow et al. showed a steep learning curve for operation time and tunnel placement for an experienced ACL surgeon.88

The CMS assesses the quality of the studies, helping us to verify the methodology of the results presented. Based on these studies, we can conclude that for subjective outcome, expressed by scoring system, there is no difference between the DB and SB technique for the ACL reconstruction, whereas for objective outcome expressed by Lachman test, Pivot shift and KT arthrometer, DB have better rotational stability, possibly because of the PL bundle reconstruction.

However, without long-term follow up, no definite conclusions about the influence of this improved rotational stability on chondral degeneration, secondary meniscus lesions and onset of osteoarthritis can be made.89–94 There is a strong need for multicenter RCTs with adequate statistical power and long-term follow-up comparing SB with DB technique to evaluate the differences in cost and operating time, and to correctly define the indication for each technique. In addition, the long-term outcome of the reconstruction in terms of preventing or slowing down the progression of degenerative joint disease should be taken into account.95–117

Conclusions

Given the limitations of the available studies, it is not possible to give clear recommendations regarding the systematic use of DB ACL reconstruction, even though preliminary results are encouraging. With the current evidence available, a simple SB ACL reconstruction is a suitable technique, and it should not be abandoned until stronger scientific
evidence in favour of DB ACL reconstruction will be produced. Clearly, studies of higher levels of evidence, including large randomized trials, should be conducted to bring new insights into this field.\textsuperscript{118–131} Future trials should use validated functional and clinical outcomes, adequate methodology, and should be sufficiently powered.

References


Fu LL, Maffulli N, Yip KM et al. Articular cartilage lesions of the knee following immobilisation or destabilisation for 6 or 12 weeks in rabbits. *Clin Rheumatol* 1998;17:227–33.


