*British Medical Bulletin*, 2014, 19–29
doi: 10.1093/bmb/ldt038
Advance Access Publication Date: 18 December 2013

# Metallic or bioabsorbable interference screw for graft fixation in anterior cruciate ligament (ACL) reconstruction?

**Rocco Papalia[†], Sebastiano Vasta[†], Stefano D'Adamio[†], Antonino Giacalone[†], Nicola Maffulli[‡,§,*], and Vincenzo Denaro[†]**

[†]Department of Orthopaedic and Trauma Surgery, Campus Bio-Medico University of Rome, Via Alvaro del Portillo 200, Rome, Italy, [‡]Centre for Sports and Exercise Medicine, Barts and the London School of Medicine and Dentistry, Mile End Hospital, 275 Bancroft Road, London E1 4DG, UK, and [§]Department of Musculoskeletal Disorders, University of Salerno, Salerno, Italy

*Correspondence address. Centre for Sports and Exercise Medicine, Barts and The London School of Medicine and Dentistry, Mile End Hospital, 275 Bancroft Road, London E1 4DG, UK. E-mail: n.maffulli@qmul.ac.uk

Accepted 10 November 2013

## Abstract

**Background:** Approximately 100 000 anterior cruciate ligament (ACL) reconstructions are performed in the USA each year. Interference screw fixation is considered the standard for rigid fixation of the graft and provides higher fixation strength compared with other devices such as staples or buttons. The present study summarizes the latest evidence comparing the effectiveness of the available classes of interference screws for fixation of ACL grafts.

**Sources:** A comprehensive search of the CINAHL, PubMed, Google Scholar, Embase Biomedical databases and the Cochrane Central Registry of Controlled Trials was performed in March 2013. Twelve studies met our inclusion criteria.

**Areas of agreement:** Most studies showed no intergroup difference in terms of outcomes measured with validated clinical scores such as IKDC (International Knee Documentation Committee), Lysholm score and Tegner activity level. There was no significant difference regarding range of motion. Knee stability as evaluated with pivot shift and KT arthrometer showed a significant difference only in one study, favouring metallic interference screws. Tunnel widening is much more evident and marked patients who underwent ACL reconstruction with bioabsorbable screws, with no influence on the final clinical results achieved. Complication rates between the two screw classes were similar. The average modified Coleman methodology score was 74.67.

**Areas of uncertainty/research need**: The data comparing the outcomes achieved by two different materials for fixation, bioabsorbable and metallic, to be used during single-bundle ACL reconstruction, showed no significant difference in the final patient outcomes, in terms of clinical scores, clinical evaluation and imaging.

**Key words:** ACL reconstruction, ACL fixation, metallic screw, bioabsorbable screwt

## Introduction

Injury of anterior cruciate ligament (ACL) is one of the most common events in sports medicine.[1] Approximately 100 000 ACL reconstructions are performed in the USA every year, and current techniques for this procedure allow good-to-excellent results in ~85–95% of patients.[2–8]

The anterior cruciate ligament is essential in restraining the anterior translation of the tibia over the femur and provides rotational stability of the joint. ACL lesions usually occur as a result of a particular pattern of movement, most commonly when a sudden force (i.e. external impact, landing on feet etc.) acts on a straight knee with firmly planted feet causing the knee to go through a valgus motion with an associated internal rotation. ACL lesions can be functionally disabling and predispose to further injury, and also promotes early onset of degenerative articular changes.[9,10] After an ACL rupture, recurring episodes of joint instability ('giving way') are associated with meniscal injury, articular cartilage damage and abnormal osseous metabolism.[9,11–13]

An ACL tear is commonly treated arthroscopically using an autograft obtained from the hamstring tendons or patellar tendon. Graft fixation techniques have improved over the last decades with the development of several fixation procedures and materials. The use of an interference screw is considered the standard to provide rigid fixation of the graft and bone plug to insert in the tunnel, providing higher fixation strength compared with other devices such as staples or buttons.[14,15]

The first ACL graft fixation using interference screws, as early as 1983, was achieved using a metallic device, obtaining good results.[16] At present, titanium is the most common material used for this class of devices. Titanium screws provide high initial fixation strength and promote early integration into the bone, but, in case of revision surgery, hardware removal may be technically challenging, and the advantages of absorbable screws consist of reduced MRI artefacts and no need to remove the implant, justifying the widespread use of bioabsorbable screws.[17,18]

Bioabsorbable materials were developed to overcome these perceived weak points. Different combinations of synthetic materials have been used: PGA (polyglycolic acid), copolymers of PGA/PLA (polyglycolic acid/poly lactic acid), polyparadioxanone and various stereoisomers of lactic acid, poly-L-lactic acid and poly-D-lactic acid. Recently, biocomposite materials, composed of a mix of the polymers listed above, calcium phosphate and brushite have been also investigated.[19,20] The advantages of absorbable screws, consisting in minimized MRI artefacts and no need to remove the implant, justify their now widespread use. These devices are very likely to break during surgery,[21] and the integration of compound into bone might be incomplete and consequently the bone tunnel could widen.[22–24]

Our study summarizes and updates evidence for clinical results, stability testing, complication rates and imaging assessment of the two available classes of interference screws for the fixation of ACL grafts in single bundle reconstructions. We also tried to assess the methodological quality of the studies reviewed in order to evaluate the level of the available evidence on the issue.

## Materials and methods

### Literature search and data extraction

A comprehensive search of CINAHL, Pub Med (http://www.ncbi.nlm.nih.gov/sites/entrez/), Google Scholar (http://scholar.google.it/), Embase Biomedical databases (http://www.embase.com/) and the Cochrane Central Registry of Controlled Trials (http://www.thecochranelibrary.com/view/0/index.html), from inception of the database to March 2013, was conducted to identify all papers reporting outcomes of patients who had undergone ACL reconstruction. Isolated or combined keywords used were 'ACL reconstruction', 'ACL fixation', 'metallic screw' and 'bioabsorbable screw'. Subheadings were 'surgery', 'outcomes', 'pathology', 'physiology' and 'operation'.

All articles relevant to the subject were retrieved and the bibliographies were searched by hand for further references in the context of ACL reconstruction. The search was limited to articles published in peer-reviewed journals in English and Italian, given the language capabilities of the research team. We excluded case reports, letter to editors and articles lacking the postoperative outcomes of the procedure using the screws investigated here. All journals were considered with no limit set during online research.

From each article, two investigators (A.G. and R.P.) independently extracted the year of publication, type of study, number of patients, duration of follow-up, method of management, functional outcome measures, knee joint stability outcomes, intraoperative and postoperative complications and imaging evaluations.

After the first electronic search, 196 articles were identified. Two authors (R.P. and A.G.) independently reviewed the text of each abstract. Full-text versions were obtained to include or exclude the study. The reference lists of the selected articles were reviewed by hand to identify articles not identified at the electronic search. Biomechanical reports, studies on animals, cadavers, *in vitro*, literature reviews, technical notes and instructional courses were also excluded, leaving 12 studies to be included in our current review. We also decided to include only two groups of patients treated in the study by Jarvela *et al.*,[25] since they were only comparable in terms of the variables we intended to analyse, while we excluded patients in that study who underwent reconstruction different from all other patients and had not received a different screw as control.

## Quality assessment

Each scientific article was scored using the Coleman Methodology Score (CMS) system,[26] an accurate and reproducible 10 criteria method assessing the study methodological quality, ranging from 0 to 100. A score of 100 would represent a perfect well designed study with no influence of bias, chance and confounding factors. The CMS assesses the methodology of a study reviewed 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 greater than 85 is considered excellent; scores from 84 to 70 are good; from 69 to 50 are moderate; and less than 50 are poor.

Two investigators (R.P. and A.G.) scored independently each article and discussed scores reporting evident difference, until consensus was reached (Table 1).

# Results

## Number and types of studies

Given the limitations listed above, 12[25,27–37] articles were included in this review, published from October 1995 to March 2013. All examined metallic versus bioabsorbable interference screws for fixation of reconstructed ACL grafts. Of the 12 articles, 11[25,27–30,32,34–36] were prospective randomized controls trials and 1[33] was a retrospective study.

## Pre-operative feature, study size and follow-up

Twelve studies were analysed in this systematic review, for a total 1017 patients (612 males and 405 females). Metallic interference screws were used in 493 patients (48.5%), whereas the number of patients undergoing ACL reconstruction with bioabsorbable interference screw fixation was 499 (49.1%): the remaining 25 (2.4%) patients were the ones we excluded from the cohort investigated by Jarvela *et al.*, because they were undergoing a double-bundle reconstruction with only a class of screws being involved. This made them not comparable to the rest of the sample patients analysed

**Table 1** Coleman methodology scoring system

| Studies | Size of the study | Mean follow-up | Numbers of different surgical procedures included in each reported outcome | Type of study | Diagnostic certainty | Description of surgical procedure given | Description of postoperative rehabilitation | Outcome criteria | Procedure for assessing outcomes | Description of subject selection process | Coleman Score |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Drogset *et al.*[27] | 7 | 5 | 0 | 15 | 5 | 0 | 5 | 8 | 10 | 10 | 65 |
| Myers *et al.*[28] | 10 | 2 | 10 | 15 | 5 | 4 | 5 | 10 | 8 | 8 | 77 |
| Moisala *et al.*[29] | 10 | 2 | 0 | 15 | 5 | 0 | 10 | 10 | 10 | 10 | 72 |
| Laxdal *et al.*[30] | 10 | 2 | 10 | 15 | 5 | 5 | 8 | 6 | 9 | 10 | 80 |
| Kaeding *et al.*[31] | 10 | 2 | 10 | 15 | 5 | 3 | 5 | 7 | 9 | 10 | 76 |
| McGuire *et al.*[32] | 10 | 5 | 0 | 15 | 5 | 3 | 5 | 10 | 7 | 10 | 70 |
| Marti *et al.*[33] | 10 | 2 | 10 | 0 | 5 | 2 | 3 | 6 | 6 | 8 | 52 |
| Drogset *et al.*[34] | 7 | 2 | 10 | 15 | 5 | 5 | 10 | 10 | 7 | 10 | 81 |
| Jarvela *et al.*[25] | 7 | 2 | 0 | 15 | 5 | 5 | 10 | 10 | 11 | 10 | 75 |
| Benedetto *et al.*[35] | 10 | 2 | 10 | 15 | 5 | 3 | 5 | 10 | 8 | 11 | 79 |
| Fink *et al.*[36] | 4 | 2 | 10 | 15 | 5 | 5 | 5 | 10 | 9 | 10 | 75 |
| Barber *et al.*[21] | 10 | 2 | 10 | 15 | 5 | 5 | 10 | 8 | 10 | 9 | 84 |

in all the included studies. Therefore, the mean number of patients in each study after this distinction was 82.

The median duration of follow-up was 27.3 months. Detailed data are provided in Table 2.

## Quality assessment

The average modified Coleman methodology score was 74.7 (Fig. 1). The following four categories had, respectively, the lowest scores: mean follow-up, description of subject selection process, description of given surgical procedure and description of post-operative rehabilitation. The Coleman methodology score for each criterion are given in Table 1.

## Study outcomes

### Range of motion

The range of motion of the knee was evaluated in two studies.[31,34] Drogset *et al.*[34] reported a loss of extension from baseline between 5° and 10° after 3 months from the procedure in six patients in the bioabsorbable interference screw group, compared with only one patient in the metal interference screw group ($P < 0.05$). This difference becomes statistically non-significant between the two groups for all subsequent evaluations during their follow-up.

Kaeding *et al.*[31] showed that no statistical difference between the groups analysed in terms of range of motion at any time.

### Knee stability

Most of the included studies reported results of side-to-side anterior laxity evaluated with KT arthrometers in postoperative assessment of ACL reconstructed and fixed with the two types of interference screw. Rotational stability is often evaluated with the pivot shift test.

KT arthrometer was used in 11 studies,[25,27,29–37] and 10 of these[37,35,25,29–34,36] showed no statistically significant difference between the group fixed with metal interference screw and the group fixed with bioabsorbable screw. Only Drogset *et al.*[27] reported that, at 2-year follow-up, six patients in the bioabsorbable screw group showed an increased laxity compared with one patient in the metal screw group ($P < 0.05$).

**Table 2** Demographic data

| Studies | Year | Level of evidence | No of patients operated | W | M | Follow-up (months) | Screws implanted | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | Bio | Met |
| Drogset *et al.*[27] | 2011 | 1 | 41 | 22 | 19 | 90 (79.2–99.6) | 21 | 20 |
| Myers *et al.*[28] | 2008 | 1 | 100 | 42 | 58 | 24 | 50 | 50 |
| Moisala *et al.*[29] | 2008 | 1 | 62 | 31 | 31 | 24 | 21 | 41 |
| Laxdal *et al.*[30] | 2006 | 1 | 77 | 20 | 57 | 6 ; 24 | 38 | 39 |
| Kaeding *et al.*[31] | 2005 | 2 | 97 | 32 | 65 | 12 ; 24 | 48 | 49 |
| McGuire *et al.*[32] | 1999 | 1 | 204 | 66 | 138 | 28.8 | 103 | 101 |
| Marti *et al.*[33] | 1997 | 3 | 69 | 25 | 44 | 9.6 in BG and 20.5 in MG | 31 | 38 |
| Drogset *et al.*[34] | 2005 | 1 | 41 | 22 | 18 | 24 | 21 | 20 |
| Jarvela *et al.*[25] | 2008 | 1 | 52[a] | 26[a] | 51[a] | 24 | 27[a] | 25[a] |
| Benedetto *et al.*[35] | 2000 | 1 | 40 | 11 | 29 | 24 | 20 | 20 |
| Fink *et al.*[36] | 2000 | 1 | 124 | 89 | 35 | 13 | 67 | 57 |
| Barber *et al.*[21] | 1995 | 2 | 85 | 29 | 56 | 19 (12–33) | 42 | 43 |

[a]We included only the group of patients undergoing reconstruction with single-bundle technique since they were the only branch comparing two classes of screws.

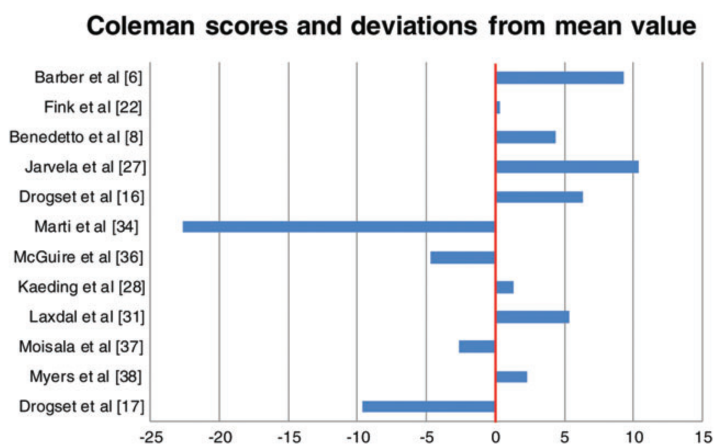


**Fig. 1** Coleman scores and deviations from the mean value.

The pivot shift test was evaluated in four studies:[25,27,28,35] Jarvela *et al.*,[25] Myers *et al.*[28] and Benedetto *et al.*[35] did not observe any statistically significant difference between the two groups, whereas Drogset *et al.*[27] reported better joint stability in the bioabsorbable group compared with the metallic group ($P = 0.04$). Specifically, two patients of the metallic group showed a pivot glide (laxity measurement between 3 and 5 mm), while none in the bioabsorbable screw group did.

### Knee functional outcome score

Most studies also reported clinical outcomes measured by International Knee Documentation Committee (IKDC) score, Lysholm score and Tegner activity level.

The IKDC score was evaluated in 7 studies[25,28–30,33,35,36] Most of the studies showed no statistically significant difference between the two groups, but Laxdal *et al.*[30] indicated that the bioabsorbable screw group had significantly higher scores compared with controls receiving metallic fixation ($P < 0.05$).

The Lysholm score was evaluated in 10 studies.[25,27–30,32–34,36,37] Nine[37,27,25,28–30,32,33,36] showed no statistically significant difference between the two groups, but one study[34] reported that the metallic screw group had a significantly better outcome in measurements after a 2-year-follow-up.

The Tegner activity score was evaluated in 5 studies.[30,32–34,37] Three studies[30,33,37] did not find any significant difference between groups. Drogset *et al.*[34] reported that the metallic screw group had a significantly better outcome in measurements after 2-years follow-up ($P < 0.05$). McGuire *et al.*[32] reported that the bioabsorbable screw group had a significantly better outcome in measurements after 5 years of follow-up ($P < 0.05$).

Detailed data on these outcomes for each study are available in Table 3 and Figure 2.

#### Imaging evaluation

MRI assessment of tunnel widening was reported in eight studies.[27–31,35–37] Of these, five[27,31,35–37] showed no statistical differences between the two groups, while Myers *et al.*[28] Moisala *et al.*[29] and Laxdal *et al.*[30] reported that the enlargement of the tunnels was significantly greater for the bioabsorbable interference screw groups.

Moisala *et al.*[29] reported that the mean diameter of the femoral tunnel anterior–posteriorly was 10.9 ± 2.0 mm in the bioabsorbable screw group and 9.2 ± 1.9 mm in the metallic screw group at 2-year follow up. This difference between the two groups was statistically significant ($P < 0.01$). Laxdal *et al.*[30] reported that tunnels of the absorbable screw group had an overall larger mean diameter than the metallic screw group (6.2 ± 2.3 mm on the tibial side and 6.3 ± 3.0 mm on the femoral side vs. 3.0 ± 2.2 mm on the tibial side and 1.9 ± 2.2 on the femoral side) with a $P$ value of <0.0001. Finally, Myers *et al.*[28] found a wider middle part of the femoral tunnel in the bioabsorbable screw group when both anterior–posterior ($P < 0.05$) and medial–lateral ($P < 0.003$) dimensions of the tunnels were measured, but the tibial tunnel sizes were not different between the groups.

### Intraoperative complications

A total of 29 intraoperative complications were reported in 6[28,32,33,35–37] of the 12 studies (rate of occurrence = 4.6%). These include 22 screws breakage (75.8% of these occurred intraoperatively), all in the bioabsorbable screw group; 6 graft damage (20.7%), 5 in the bioabsorbable screw group and 1 in the metallic screw group. Also, one patellar fracture (3.5%) was reported[36] during graft harvest, but obviously this cannot be related to the class of device used.

### Post-operative complications

The most frequently reported postoperative complications included infection, knee effusion and graft failure.

Eleven[25,27–32,34–37] of the 12 studies analysed 62 complications (rate of occurrence = 6.7%); of these, 43 (69.3%) occurred intraoperatively in the bioabsorbable screw group and 19 in the metal screw group (30.6%).

There were 21 graft failures, 12 infections and knee effusion was reported in 29 patients (Fig. 3).

## Discussion

Metal interference screws were first described in ACL reconstruction surgery[16] and bioabsorbable interference screws were developed to overcome some weak points related to their ferromagnetic quality and the difficulty in removal during revision surgery.[17,18] However, the use of this type of screws does carry some disadvantages, such as greater chance to break during surgery and a possible inflammatory response leading to knee effusion.

This systematic review tries to give clinically relevant evidence comparing the clinical outcomes while analysing complications and imaging assessment of bioabsorbable and metallic screws for ACL single bundle reconstruction to assess whether this more recent and expensive bioabsorbable fixation can be as effective as the standard metallic screws.

As for the specific measures taken into account to assess clinical results obtained by the procedure using the two different materials, all the studies[31,34] presenting range of motion of the knee did not show

**Table 3** Outcome scores

| Studies | Functional outcome scores | Knee joint stability measures |
|---|---|---|
| Drogset *et al.*[27] | Lysholm: 90 (±9) in MG and 89 (±10) in BG (*P* = n.s.). | Pivot-shift test showed less laxity in the BG than in MG (*P* = 0.04)<br>KT-1000 arthrometer was 1.8 mm in MG and 1.7 mm in BG (*P* = n.s.) |
| Myers *et al.*[28] | Lysholm: 91.7 in MG and 90.5 in BG (*P* = n.s.)<br>IKDC: 85.2 in MG and 87.5 in BG (*P* = n.s.) | Pivot-shift test:<br>In BG 22% of pt '+glide' and 4% '++clunk'<br>In MG 22% '−glide' and none '++clunk' (*P* = n.s.) |
| Moisala *et al.*[29] | Lysholm: 94 (±7) in BG and 88 (±6) in MG (*P* = 0.3)<br>IKDC: BG: 18/20 pt as N or NN and MG: 21/22 pt as N or NN (*P* = 0.2) | KT-1000: was 1.7 (±2.9) mm in BG and 1.9 (±2.0) mm in MG (*P* = 0.5) |
| Laxdal *et al.*[30] | Lysholm: 90 in BG and 94 in MG (*P* = n.s.)<br>IKDC: BG: 77% of pt as N or NN and MG: 60% of pt as N or NN (*P* = 0.03)<br>Tegner activity score: 7 in BG and 6 in MG (*P* = n.s.) | KT-1000: 1 mm in BG and 2.1 mm in MG (*P* = n.s.) |
| Kaeding *et al.*[31] | NR | KT-1000: 1.3 (±2.7) in BG and 0.6 (±1.8) in MG (*P* = n.s.)<br>ROM flexion limit: 127.9° (±38.8°) in BG and 121.2° (±47.8°) in MG (*P* = n.s.)<br>ROM hyperextension limit: 2.3° (±3.3°) in BG and 3.4° (±4.1°) in MG (*P* = n.s.) |
| McGuire *et al.*[32] | Lysholm: 95.0 in BG and 97.2 in MG<br>Tegner activity: 6. 1 in BG and 5.8 in MG | KT-1000: 1.8 mm in BG and 1.6 mm in MG |
| Marti *et al.*[33] | Tegner activity: 4 in BG and 5.5 in MG (*P* = n.s.)<br>Lysholm: 97% of pt in BG and 92% of pt in MG had 81–100 points (*P* = n.s.)<br>IKDC: BG: 31/31 (100%) pt as N or NN and MG: 36/38 (95%) pt as N or NN (*P* = n.s.) | KT-2000: 2.0 mm (±2.2) in BG and 2.2 mm (±2.4) in MG. (*P* = n.s.) |
| Drogset *et al.*[34] | Tegner activity: *P* = n.s. between the two groups at any time except for the 2-year follow-up (*P* < 0.005)<br>Lysholm: 97 in MG and 94 in BG (*P* < 0.05) | ROM: six patients in the BG had an extension deficit between 5° and 10° after 3 months, compared with only one patient MG (*P* < 0.05)<br>KT-1000: 0.3 mm in BG and 0.9 mm in MG (*P* < 0.01) |
| Jarvela *et al.*[25] | IKDC:<br>BG: 18/21(86%) pt as N or NN and<br>MG: 19 /20(95%) pt as N or NN (*P* = n.s.)<br>Lysholm: 94(±7) in BG and 90(±16) in MG (*P* = n.s.) | KT-1000: 2.2(±2.9) in BG and 2.1(±2.0) in MG (*P* = n.s.)<br>Pivot-Shift Test: BG and MG: 23/23(100%) pt as N or NN (*P* = n.s.) |
| Benedetto *et al.*[35] | Lysholm: 98.1 (±2.3) in BG and 97.7 (±3.0) in MG Tegner activity 7.4 (±1.1) in BG and 7.5 (±0.8) in MG<br>IKDC: BG: 94.5% pt as N or NN and MG: 88.9 pt as N or NN | KT-1000: 1.5(±0.8) in BG and 1.6(±0.8) in MG (*P* = n.s.) |

continued

**Table 3** Continued

| Studies | Functional outcome scores | Knee joint stability measures |
|---|---|---|
| Fink *et al.*[36] | IKDC: BG: 92% pt as N or NN and MG: 90% pt as N or NN ($P$ = n.s.) | KT-1000: there was no difference between the two group ($P$ = n.s.)<br>Pivot-shift: BG: 98% pt as N or NN and MG: 92% pt as N or NN ($P$ = n.s.) |
| Barber *et al.*[21] | Tegner activity: 6.6 (±2.1) in BG and 6.2 (±1.4) in MG ($P$ = n.s.)<br>Lysholm: 94 (±9.6) in BG and 96 (±6.9) in MG ($P$ = n.s.) | KT-2000: 1.3 (±2) in BG and 0.4 (±2) in MG ($P$ = n.s.) |

BG, bioabsorbable group; MG, metallic group; N or NN, normal or near normal value; n.s., non-significant; pt, patient.

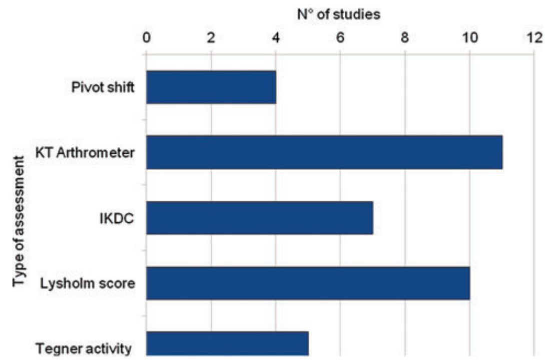


**Fig. 2** Outcome assessments used.

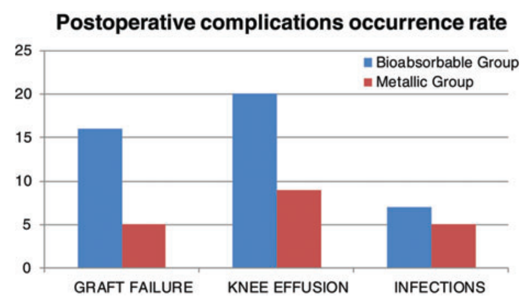


**Fig. 3** Occurrence rate of postoperative complications.

significant differences between two groups at long-term follow-up. Knee stability as evaluated with the pivot shift and KT arthrometry showed significant differences only in one study[27] in favour of metallic interference screw. However, the authors were not able to provide an explanation for this finding.

Regarding the outcome, using validated scores such as the IKDC score, only Laxdal *et al.*[30] found difference in outcomes between the devices, classifying 77% of the patients in their bioabsorbable screw group as normal or nearly normal (IKDC grade A or B) compared with 60% of the patients in their metal screw group ($P = 0.03$). They described these results as ‘interesting’, and recommended longer follow-up to draw definitive conclusions about the clinical superiority of the bioabsorbable material. All but the study by Drogset *et al.*[34] presented no difference in Lysholm scores between the two groups. Nevertheless, they reported that this score at 6 weeks and 2 years were significantly lower in the bioabsorbable group instead. They also reported that this last group had a significantly lower Tegner score at last follow-up. These authors interpreted this result as caused by activation of the complement by integration into bone tissue of the screws leading to persistent pain in the site due to the inflammatory response.

On the other hand, McGuire *et al.*[32] reported that the bioabsorbable screw group scored significantly better in clinical outcome measurements of the Tegner activity level 5 years postoperatively, but they attributed this outcome to the small sample examined ($n = 3$).

Tunnel widening, considered as an inflammatory reaction to the implanted screw mediated by inflammatory cytokines,[38–44] has been investigated in many of the reviewed studies. Three investigations[28–30] concluded that this phenomenon, detectable on either the tibial or femoral side, was much more evident and significant at imaging in patients who underwent ACL reconstruction fixed with bioabsorbable screws rather than those who received metallic screw implantation. However, they did not show any association between this phenomenon and the clinical results, which appeared to be equivalent in both groups of patients. Therefore, the final outcome achieved by the patients did not seem to be ultimately affected by a wider diameter of the tunnel measured at MRI assessment.

We divided complications encountered into intraoperative (screw breakage, graft damage and others) and postoperative (knee effusion, infection and graft failure). Difference in rates between the two screw classes did not reach statistical significance in any of the studies analysed; however, overall intraoperative and postoperative complications are slightly more common when using bioabsorbable screws (Fig. 3). In particular, we considered remarkable how screw breakages were associated only with procedures using bioabsorbable screws, which may suggest a lower intrinsic mechanical resistance of this class of device. However, screw breakages occurred more frequently in the early studies, and only when screws >7 mm in diameter were used.[28,32,33,35–37] In this regard, Mcguire *et al.*[32] suggest that an additional 0.125 mm to the core diameter of the 7 mm screw would markedly increase the overall strength of the device, thus reducing the risk of screw ruptures. Graft damage was also reported in six cases, again caused by technical difficulties in applying torque in both classes of device.

Likewise, no overall significant differences in incidence could be found regarding infections and graft failure, but there was a slight increase in the risk of effusion in the bioabsorbable screw groups.

Moisala *et al.*[29] reported that graft failures were more common after procedures using bioabsorbable screws compared with metallic screws. They discussed these result claiming that the cause may be related to the different mechanical properties of the two classes of materials, affecting graft healing in a negative way by the bioabsorbable screw.

Finally, we evaluated the methodological quality of the studies using Coleman Methodological Score,[26] a validated score already adopted by authors reviewing the literature published about many orthopaedic techniques and disorders.[45–48] The average score of 74/100 shows an overall good methodological quality. Indeed, most of the studies included in this systematic review were prospective randomized controlled trials, providing conclusions supported by a solid level of evidence because of protocol and study design.

## Conclusion

The data reviewed comparing the outcomes achieved by two different materials for fixation screws, bioabsorbable and metallic, used for graft fixation in single-bundle ACL reconstruction, showed no significant difference in the final patient outcomes achieved, in terms of clinical scores, clinical evaluation and imaging assessment. Bioabsorbable materials may be preferable because of their final osteo-integration, but, given their higher costs and the equivalent results achieved when compared with metallic screws, bioabsorbable screws still cannot be fully supported as more effective fixation devices.

## References

1. Gottlob CA, Baker CL Jr. Anterior cruciate ligament reconstruction: socioeconomic issues and cost effectiveness. *Am J Orthop (Belle Mead NJ)* 2000;29:472–6.

2. Aglietti P, Buzzi R, Zaccherotti G, et al. Patellar tendon versus doubled semitendinosus and gracilis tendons for anterior cruciate ligament reconstruction. *Am J Sports Med* 1994;22:211–7; discussion 217–218.
3. Buss DD, Warren RF, Wickiewicz TL, et al. Arthroscopically assisted reconstruction of the anterior cruciate ligament with use of autogenous patellar-ligament grafts. Results after twenty-four to forty-two months. *J Bone Joint Surg Am* 1993;75:1346–55.
4. Corry IS, Webb JM, Clingeleffer AJ, et al. Arthroscopic reconstruction of the anterior cruciate ligament. A comparison of patellar tendon autograft and four-strand hamstring tendon autograft. *Am J Sports Med* 1999;27: 444–54.
5. Engebretsen L, Benum P, Fasting O, et al. A prospective, randomized study of three surgical techniques for treatment of acute ruptures of the anterior cruciate ligament. *Am J Sports Med* 1990;18:585–90.
6. Eriksson K, Anderberg P, Hamberg P, et al. A comparison of quadruple semitendinosus and patellar tendon grafts in reconstruction of the anterior cruciate ligament. *J Bone Joint Surg Br* 2001;83:348–54.
7. Feagin JA Jr, Wills RP, Lambert KL, et al. Anterior cruciate ligament reconstruction. Bone-patella tendon-bone versus semitendinosus anatomic reconstruction. *Clin Orthop Relat Res* 1997;69–72.
8. Osti L, Papalia R, Del Buono A, et al. Good results five years after surgical management of anterior cruciate ligament tears, and meniscal and cartilage injuries. *Knee Surg Sports Traumatol Arthrosc* 2010;18:1385–90.
9. Andersson D, Samuelsson K, Karlsson J. Treatment of anterior cruciate ligament injuries with special reference to surgical technique and rehabilitation: an assessment of randomized controlled trials. *Arthroscopy* 2009;25: 653–85.
10. Maffulli N, Osti L. ACL stability, function, and arthritis: what have we been missing? *Orthopedics* 2013;36:90–2.
11. Dhillon MS, Ball K, Prabhakar S. Differences among mechanoreceptors in healthy and injured anterior cruciate ligaments and their clinical importance. *Muscles Ligaments Tendon J* 2012;2:5.
12. Maffulli N, Binfield PM, King JB. Articular cartilage lesions in the symptomatic anterior cruciate ligament-deficient knee. *Arthroscopy* 2003;19:685–90.
13. van der Hart CP, van den Bekerom MPJ, Patt TW. The occurrence of osteoarthritis at a minimum of ten years after reconstruction of the anterior cruciate ligament. *J Orthop Surg Res* 2008;3:9.
14. Kurosaka M, Yoshiya S, Andrish JT. A biomechanical comparison of different surgical techniques of graft fixation in anterior cruciate ligament reconstruction. *Am J Sports Med* 1987;15:225–9.
15. Woo SLY, Wu C, Dede O, et al. Biomechanics and anterior cruciate ligament reconstruction. *J Orthop Surg Res* 2006;1:9.
16. Lambert KL. Vascularized patellar tendon graft with rigid internal fixation for anterior cruciate ligament insufficiency. *Clin Orthop Relat Res* 1983;85–9.
17. Almazan A, Miguel A, Odor A, et al. Intraoperative incidents and complications in primary arthroscopic anterior cruciate ligament reconstruction. *Arthroscopy* 2006;22: 1211–7.
18. Matthews LS, Soffer SR. Pitfalls in the use of interference screws for anterior cruciate ligament reconstruction: brief report. *Arthroscopy* 1989;5:225–6.
19. Beevers DJ. Metal vs bioabsorbable interference screws: initial fixation. *Proc Inst Mech Eng H* 2003;217:59–75.
20. Capuano L, Hardy P, Longo UG, et al. No difference in clinical results between femoral transfixation and bio-interference screw fixation in hamstring tendon ACL reconstruction. A preliminary study. *Knee* 2008;15: 174–9.
21. Barber FA, Elrod BF, McGuire DA, et al. Bioscrew fixation of patellar tendon autografts. *Biomaterials* 2000; 21:2623–9.
22. Bach FD, Carlier RY, Elis JB, et al. Anterior cruciate ligament reconstruction with bioabsorbable polyglycolic acid interference screws: MR imaging follow-up. *Radiology* 2002;225:541–50.
23. Nyland J, Kocabey Y, Caborn DN. Insertion torque pullout strength relationship of soft tissue tendon graft tibia tunnel fixation with a bioabsorbable interference screw. *Arthroscopy* 2004;20:379–84.
24. Weiler A, Helling HJ, Kirch U, et al. Foreign-body reaction and the course of osteolysis after polyglycolide implants for fracture fixation: experimental study in sheep. *J Bone Joint Surg Br* 1996;78:369–76.
25. Jarvela T, Moisala AS, Sihvonen R, et al. Double-bundle anterior cruciate ligament reconstruction using hamstring autografts and bioabsorbable interference screw fixation: prospective, randomized, clinical study with 2-year results. *Am J Sports Med* 2008;36:290–7.
26. Coleman BD, Khan KM, Maffulli N, et al. Studies of surgical outcome after patellar tendinopathy: clinical significance of methodological deficiencies and guidelines for future studies. Victorian Institute of Sport Tendon Study Group. *Scand J Med Sci Sports* 2000;10:2–11.
27. Drogset JO, Straume LG, Bjorkmo I, et al. A prospective randomized study of ACL-reconstructions using bone-patellar tendon-bone grafts fixed with bioabsorbable or

metal interference screws. *Knee Surg Sports Traumatol Arthrosc* 2011;19:753–9.
28. Myers P, Logan M, Stokes A, et al. Bioabsorbable versus titanium interference screws with hamstring autograft in anterior cruciate ligament reconstruction: a prospective randomized trial with 2-year follow-up. *Arthroscopy* 2008;24:817–23.
29. Moisala AS, Jarvela T, Paakkala A, et al. Comparison of the bioabsorbable and metal screw fixation after ACL reconstruction with a hamstring autograft in MRI and clinical outcome: a prospective randomized study. *Knee Surg Sports Traumatol Arthrosc* 2008;16:1080–6.
30. Laxdal G, Kartus J, Eriksson BI, et al. Biodegradable and metallic interference screws in anterior cruciate ligament reconstruction surgery using hamstring tendon grafts: prospective randomized study of radiographic results and clinical outcome. *Am J Sports Med* 2006;34: 1574–80.
31. Kaeding C, Farr J, Kavanaugh T, et al. A prospective randomized comparison of bioabsorbable and titanium anterior cruciate ligament interference screws. *Arthroscopy* 2005;21:147–51.
32. McGuire DA, Barber FA, Elrod BF, et al. Bioabsorbable interference screws for graft fixation in anterior cruciate ligament reconstruction. *Arthroscopy* 1999;15:463–73.
33. Marti C, Imhoff AB, Bahrs C, et al. Metallic versus bioabsorbable interference screw for fixation of bone-patellar tendon-bone autograft in arthroscopic anterior cruciate ligament reconstruction. A preliminary report. *Knee Surg Sports Traumatol Arthrosc* 1997;5:217–21.
34. Drogset JO, Grontvedt T, Tegnander A. Endoscopic reconstruction of the anterior cruciate ligament using bone-patellar tendon-bone grafts fixed with bioabsorbable or metal interference screws: a prospective randomized study of the clinical outcome. *Am J Sports Med* 2005;33:1160–5.
35. Benedetto KP, Fellinger M, Lim TE, et al. A new bioabsorbable interference screw: preliminary results of a prospective, multicenter, randomized clinical trial. *Arthroscopy* 2000;16:41–8.
36. Fink C, Benedetto KP, Hackl W, et al. Bioabsorbable polyglyconate interference screw fixation in anterior cruciate ligament reconstruction: a prospective computed tomography-controlled study. *Arthroscopy* 2000;16: 491–8.
37. Barber FA, Elrod BF, McGuire DA, et al. Preliminary results of an absorbable interference screw. *Arthroscopy* 1995;11:537–48.
38. Clatworthy MG, Annear P, Bulow JU, et al. Tunnel widening in anterior cruciate ligament reconstruction: a prospective evaluation of hamstring and patella tendon grafts. *Knee Surg Sports Traumatol Arthrosc* 1999;7: 138–45.
39. Fahey M, Indelicato PA. Bone tunnel enlargement after anterior cruciate ligament replacement. *Am J Sports Med* 1994;22:410–4.
40. Fules PJ, Madhav RT, Goddard RK, et al. Evaluation of tibial bone tunnel enlargement using MRI scan cross-sectional area measurement after autologous hamstring tendon ACL replacement. *Knee* 2003;10:87–91.
41. Hoher J, Moller HD, Fu FH. Bone tunnel enlargement after anterior cruciate ligament reconstruction: fact or fiction? *Knee Surg Sports Traumatol Arthrosc* 1998;6: 231–40.
42. Peyrache MD, Djian P, Christel P, et al. Tibial tunnel enlargement after anterior cruciate ligament reconstruction by autogenous bone-patellar tendon-bone graft. *Knee Surg Sports Traumatol Arthrosc* 1996;4:2–8.
43. Robinson J, Huber C, Jaraj P, et al. Reduced bone tunnel enlargement post hamstring ACL reconstruction with poly-L-lactic acid/hydroxyapatite bioabsorbable screws. *Knee* 2006;13:127–31.
44. Zysk SP, Fraunberger P, Veihelmann A, et al. Tunnel enlargement and changes in synovial fluid cytokine profile following anterior cruciate ligament reconstruction with patellar tendon and hamstring tendon autografts. *Knee Surg Sports Traumatol Arthrosc* 2004;12: 98–103.
45. Denaro V, Papalia R, Di Martino A, et al. The best surgical treatment for type II fractures of the dens is still controversial. *Clin Orthop Relat Res* 2011;469:742–50.
46. Jakobsen RB, Engebretsen L, Slauterbeck JR. An analysis of the quality of cartilage repair studies. *J Bone Joint Surg Am* 2005;87:2232–9.
47. Papalia R, Del Buono A, Zampogna B, et al. Sport activity following joint arthroplasty: a systematic review. *Br Med Bull* 2012;101:81–103.
48. Papalia R, Franceschi F, Zampogna B, et al. Augmentation techniques for rotator cuff repair. *Br Med Bull* 2012.