Chapter 13
The Sacroiliac Joint: A Minimally Invasive Approach

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Introduction

In antiquity, the Greek physician Hippocrates discussed the function of the sacroiliac joint (SIJ). On the basis of his study of animals, he concluded that the SIJ was normally immobile but that some mobility was possible during pregnancy [1]. In the early twentieth century, the SIJs were believed to be the main source of low-back pain [2–9]. However, this belief went out of fashion during the 1930s when interest became focused on the intervertebral disc, after the herniated disc was demonstrated to be a source of sciatic pain [10]. In the 1950s, Weisl [11, 12] and Solonen [13], using different approaches, shed new light on the knowledge concerning the SIJs. Weisl demonstrated movement of the SIJ; Solonen [13] made an anatomical and biomechanical analysis of the SIJ and also described its innervation.

Currently, in the fields of manual medicine, physiotherapy, and chiropractic, the consideration of SIJ dysfunction plays a fundamental role in diagnostics and treatment. Various clinical tests that evaluate position, movement, tenderness, and pain provocation are regarded as essential for diagnosis. The terminology used to discuss the SIJ includes such terms as *locking* and *hypo*- and *hypermobility*.

In the debate on the role of the SIJs as a source of back pain, the crucial questions to be answered are: Do the SIJs move? How can a sacroiliac disorder be diagnosed? If SIJ dysfunction is diagnosed, what treatment can be recommended?

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Background and Etiology

Development of the Sacroiliac Joint

The cartilage that lines the sacral and iliac joint surfaces develops from the pelvic mesenchyme around the eighth intrauterine week. At that time, a layer of mesenchymal cells forms cavities from which the SIJs develop [14]. In the eighth month, the SIJs are fully developed and differences can be seen between the smooth, white, and shining cartilage of the sacrum and the dull, gray, and irregular cartilage of the iliac side [15].

During the first decade of life, the articular surfaces of the SIJ are flat and even. In the second decade, congruent irregularities develop on both the iliac and sacral articular surfaces [15, 16]. In the third decade, running centrally along the entire length of the iliac surface is a convex ridge, which fits into a corresponding sacral groove [15]. The elevations on the iliac side become about 10 mm high in the fourth decade of life. Contemporaneously, sacral margin osteophytes appear and the joint surface becomes more "yellowish and roughened" [15]. Symmetry between the right and left SIJ is now an exception rather than a rule [13–15].

Over the age of 50, osteophytes are more frequent and ankylosis occurs. Brooke [5] found that 77 % of all men over the age of 53 had an ankylosis. However, Stewart [17] found that only 3 of 308 cases had ankylosis, Vleeming [18] found ankylosis in 2 of 13 men, and Resnick [19] in 4 of 46 specimens.

Biomechanics

The function of the SIJ is to transfer the force of the upper part of the body through the pelvis to the legs [20]. It has also a shock-absorptive function in walking, running, and jumping with a reciprocal movement in the SIJ [21]. The location and the vertical position of the SIJ make it vulnerable to extensive loading by daily activities [22]. Solonen [13] used a purely mathematical model where the SIJ angle in the frontal plane was the essential factor determining the load over the SIJ. He estimated that with an angle of 10° in the frontal plane, the load over each SIJ in standing and slow walking was three times the weight of the upper body. This load increases to four times the weight of the upper body in rapid walking.

The movement of the SIJs is small and varies between individuals and according to the load applied [12, 21, 23–25]. Different techniques for analyzing sacroiliac movement in living persons have been used. Radiostereometric analysis (RSA) is currently the most exact procedure. This technique is widely used to measure small movement in orthopedic research [26, 27] and is used independently by different groups measuring SIJ movements [21, 23, 24, 27–29]. Tantalum markers with a diameter of 0.8 mm are implanted into the pelvic bones. At least three, but usually four to six markers are placed geometrically well spread into each ilium and into the sacrum. In various studies, Sturesson et al. [21, 23, 24] demonstrated that the sacrum is rotated forwards (nutation) when patients change from a supine position to a sitting or standing position. Between the supine and standing positions the average nutation is 1.2°, and 90 % of the movement is located around the *x*-axis [23]. Sturesson also demonstrated that movements do not differ between symptomatic and asymptomatic joints. Also, SIJ movements were reduced when standing on one leg with the other leg flexed, as additional muscle force was applied to the joint. The largest movement, averaging 2°, occurred when changing from standing to lying prone with forced hyperextension of a leg. SIJ mobility in men is on average 30–40 % less than in women [23].

In another study, an external Hoffman Slätis frame was used and a slight compression applied. The movement in the SIJ that occurred from lying supine to standing was reduced by half, on average 0.6°; there was also a reduction in pain [30]. This finding is in agreement with studies that use pelvic belts to normalize SIJ movement [31–33]. In a mathematical model, Snijders et al. [34] showed that the muscle force needed at the anterior iliac spine to stabilize the SIJ is relatively low. The SIJ can effectively be stabilized with the low force exerted by the oblique and transverse muscles at the anterior pelvis, combined with a long lever from the SIJ to the anterior iliac spine. Tullberg et al. [29] studied the effect of successful manipulation of the SIJ. The patients ($n = 10$) were examined both clinically and with RSA, before and after manipulation. Manipulation did not alter the position of the sacrum in relation to the ilium. The result seems to indicate that effective manipulation is not dependent on positional change of the joints [35].

The theory of form and force closure [16, 18, 35–37] is a biomechanical model that takes the friction in the SIJ as well as the muscle forces exerted on the SIJ into consideration [38]. The shear forces applied on the SIJ in the standing position would create creep if friction did not exist in the SIJ. The theory assumes that to stabilize the SIJ, it is necessary that the forces of the trunk, pelvis, and leg muscles be effectively coupled.

Form closure refers to a stable situation with closely fitting joint surfaces, where no extra forces are needed to maintain the state of the joints, irrespective of the load situation. If the sacrum fits perfectly between the iliac bones, no additional forces are needed to maintain the position. However, in this situation mobility is almost impossible (Fig. 13.1).

Force closure is described as the opposite situation: a bilateral force exerted on the iliac bones is needed to keep the sacrum in place (Fig. 13.1). The force needed is to increase friction between the elements so no movement occurs. Force closure can be exerted by muscle forces [34, 38–41] or by a pelvic belt [39] or an external fixator [30].

In reality, a combination of the irregularities in the SIJs, the wedge shape of the SIJ (form), and the compression forces generated by muscles and ligaments (force) stabilize the joint in the loaded situation. This combination of form and force closure, preventing shear forces, is also called the self-locking mechanism (Fig. 13.1).

The strong ligaments around the SIJ cannot alone effect the stability of the SIJ. However, according to the theory of form and force closure, a dynamic stabilization of the pelvis is necessary. It is proposed that the posterior muscles, such as the

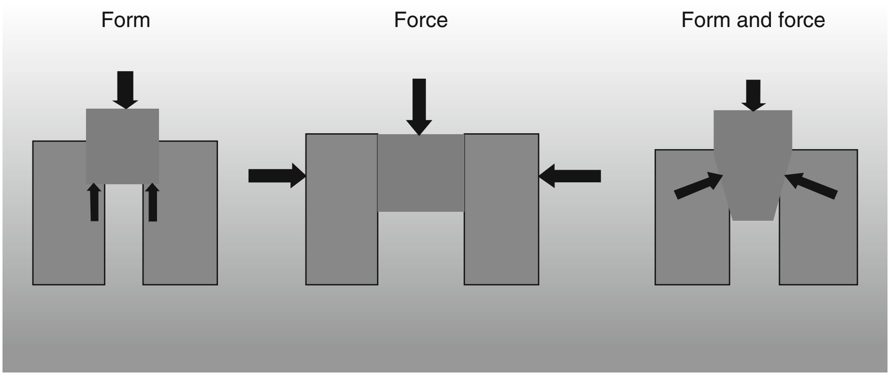


Fig. 13.1 Model of form and force closure (Adapted after Vleeming et al. [16])

latissimus dorsi, erector spinae, gluteus maximus, and biceps femoris muscles, together with the anterior transverse and oblique muscles generate forces that are effective in compressing the SIJ and inducing friction [42].

Various electromyography (EMG) studies [34, 38–41] indicate that the transverse and oblique abdominal muscles take part in the stabilization of the pelvis and the SIJ. In the biomechanical model, Snijders et al. [38] proposed that the transverse and oblique muscles, together with stiff dorsal sacroiliac ligaments, exert a stabilizing effect with gentle contraction on the iliac wing. A comparison of EMG activity in the transverse and oblique muscles with and without a pelvic belt in ten healthy volunteers showed that the muscle activity was significantly lower with a belt. In another study, the same research group examined the differences in EMG recordings of the same muscle groups between sitting on an office chair with and without crossed legs [34]. The results show that sitting with crossed legs leads to a significant decrease in the EMG activity in the muscles studied, indicating that sitting with crossed legs provides a stabilized situation in the SIJ. Hodges and Richardson [40] showed that the transverse abdominal muscles are activated in advance by reflexes in the central nervous system prior to limb movement in either the upper or of lower extremities. Moreover, they showed that this function is disturbed in patients with chronic low-back pain [39, 41]. This supports the position that these individuals are unable to stabilize the pelvis and thus need treatment.

Etiology

The SIJ undergoes degenerative changes from the third decade [15]. Why some individuals experience pain from degeneration is poorly understood. The same situation exists with all joints and is well studied in knee arthritis [43, 44]. Sacroiliac pain during pregnancy is well described [45–48], and some women develop chronic sacroiliac pain [49]. The incidence of different etiologies is not fully described. The combination of cartilage degeneration, lack of stability, and pain sensitization exists with all different causes of sacroiliac pain.

- Degeneration of the SIJ, *degenerative sacroiliitis,* occurs as earlier described. It is possible that movement increases with age [23] and together with reduced ability of stabilization, pain occurs.
- Posttraumatic degenerative sacroiliitis can occur after a disruption to the SIJ after a low-energy fall, a direct high-energy hit, a compression of the pelvis from side to side, or an extreme rotation of the joint without visible fracture. The mechanism behind this is probably that either the cartilage or the strong sacroiliac ligaments are injured. The pain can start immediately or slowly increase after the trauma.
- Posttraumatic sacroiliitis also occurs after pelvic fractures where the SIJ is clearly torn but no posttraumatic fusion in the SIJ occurs. The most usual case is the open book fracture, but posttraumatic pseudarthrosis can also occur after more severe pelvic fractures.
- Persistent sacroiliac pain after pregnancy – pelvic girdle pain (PGP) – occurs after about 0.1 % of all pregnancies. During pregnancy, around 25 % of women experience PGP with different severity. Most women recover during the first week after delivery, but in some cases the recovery can take up to 18 months. After that, about 0.1 % continue to experience severe pain and disability.
- Inflammation of the SIJ: Ankylosing spondylitis can be seen with sacroiliitis many years before factors are visible in blood tests. Sacroiliitis can occur together with psoriasis and inflammatory bowel disease and can also be seen in reactive arthritis after infection (Reiter's syndrome).
- Acute bacterial infection can occur in the SIJ.
- Congenital abnormalities with variations in the lumbosacral transition are not unusual. For example, an enlarged transverse process from L5 can articulate in the SIJ. The differences in the movement pattern in the SIJ and in the lumbosacral disk increase the chances of local degeneration

Presentation, Diagnosis, and Treatment Options

Diagnosis

Several clinical diagnostic SIJ tests were reviewed in the European Guidelines for Pelvic Girdle Pain [50]. The authors reviewed a wide variety of examinations, procedures, and tests that have been used to investigate pregnant and nonpregnant patients. It has been stated that position or movement tests have no diagnostic value, and that the widely used standing hip flexion test (Gillet test or "rücklauf") [51] is an illusion [24].

> In the studies where the examination procedures of pregnant women are described, a combination of methods for diagnosis has been used: inspection of walking, posture and pelvic tilt, palpation of ligaments and muscles, tests for a locked SIJ, and pain provocation tests for the SIJ and the symphysis. The early studies focused more on the inspection and palpatoric findings, whereas the later studies have focused more on pain provocation tests, probably due to the higher reliability and specificity of these latter tests. The pain provocation tests with the highest reliability and most frequently used for SIJ pain are the P4/thigh thrust test and Patrick's FABER (*f*lexion, *ab*duction, and *e*xternal *r*otation) test. For pain in the symphysis, these tests include palpation of the symphysis, and the modified Trendelenburg test is used as a pain provocation test [50].

Fig. 13.2 Posterior pelvic pain provocation test (P4/thigh thrust test)

The recommendations from the European guidelines for clinical examination tests of PGP are as follows.

For SIJ pain:

- Posterior pelvic pain provocation test (P4/thigh thrust test) [52] (Fig. 13.2)
- Patrick's FABER test (Fig. 13.3)
- Palpation of the long dorsal SIJ ligament [53]
- Gaenslen's test [54] (Fig. 13.4)

For symphysis pain:

- Palpation of the symphysis
- Modified Trendelenburg function test of the pelvic girdle

Functional pelvic test

- Active straight leg raise test (ASLR) [40] (Fig. 13.5).

Functional pain history

- It is strongly recommended that a pain history be taken with special attention paid to pain arising during prolonged standing, walking, and/or sitting. To ensure that the pain is in the pelvic girdle area, it is important that the precise area of pain be indicated: the patient should either point out the exact location on his/her body, or preferably shade-in the painful area on a pain location diagram [50].

Fig. 13.3 Patrick's FABER test

Fig. 13.4 Gaenslen's test

Fig. 13.5 Active straight leg raise test (ASLR)

Diagnostic Blocks

A sacroiliac intraarticular block has been proposed as the gold standard in diagnosing SIJ pain [55, 56]. This has also been proven in a double-blind trial where three diagnostic tests assessing the SIJ have been used to determine sacroiliac pathology [57]. A recent clinical review of SIJ interventions concluded that the evidence for the diagnostic accuracy of SIJ injections is good [58].

Physical Treatment

Different physical exercise programs have been proposed for sacroiliac pain, but the level of evidence is low. In the European guidelines [50] the recommendation is to use an individualized training program with specific stabilizing exercises as a part of a multimodal treatment program [59, 60]. The exercise program is recommended to start with activation and control of local deep lumbopelvic muscles. Gradually, the program can be enlarged to include the training of more superficial muscles in dynamic exercises to improve control mobility, strength, and endurance capacity. A pelvic belt can be fitted to test for symptomatic relief. The risk of using a pelvic belt for a longer period is subcutaneous fat hypotrophy. There is no evidence for the effect of manipulation or mobilization. Water gymnastics, acupuncture, and massage might be helpful as part of a multidisciplinary individualized treatment.

Surgical Techniques

Surgical Treatment

Surgical treatment for the SIJ was described early in the last century [54, 61]. In all reports of sacroiliac fusion, the preoperative evaluation was thorough and surgery was performed only on patients for whom nonoperative treatment had been unsuccessful [54, 61–74]. The studies include from 2 to 78 patients and the results were assessed by the authors as fair to excellent in 48–89 % of the patients. In a case report by Berthelot et al. [67], two patients who underwent surgery experienced total pain relief. Different techniques are described, but the transiliac technique described by Smith-Petersen and Rogers [61] with some modifications was the most widely used. The different surgical techniques are demanding for both surgeon and patient and the pseudarthrosis rate is around 10 %. The perioperative bleeding can be quite considerable, as the surgical access is through the cancellous bone in the posterior iliac wing. The hospital stay is long (5–7 days) and the rehabilitation is demanding for the patient.

Minimally Invasive Techniques

Following the development of minimally invasive surgery in the lumbar spine, several new techniques for sacroiliac fusion have been proposed. Transiliac screw fixation without fusion has been used, but no clinical studies are reported for degenerative sacroiliac disorders. Different new procedures with minimally invasive fusion techniques are proposed [75–78] but still no evidence for surgical treatment exists. A minimally invasive technique that fits well with the theory of form and force closure is the iFuse® implant system from SI-BONE [78]. However, before any surgical technique is offered, at least 6 months of physical exercise that follows an individualized and specifically tailored exercise program should be prescribed.

The iFuse® Technique

The iFuse® technique is an easy procedure, but it presupposes good knowledge of the iliosacral anatomy. Necessary imaging before surgery consists of either an MRI of a CT scan of the pelvis. If a sacral MRI does not reveal any abnormalities in the lumbosacral transition, no additional imaging is needed preoperatively. The main reason for the MRI examination is to rule out red flags prior to any surgery. However, if a sacral anomaly is shown on the MRI examination, a CT is recommended.

Fig. 13.6 C-arm that can be moved to obtain optimal images of patient on table

Patient Positioning

The patient is placed on a Jackson table or a flat table allowing a C-arm to be freely moved to obtain optimal images in lateral, inlet, and outlet views (Fig. 13.6). These positions are necessary to get an optimal result and reduce the risk of surgical complications. Three implants are recommended to achieve enough contact between bone and implants. The iFuse® implant is a titanium plasma-coated triangular rod with the similar coating used for joint implants with noncemented techniques.

The first implant is directed to the first sacral body. The technique used is similar to implanting an iliosacral screw. The main surgical risk is of injury to the L5 nerve, though care must be taken to avoid injuring all neural structures and vessels in and around sacrum. The L5 nerve is located anterior to the sacral ala. If the sacral ala is well visible with the C-arm, a skin mark for the incision can be made (Fig. 13.7). A 3-cm incision is made 1 cm caudal to the ala line along the sacral line down to the fascia.

Pin

A 3 mm Steinmann pin is introduced just anterior to the sacral line and 1 cm caudal to the ala line in the lateral view of the fluoroscopy. The Steinmann pin is advanced with care, taking the pin position in the outlet and inlet view into consideration. The tip of the pin has to be advanced to the position below the sacral ala and superior to the first foramen, and just in the middle of the sacrum in the lateral view (Fig. 13.8).

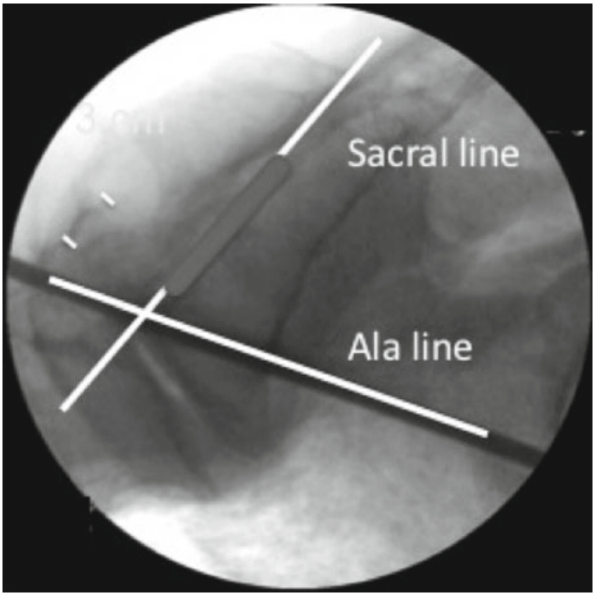


Fig. 13.7 Skin mark for incision caudal to the ala line

Fig. 13.8 Introduction of Steinmann pin

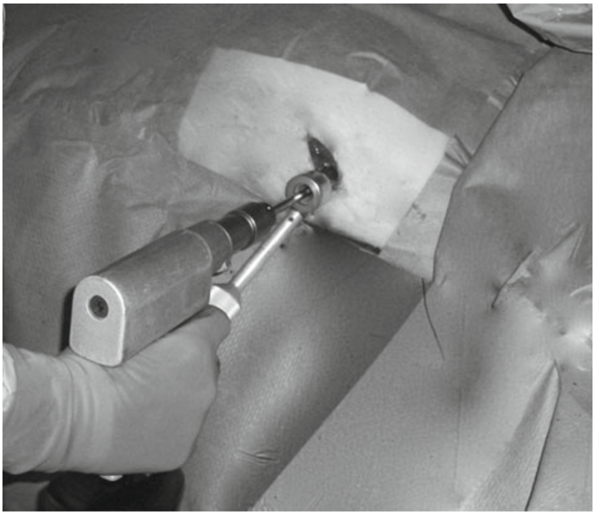


Fig. 13.9 Drill penetrating the ilium and SIJ

The first implant located in the S1 area should be as long as is practical so it will have as much contact with sacral bone as possible. This is important for bone fusion to the implant. The length of the first implant also has to be selected so it will be possible to introduce a posterior lumbosacral screw if lumbar spine surgery becomes necessary in the future.

Drill

The pin sleeve is removed and a cannulated drill is introduced over the Steinmann pin. The drill is advanced through the iliac bone and the SIJ. The sacral bone, being softer than the SIJ, does not need to be drilled (Fig. 13.9).

Broach

The drill sleeve is removed and a triangular broach is introduced, one flat side of its profile being parallel to the sacral ala line. The broach has to be tapped deep enough that the last teeth pass the SIJ (Fig. 13.10).

Implant

The broach is removed and an in appropriate length implant is introduced (Fig. 13.11). The position and depth is checked in all three views (lateral, inlet,

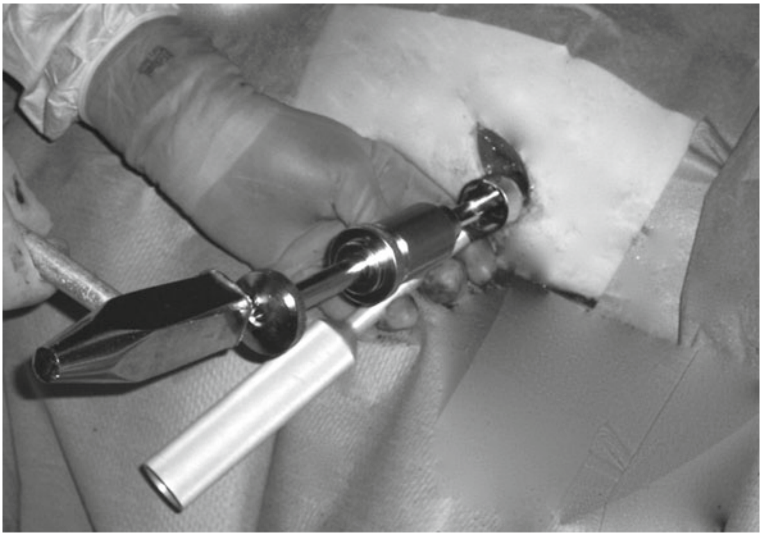
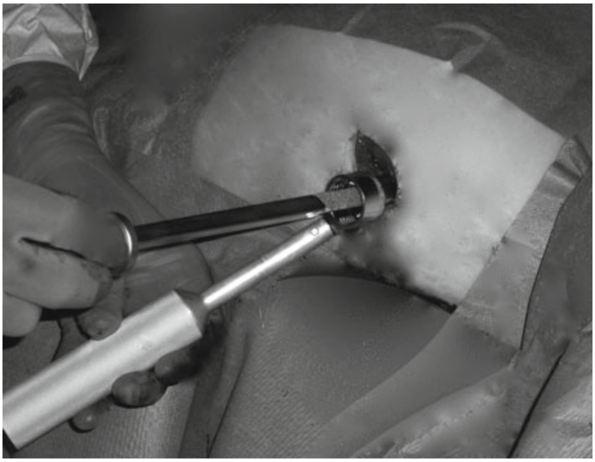


Fig. 13.10 Tapping the broach

Fig. 13.11 Introduction of implant



outlet). The tip of the implant lateral to the iliac wall has to be 2–5 mm proud. This is easiest done with a finger in the wound, feeling the lateral end of the implant. After that the second and third implants are introduced with the same procedure, taking care of the anatomy. It is recommended that the implants be more or less parallel to each other. This is easily achieved with the help of the parallel guide. It is also recommended that the second implant be placed somewhat more anterior in the lateral view than the first, and that bridge the cartilaginous joint rather than the ligamentous part of the SIJ.

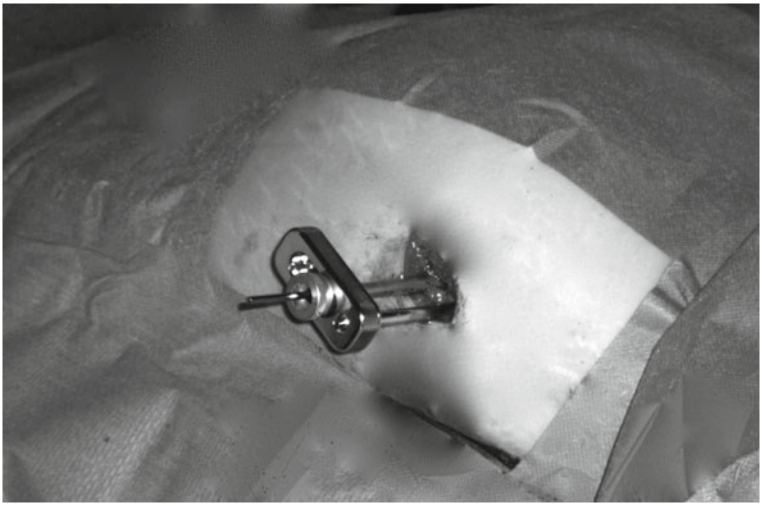


Fig. 13.12 Introduction of second implant after device positioning, in order to obtain a parallel positioning

Postoperative Care

Partial weight bearing with crutches and with the affected side bearing only half the body weight is immediately allowed and is recommended for 3–6 weeks. Postoperative low-dose computer tomography is recommended for monitoring the implant positioning. The healing period is the same as with fusion healing, which is roughly 5 months. During this period, the patient should not undertake heavy physical work. The follow-up is mainly clinical, checking pain and function. The ASLR test is recommended as a functional test during the healing period. At a 5-month follow-up, clinical diagnostic tests can be used to assess the outcome. If the patient is still in pain at the 5-month follow-up, a plain outlet view X-ray and/or a CT is recommended to look for radiolucent zones.

Complications

So far, neither infection nor implant breakage has been reported. Revisions have been performed because of malpositioning of the implant in about 1 % of cases and because of healing disturbances in about 1 %. Compared with the 10 % pseudarthrosis rate reported from the open procedures, the iFuse® complication rate is low. No serious nerve or vascular damage has been reported.

Conclusions and Personal View

The author has more than 25 years of experience with patients with pain that originates from the SIJs. Around 50 patients have undergone surgery with a modified Smith-Peterson technique, with about 80 % good or excellent results [73]. In most cases, an external fixator was used as a postoperative stabilizer. However, this technique was demanding for both patient and surgeon, and the soft tissue exploration persistently resulted in a reduced muscle condition in the greater gluteal muscle, even in patients with optimal bone healing. The minimally invasive technique with iFuse® offers the patient a procedure that results in minimal harm to the muscles and soft tissues, a short hospital stay, and a relatively fast recovery. For the surgeon, this technique is easy to learn and less demanding than any open technique. The personal impression after the performance of about 50 iFuse® procedures is that the patient outcome is more than 90 % excellent. Nonetheless, differentiating the SIJ as the pain source in patients with low or lowest lumbar pain is challenging. As with many therapeutic procedures, the technique is still not evidence based. Scientific reports of the outcomes of this method have begun to appear [78–80], and longitudinal studies as well as randomized controlled studies are in progress.

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