Implant Failure After Biodegradable Screw Fixation in Osteochondritis Dissecans of the Knee in Skeletally Immature Patients

Carlo Camathias, M.D., Ulas Göğüs, M.D., Michael T. Hirschmann, M.D., Erich Rutz, M.D., Reinald Brunner, M.D., David Haeni, M.D., and Patrick Vavken, M.D.

Purpose: The primary purpose of this study was to retrospectively assess the incidence of bioabsorbable screw failure in skeletally immature patients treated for osteochondritis dissecans (OCD) of the knee. The second purpose was to assess implant degradation, focusing on differential breakdown of the intraosseous and extraosseous parts of the screw on magnetic resonance imaging (MRI).

Methods: In this retrospective study, 24 patients (30 knees) with MRI-confirmed OCD were treated with a total of 61 biodegradable screws and followed up for a minimum of 2 years or until the onset of new symptoms. MRI scans were performed every 6 months to assess differences in signal intensity between the head and body of the screw. The angle between the surface of the head and the body of the screw was measured, with an angle greater than 90° interpreted as indicating a broken screw (i.e., failed implant).

Results: Seven screws (all 2.7 mm, 11.5% of all screws) in 5 patients were considered broken screws. The implant failed completely in an additional 4 patients with breakage of 7 of 9 screws; 3 patients were considered late failures, occurring after more than 6 months. Altogether, 14 of a total of 61 screws (23%) were broken.

Conclusions: Screw breakage is a surprisingly frequent cause of failure in resorbable OCD fixation in skeletally immature patients. MRI data showed differential decomposition of the screw within and outside of bone as a possible cause.

Level of Evidence: Level IV, therapeutic case series.

Osteochondritis dissecans (OCD) is an important clinical entity in sports medicine for 2 reasons. First, it affects numerous joints, and even though the knee is the most common location, lesions in the talus or the capitellum are frequently encountered as well.1-5 Second, with increasing participation of children and adolescents in competitive sports, the incidence of OCD among skeletally immature patients has risen substantially.3 As a consequence of the increasing number of skeletally immature patients presenting with OCD, treatment options have to accommodate the characteristics of this population, that is, open physes, with remaining growth, and child-friendly postoperative rehabilitation.6,7 Treatment options span from conservative treatment to surgical treatments of different levels of invasiveness, including drilling, debridement, and microfracture, as well as the various cartilage repair techniques, and are chosen according to defect severity and patient history. An excellent overview of alternative treatments has been presented by Kocher et al.3

One treatment option that has been proved to be highly effective in adolescents and adults alike is fragment fixation with bioresorbable screws or pins. Such implants allow stable fixation and fragment compression and decompose over time, thus avoiding the need for a second operation for hardware removal. More importantly, bioabsorbable screws allow magnetic resonance imaging (MRI) monitoring of OCD healing, which is severely limited after fixation with metallic screws. The recent literature has shown excellent clinical and radiologic results after such treatment for OCD.3,6-8,12 However, prior research has also elucidated a certain risk profile for such implants, such as reduced biomechanical properties compared with metallic screws and local inflammation due to glycolic and lactic
acid, leading to effusion and synovitis, as well as the considerably higher cost.\textsuperscript{12-14}

Of particular interest, however, is mechanical implant failure. Screw breakage has 2 critically detrimental effects, depending on the time since implantation. Obviously, early breakage may lead to instability and displacement of the OCD fragment (i.e., full recurrence of the initial lesion, if not further progression). Late breakage, after successful integration of the fragment, typically does not influence fragment stability but may lead to a free-floating foreign body, causing blockage at best and frank cartilage damage in the worst-case scenario.

However, we were curious not only to find out how often screws fail but also to shed light on possible causes. We conducted an extensive literature review but were not able to find any data beyond Level V evidence on this issue. The only assessable objective variable in this context is the MRI scan. Therefore we conducted a second literature review on MRI-based follow-up of bioabsorbable screws, but again, we found no hard data. Consequently, we designed our own assessment technique as a first step in this potential new field of inquiry.

The primary purpose of this study was to prospectively assess the incidence of bioabsorbable screw failure in skeletally immature patients treated for OCD of the knee. The second purpose was to assess implant degradation, focusing on differential breakdown of the intraosseous and extraosseous parts of the screw on MRI. We hypothesized that a major factor in the occurrence of screw failure is a mismatch in implant degradation between the intraosseous part and the extraosseous part. To test this hypothesis, we assessed the level of degradation of these 2 parts on MRI.

**Methods**

This study was designed as a cohort study, approved by the responsible authorities (Ethical Committee Basel, No. 12.072). A consecutive series of 24 patients (30 knees) with OCD diagnosed on MRI was included in this retrospective study. The inclusion criteria were MRI-confirmed (Siemens Skyra, 3.0 T; Siemens Medical Solutions, Malvern, PA) OCD with clinical symptoms treated surgically with absorbable screws after failed conservative treatment for at least 6 months. The exclusion criteria included previous surgery, systemic diseases, ligamentous trauma or infection of the knee, lack of informed consent, and anatomic variants.

Of the patients, 18 had reached skeletal maturity (defined by the presence of open distal femoral physis): the mean age of all 24 patients was 12.3 years (range, 11 to 18 years). There were 15 boys and 9 girls, and they were all seen in a specialist pediatric knee clinic at the same institution by the same clinician (C.C.). The duration of preoperative symptoms ranged from 26 to 197 weeks, with a mean of 95 weeks.

Each OCD was fixed with 1 to 3 biodegradable screws (Smart screw; ConMed Linvatec Biomaterials, Tampere, Finland) under arthroscopic visualization. The OCD lesions were located in the medial condyle in 25 knees and the lateral condyle in 5 knees. There were 17 left knees and 13 right knees affected. On preoperative MRI, 6 knees were classified as Hughes grade II, 15 knees as Hughes grade III, and 9 knees as Hughes grade IVa.\textsuperscript{15}

**Surgical Procedure**

Under direct visualization, the stability of the OCD fragment was assessed. The Guhl\textsuperscript{16} classification was grade III in 10 knees (33%), grade II in 12 knees (36%), and grade I in 8 knees (31%). The OCD was fixed in situ usually with 1 to 3 biodegradable screws (diameter of 2.0 or 2.7 mm) made of poly-L-lactic acid (96L/4D copolymer). The mean length of the screws was 14 mm (range, 12 to 16 mm). All screws were countersunk to the level of the cartilage to leave a smooth articular surface with no prominent head.

**Follow-up Assessment**

All patients were managed with the same postoperative regimen. Partial weight bearing with crutches with active and passive mobilization was commenced immediately after the intervention. The patients were followed up at 6 weeks and 4 months postoperatively and then at 6-month intervals with MRI at each clinic visit. They were followed up for a minimum of 2 years or until implant failure and/or revision surgery.

**Assessment of Implant Integrity**

MRI scans were performed every 6 months postoperatively. Patients with clinical complaints suggestive of implant failure (blocking, catching, crepitus, and so on) received additional MRI after the onset of symptoms. OCD lesions were graded according to the Hughes classification.

The size of the OCD was measured initially in the coronal and sagittal planes. MRI scans were used for the assessment of the integrity of the implant. First, edema around the screw was recorded as present or not present.

Second, differences in the signal intensity between the body of the screw and the head and neck of the screw were assessed. Our assessment was based on principal image changes during degradation of biodegradable interference screws used for anterior cruciate ligament reconstruction. Initially, these screws can be well identified as hypointense structures on MRI scans.\textsuperscript{17} Further degradation fades this clear hypointense signal to a more heterogeneous signal. Finally, the intensity of the signal of the screws does not differ from bone signal anymore.\textsuperscript{18,19} Therefore varied intensity within the same screw indicates a different stage
of degradation. A binary outcome—head versus body degradation—was registered as different or not different. Differences were interpreted as a mismatch in implant degradation, indicative of a structural gradient within the screw or risk factor for implant failure. Hence screws with such differences in signal intensity were considered at risk of an impending fracture.

Finally, the angle between the surface of the head and the body of the screw was measured in at least 2 planes (angle $\alpha$) (Fig 1). During degradation, biodegradable screws lose their resistance to shear and bending forces. A few months after implantation, less than 10% of their initial strength can be detected. Therefore an angle different than 90° measured 6 months after implantation is not compatible with the brittleness of the screw and must be considered to indicate a broken screw. Moreover, loose bodies were looked for within the joint and considered to indicate implant failure.

All MRI assessments were performed independently by 2 board-certified orthopaedic surgeons with fellowship training in sports medicine (C.C., D.H.). For all MRI assessments, an inter-rater correlation was calculated.

**Results**

Of the 24 patients (30 knees), 20 patients (26 knees) presented without pain or locking sensations at the last follow-up. All lesions were in situ, and the mean size of OCDs measured initially was 256 mm$^2$ (range, 50 to 961 mm$^2$). All patients completed a minimum follow-up period of 2 years. Four patients underwent surgical revision for implant failure during the follow-up at 2 months ($n = 1$), 8 months ($n = 1$), or 12 months ($n = 2$). The OCD was completely resolved in 23 patients (29 knees) with no signs of a present OCD according to the Hughes classification.

In 8 knees the OCD was fixed with 3 screws (16 with 2.0-mm diameter and 8 with 2.7-mm diameter), in 15 knees with 2 screws (20 with 2.0-mm diameter and 10 with 2.7-mm diameter), and in 7 knees with only 1 screw (2 with 2.0-mm diameter and 5 with 2.7-mm diameter), with a total of 61 screws implanted in 24 patients (30 knees). All bioabsorbable screws (100%) were clearly discernible on all MRI scans in all patients during the entire follow-up. However, their signal intensity decreased gradually.

Edema was present around 34 screws (55.7% of the total population of 61 screws) in 17 of 30 knees (56.7%) after 6 months. Afterward, this edema did not appear anymore on follow-up.

The intensity of the body compared with the head of the screw differed clearly for 18 of 61 screws (29.5% of the total population of 61 screws), affecting 9 of 24 patients (10 knees). Hence these screws were considered at risk of impending fractures. Fourteen of these screws had a diameter of 2.7 mm; the remaining 4 had a diameter of 2.0 mm.

Of the 18 screws with impending fractures, 7 (11.5% of the total population of 61 screws) had an angle different than 90° between the body and head and were considered broken screws. Three of these broken screws showed an obvious fracture line at the center of angulation (Fig 1). However, no loose bodies were found, and none of these patients had any locking symptoms or pain. Interestingly, all of these patients still had completely healed OCD lesions.

Another 4 patients (9 screws) had implant failure, with clinical locking symptoms and pain. They all needed revision surgery. In 3 of these patients, these symptoms started later than 8 months (range, 8 to 16 months) postoperatively; in 1 patient these symptoms had already started at 6 weeks after the initial operation. Before these symptoms started, the course of these patients was uneventful. The MRI scans of the 3
patients with late-onset symptoms showed a healed OCD but an implant failure with breakage of 4 of 6 screws. In 2 patients with late-onset symptoms, the head of the screw was visible as a free body within the joint on MRI. During revision, the free-floating heads of the screws were removed. Arthroscopy showed a healed and stable OCD but relevant cartilage defects on the tibia plateau, caused by the screws (Figs 2 and 3). After removal of these loose bodies, all patients went on to have a full recovery without further complications.

The fourth patient, with early-onset complaints, had a large grade IVa OCD on the medial condyle (Fig 4) treated with 3 biodegradable screws. He reported recalling a cracking sensation and locked knee 6 weeks after the intervention. The MRI scan showed a completely detached OCD. All 3 screws were broken. At revision, the visible parts of the broken screws were removed and the OCD was reattached arthroscopically with three 2.0-mm titanium screws. After half a year, the OCD was healed and the screws were removed (Fig 4).

Altogether, 14 of a total of 61 screws (23%) were broken. The inter-rater correlation coefficient was 0.87 for broken screws and 0.81 for impending fractures.

Discussion

We found 4 patients (out of 24, 17%) with implant failure in 7 screws (out of 61, 11.5%), as well as an additional 7 broken screws. All implant failures led to revision surgery for refractory mechanical symptoms.

Fig 2. Case of late failure. The patient had a grade III OCD treated with 2 biodegradable screws. (A) After 6 months, both screws were intact and the OCD had almost healed. After 13 months, the OCD had healed but the patient had pain and locking sensations. (B) The MRI scan showed a broken screw (arrow). (C, D) On revision, the head of the screw was visible as a free body within the joint (arrows). Arthroscopy showed a healed and stable OCD but relevant cartilage defects on the tibia plateau, caused by the screws. After removal of this broken screw, the patient went on to have a full recovery without further complications.

Fig 3. Case of late failure. The patient had a healed OCD after 6 months. After 14 months, the patient reported serious pain, swelling, and locking sensations. Arthroscopy showed a broken screw with severe damage to the tibial cartilage.
Three cases were late failures, which we attribute to differential screw decomposition intraosseously and extraosseously, as supported by MRI findings.

Even in the presence of prior, corroborating literature on the topic, the incidence of screw breakage after OCD fixation was still surprisingly high. We chose to stop follow-up for this particular endpoint at 2 years because most screws had completely dissolved by then, making later screw breakage unlikely. In this same cohort, we found no other major complications, making screw breakage the leading cause for repeat visits to our clinic and repeat surgery. Compiled with other published data, a complication rate of 23% makes screw breakage the leading complication.8,14

We hypothesized that differential decomposition is a major factor in screw breakage. It is biologically plausible that the intraosseous part of a bioabsorbable screw decomposes much more quickly because of better circulation and higher exposure to resorptive cells and chemicals when compared with the head of the screw located within the cartilage or the joint cavity itself.22 Our MRI findings strongly support this notion by showing faster screw material absorption within bone but often largely unchanged screw heads. A clinically very important corollary of this finding is that this mechanism is independent from defect size, that is, late screw fracture due to chemical degradation can and will occur in defects of all sizes and classifications.

Surprisingly, not more than 4 cases with broken implants were noted, although an additional 7 cases showed signs of implant failure but had no pain or locking symptoms. However, considering that most screw breakage occurred late (i.e., at a ratio of 3:1), there is a good chance that the broken screw head had softened to a point where it was not sufficiently rigid to cause clinically appraisable symptoms or complaints. Thus there might be a high number of undiagnosed, yet luckily clinically irrelevant screw failures.

Another logical reason for screw breakage is shear and torsional stress in large defects, which will lead to early screw failure. If one looks at the long history of and substantial knowledge on the mechanics of internal fixation that we have gathered in trauma surgery, these failure mechanisms do not need much scientific testing.23 However, we were impressed that late breakage due to differential screw decomposition occurred 3 times more often than frank mechanical (early) failure.

In those patients who underwent revision for screw head removal, we found defects in the cartilage. Although the course of these defects in unclear, some damage will remain and increase the risk of future knee problems, such as pain or maybe even arthritis. This might be of less concern in an adult, but in a highly active child or adolescent, this might turn out to be a clinically relevant problem. On the other hand, screw

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**Fig 4.** Case of early failure. (A, B) The patient had a large grade IVa OCD on the medial condyle treated with 3 biodegradable screws. Only 6 weeks after the intervention, the patient reported a serious cracking sensation and a locked knee. (C, D, E) The MRI scans showed a completely detached OCD, and all 3 screws were broken (arrows). At revision, the visible parts of the broken screws were removed and the OCD was reattached arthroscopically with three 2.0-mm titanium screws. After half a year, the OCD was healed and the screws were removed.
failure does not necessarily equate to clinical failure. On the basis of these considerations, alternative treatments to direct fixation should be considered, such as consequent conservative treatment attempts before surgical repair or drilling alone without fixation. The current literature has shown excellent results with such approaches.3

Limitations
Our study has certain limitations. First, it is a retrospective analysis, but the cohort was collected prospectively for a different study. Because our intention was to follow the implant performance longitudinally, a control group would not add extra information. However, the lack of a control group can be considered a limitation. Second, we did not perform a formal, a priori sample size calculation, and with 30 knees, the sample size of our study is comparatively low. Nevertheless, we did find 4 cases of screw breakage, showing that our study was sufficiently large to detect this clinically important complication. Therefore only a descriptive statistical analysis with limited value was performed. Furthermore, MRI is not a validated tool to assess screw degradation. Lastly, we only tested 1 specific implant that we use at our institution. Different implants might have different rates of failure, but it is unlikely that they differ substantially and the variety of approved implants is very limited.

Conclusions
Screw breakage is a surprisingly frequent cause of failure in resorbable OCD fixation in skeletally immature patients. MRI data showed differential decomposition of the screw within and outside of bone as a possible cause.

References