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Reviews

Minimally Invasive and Conservative Interventions for the Treatment of Sacroiliac Joint Pain: A Review of Recent Literature

Mayank Aranke, MD, MPH[1], Grace McCrudy, BS[2], Kelsey Rooney, BS[2], Kunaal Patel, BS[2], Christopher A. Lee, MD[3] [a], Jamal Hasoon, MD[4], Alan D. Kaye, MD, PhD[5]

[1] Department of Anesthesiology, University of Texas Health Science Center, [2] LSU Health Sciences Center Shreveport School of Medicine, [3] Department of Internal Medicine, Creighton University School of Medicine—Phoenix Regional Campus, [4] Department of Anesthesiology, Critical Care, and Pain Medicine, Beth Israel Deaconess Medical Center, [5] Department of Anesthesiology, Louisiana State University Shreveport

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Sacroiliac joint (SIJ) pain is responsible for approximately 15-25% of reported back pain. Patients with SIJ pain report some of the lowest quality of life scores of any chronic disease. Understanding of the physiology and pathology of the SI joint has changed dramatically over the years, and SI joint pain and injury can now be thought of in two broad categories: traumatic and atraumatic. Both categories of SI joint injury are thought to be caused by inflammation or injury of the joint capsule, ligaments, or subchondral bone in the SI joint. Treatment of SI joint pain usually involves a multi-pronged approach, utilizing both, multi-modal medical pain control and interventional pain/surgical techniques such as steroid injections, radiofrequency nerve ablation, and minimally invasive sacroiliac arthrodesis. Though conservative management through multi-modal pain control and physical therapy have their role as first line therapies, an increasing body of evidence supports the use of minimally invasive procedures, both as adjuvant treatments to conservative management and as second line therapies for patient's that fail first line treatment.

INTRODUCTION

15-25% of axial low back pain arises from pathologies of the sacroiliac (SI) joint, a synovial or diarthrosis-amphiarthrosis joint, whose primary function is to transfer weight to and from the lower extremities to the axial skeleton.[1,2] Understanding of the physiology and pathology of the SI joint has changed dramatically over the years, and SI joint pain and injury can now be thought of in two broad categories: traumatic and atraumatic. Common traumatic include pelvic fractures, motor vehicle collisions, and torsion injuries from heavy lifting, while common atraumatic causes include osteoarthritis, pregnancy, and structural pathologies of the axial skeleton (spondyloarthropathies and scoliosis).[1,3,4]

Both categories of SI joint injury are thought to be caused by inflammation or injury of the joint capsule, ligaments, or subchondral bone in the SI joint (all of which have been linked to nociceptors on immunohistology).[5] The most common patient presentation is that of a deep pain that follows an inciting event (an important point of differentiation from radicular pain, which is often insidious), radiating down the posterior thigh and up to the knee, reproducible upon sitting down, lying on the ipsilateral side, or when climbing stairs.[6]

Patients with certain comorbidities are at a higher risk for developing SI joint pain. These include: lower bone density, variability in auricular surface (allows forward-backward motion), autoimmune diseases, leg length discrepancy, advanced age, history of trauma, obesity.[7] The diagnostic gold standard for SI joint pain is eliciting of symptoms with clinical provocative tests that resolve following injection of local anesthetic with CT being the most efficacious imaging modality for guidance.[8]

Treatment of SI joint pain usually involves a multi-pronged approach, utilizing both, multi-modal medical

a **Corresponding author:**
Christopher Lee, MD
St. Joseph Hospital & Medical Center
Department of Internal Medicine
500 West Thomas Rd
Phoenix, AZ 85013
Chrislee0621@gmail.com

pain control and interventional pain/surgical techniques such as local anesthetic and steroid injections, radiofrequency nerve ablation, and minimally invasive sacroiliac arthrodesis.[9] In this review we will discuss the benefits and limitations of several forms of SI joint pain treatment, with a special focus on minimally invasive interventional options.

MEDICAL MANAGEMENT

Sacroiliac joint (SIJ) pain is responsible for approximately 15-25% of reported back pain. Patients with SIJ pain report some of the lowest quality of life scores of any chronic disease. There is also a large economic burden involved in treating chronic back pain. Management of SIJ pain begins with conservative managements, such as medical, physical therapy, massage, traction, and SI joint belts which wrap around the pelvis to provide external support. Intra-articular steroid injection can also be attempted for both short-term relief as well of identification of the SIJ as the pain source. Radiofrequency ablation of the sacral nerve can further be attempted if further pain relief is not achieved.[10]

PHYSICAL THERAPY

The goal of treatment in physical therapy for SIJ pain is to improve mechanics of the lumbar spine, pelvis, and hips—aiding in restoration of the patient's mechanical function. Physical therapy (PT) is often used in conjunction with pharmacologic treatment to increase positive outcomes in SIJ pain. PT can be implemented as early as the acute phase of pain, approximately within one to three days after pain onset, and is often used during the recovery phase as well, 3 days to 8 weeks after pain onset. PT is one of the first-line treatments for SIJ pain. PT is indicated for initial conservative treatment of low back pain.[11] PT techniques include direct manipulation, direct mobilization, or indirect methods.[11]

SIJ pain can be caused by pelvic asymmetry, joint hypomobility, or joint hypermobility. This can cause a spasm in the piriformis muscle, leading to radicular pain that may also increase tension in the hip and thigh muscles. Other targets of PT include the gluteus maximus as well as the pelvic core muscles due to their attachment to the SIJ musculature and fascia.[11,12] Typically, at least five sessions of lumbar and SIJ manipulation are needed to decrease SIJ pain and improve functional disability.[13,14] There is no current evidence whether exercise therapy or manipulation therapy is superior to one another.[15] Certain therapies can however be less effective for SIJ pain based on comorbidities such as osteoporosis or lumbar disc herniation.[14]

INTRA-ARTICULAR JOINT INJECTIONS

Typically intra-articular joint injections consists of simultaneous injection of local anesthetic and steroids and less often local anesthetic alone. This preference of simultaneous administration is thought to be secondary to the idea of limiting the number of injections needed to treat a single injection-offering convenience, decreasing radiation, and also decreasing risk of infection. By combining the two medications into a single injection, patients are simultaneous diagnosed and treated with a single shot if responsive to the intervention; however, in those who are unresponsive to the treatment, this line of treatment leads to unnecessary exposure to steroids.[16] Currently, however, the effectiveness of diagnostic injections of local anesthetic in determining responsive to intra-articular treatment remains unclear.[17]

The decision to consider the first intra-articular injection as a mode of treatment is based on multiple factors, primarily location of pain, diagnostic physical findings, and prior diagnostic injections. Other variables, such as imaging and history of spondyloarthritis have some, but less impact on this final decision for intra-articular injection according to guidelines set by the Spine Intervention Society. Most importantly, three or more positive diagnostic physical exams for SIJ pain makes a strong case for SIJ joint injection, while no positive diagnostic physical findings was suggestive of a poor candidate. One or two positive diagnostic physical findings was determined on a case by case scenario based on the factors discussed above, such as location of pain, history of diagnostic injections, imaging, and history.[16] In each of these cases, patients also had to meet one of the three following criteria; either they had to have symptoms that presented for longer than a month, a function limitation that had failed conservative therapy, or a functional limitation with a pain greater than four out of ten regardless of past attempts at conservative therapy.[16]

The decision guiding addition intra-articular injections after the first are determined by the amount of relief obtained from prior injection. If <50% relief is experienced, no subsequent injections are recommended. If >50% relief is experienced following the first injection, a second administration would be considered. Following a second administration, typically >75% relief is expected for further recommendation of a third.[16]

While guidelines have been developed, these guidelines are currently based on preexisting literature review of 45 articles and ratings from an expert panel consisting of members from multiple specialty societies. Further studies of these guidelines would aid in better elucidating key factors that predict responsiveness to intra-articular injections of therapeutic agents.

RADIOFREQUENCY ABLATION

Patients with sacroiliac pain that is refractory to initial treatment, often turn to opiates to help manage their chronic pain. This can lead to adverse side-effects in addition to addiction. Sacroiliac joint pain treatment with radiofrequency ablation (RFA) has been shown in a retrospective study to reduce opioid use in patients and provide pain and disability relief to patients.[18]

Radiofrequency ablation is a minimally invasive procedure aimed at providing relief from pain in patients with conditions such as sacroiliac joint pain. Radiofrequency

signals are aimed at nociceptive nerves of interest by an insulated needle. The radiofrequency signals create heat energy which ablates the nerve.[19] For the treatment of sacroiliac joint pain, radiofrequency lesions are created at the superior lateral portions of the S2 and S3 foramina, the medial branches of the higher dorsal rami in the lumbar region, at the sacral ala, and the sacroiliac junction.[20]

Three forms of RFA currently used include: pulsed, thermal, and cooled.[19]

PULSED

Pulsed RFA works by application of short pulses of radiofrequency signals from the generator into neural tissues. Heat is generated during these pulses. Due to the pulsatile nature of pulsed RFA treatment, the average tissue temperature rise is similar to traditional RFA, however, the voltage used is much less than traditional RFA. This allows higher voltages to be applied to the electrode in pulsed RFA while preventing increased temperatures from increasing to >45°C, which would denature the nerve.[21] Dutta et. al. found significant evidence of pain relief as well as functional improvement following treatment with pulsed RFA relative to that seen following treatment with intraarticular steroid injections. These benefits were seen with no accompanying complications or side effects. However, as this was a small randomized, prospective, single-blinded study, larger randomized, controlled and multi-centered study with long-term follow-up would need to be completed in order to establish the efficacy of pulsed RFA for sacroiliac joint pain.[20]

THERMAL

Thermal RFA utilizes a bipolar technique referred to as the "palisade," where two separate electrodes are placed. They are placed along the lateral branch nerve instead of the S1-S3 dorsal ganglia. The current is then driven between the two electrodes causing a continuous thermal lesion.[22] To avoid injury to ventral nerve roots, periforaminal placement of the radiofrequency probes are completed under fluoroscopic guidance. A study showed that compared to patients given intra-articular steroids, patients treated with thermal RFA achieved similar relief of symptoms at the one month follow-up. However, at the 3 and 12 month follow up, 50% in patient groups treated with thermal RFA still showed clinical improvement, whereas patients treated with intraarticular steroids did not.[22]

COOLED

Cooled RFA utilizes a probe that cools tissues abutting the electrode during the ablation. This results in larger lesions to the target nerves relative to the other forms of RFA.[23] This results in an equal or superior outcome relative to conventional RFA techniques.

Studies have indicated no moderate to severe complications from the cooled RFA procedure.[24] Occasional soreness and numbness have been reported at the procedure site, with complete resolution within 2 weeks.[25,26] One study found a patient to have transient leg pain following the procedure, this was found to resolve following one week of oral steroid treatment.[27] Svetlana et. al. found that repeated treatment with cooled RFA provided longer-lasting relief of pain symptoms relative to one-time treatment. Medical costs for the patient were also found to be decreased by almost 20% by choosing repeat therapy in place of other therapies for management of pain.[28]

A metanalysis from Shih et al. found that all three RFA techniques improved sacroiliac joint pain in patients compared to baseline pain for up to one year. Per the metanalysis, no significant differences were noted between the three techniques. Efficacy at six months of the cooled RFA was found to be better than that of thermal RFA, which was found to be better than pulsed RFA.[19]

Magnetic Resonance Imaging Guided High Intensity Focused Ultrasound (MRgHIFU) is a non-invasive ablation modality used to created thermal lesions inside the body under real-time temperature monitoring. Kaye et al. suggest that MRgHIFU may be a potential modality for treatment of SI joint dysfunction for a number of reasons. Use of MRgHIFU avoids insertion and repositioning of probes as well as allowing for continuous monitoring of the heat. This allows for continuity of the lesion during the procedure. MRgHIFU ablation of the SI joint may present a potential risk of damaging thermal exposure to adjacent sacral nerves, bone, and muscle. Vertebral nerve roots may also be damaged during the procedure. The authors of this study conclude that additional studies must be completed, however, MRgHIFU shows to be a promising treatment option for sacroiliac joint pain in the future.[29]

PLATELET RICH PLASMA, PROLOTHERAPY, AND BIOLOGICS

PLATELET RICH PLASMA

Platelet rich plasma (PRP) is made of a high concentration of autologous platelets suspended in a small amount of plasma post centrifugation. Platelet α-granules are a source of growth factors such as fibroblast growth factor (FGF), transforming growth factor beta-1 (TGF-β1), platelet derived growth factor (PDGF), and platelet-derived angiogenesis factors (PDAF). PRP possess these growth factors in higher concentrations.[30,31] In addition, platelets are also responsible for releasing substances such as fibronectin, vitronectin, and sphingosine 1-phosphate which are all essential to wound healing.[31] PRP is injected under ultrasound guidance into the sacroiliac joint.[32]

The various growth factors in PRP stimulate angiogenesis and increased fibroblast differentiation and can accelerate overall wound healing time by two to three-fold relative to normal.[31] PRP is becoming more commonly employed to improve healing of soft tissues and to improve bone regeneration.[30,33] Adverse effects of PRP therapy include post-injection pain and stiffness and are noted to be generally mild in nature.[34]

Efficacy of PRP therapy in treatment of sacroiliac joint pain still remains uncertain. Two major prospective trials have been completed to date. Singla et al. published a RCT

that compared patients treated with steroid injections to those treated with PRP for treatment of SI joint pain. They evaluated patients at 2,4, and 6 weeks as well as at 3 months assessing outcomes of pain via the visual analog score (VAS), modified Oswestry Disability Questionnaire (MODQ) scores, and short-form health survey scores (SF-12). Up to week four, both groups noted improvements in VAS, MODQ, and SF-12 scores, although no significant difference was seen between the two groups. VAS, MODQ, and SF-12 scores were found to be significantly lower in the PRP treatment group at 6 weeks and 3 months. They found at the 3-month mark, 90% of the PRP treatment group reported being pain-free, compared to only 25% of the steroid treatment group. Limitations of this study included a small sample size of only 40 participants.[34] This study was completed at 3 months, limiting the data gathered on long-term efficacy of PRP therapy. In order to address this, Wallace et al. completed a prospective nonrandomized interventional study of 50 patients. Oswestry Disability Index (ODI) was the primary outcome measured and Numeric Rating Scale for Pain (NRS) was the secondary outcome measured. Outcomes were measured at 2 and 4 weeks as well as at 3 and 6 months. The study found a reduction in pain and improvement in disability at 6 months from treatment, however, the majority of benefit was found to occur within the first 4 weeks of treatment. The main limitation of this study was the lack of a control or placebo group. The study also lacked blinding and randomization as there was only one treatment group.[35]

Various case studies have also shown the benefits of PRP therapy. A case study by Ko et al. followed four women with sacroiliac joint pain after treatment with PRP therapy. All four women experienced significant improvement in pain at one year. All four women also reported significantly improved pain metrics as far out as four years, although the benefit was not as pronounced as it was during the first year. All four women were also able to return to pre-injury levels of activity.[36] This implies a promising treatment option for both short-term and long-term pain relief. However, at this time additional large-scale prospective studies are needed to better elucidate the efficacy of PRP to other treatment therapies.[35]

In addition to PRP, various other biologics such as mesenchymal stem cells (MSC's) have been used in the treatment of SI joint pain. According to the American Society of Interventional Pain Physicians (ASIPP) Guidelines, the literature is currently limited, and the use of biologics is limited to clinically diagnosed patients that have tried and failed conservative therapy for SI joint pain.[37]

PROLOTHERAPY

Prolotherapy is a procedure where a natural irritant is injected to induce an influx of inflammatory cells, which enlists a healing response. There are three main types of prolotherapy solutions. These include osmotic agents, irritants, and chemotactic agents. Osmotic agents include agents such as hyperosmolar dextrose and zinc sulfate. Irritants act by damaging cell membranes or cause local cells to become antigens. Chemotactic agents such as sodium morrhurate are used to induce direct chemotactic effects on inflammatory cells.[38,39]

BIOLOGICS

Biologics are another form of treatment currently being investigated for SI joint pain. Adult stem cells also known as "mesenchymal stem cells" (MSCs) are the most studied of the biologic agents. MSCs are known for their unique ability to conform to various cell types allowing these cells to differentiate into cells that are required for the healing process.[37] Given that autologous products do not bear the risk of rejection as compared to allogenic therapy, the majority of studies have assessed the effectiveness of intra-articular injection of autologous MSCs.[37] Currently, a small number of studies are available regarding the use of prolotherapy and biologics in the treatment of axial spine pain, additional studies with higher quality evidence are necessary to establish the benefit of these therapies.[38] Current biologics include, autologous MSC, PRP, disc-derived chondrocyte, nucleus pulposus, and serum.[37]

SURGICAL TECHNIQUES

The Sacroiliac Joint (SIJ) transmits flexion movements at the hips and compression forces from the upper body to the proximal lower extremities, but the joint itself does not have great stability against opposing compression forces.[40] Minimally invasive sacroiliac arthrodesis is increasing in attractiveness as a treatment for chronic joint pain to help stabilize the joint.[41] The population who may be best suited for a minimally invasive arthrodesis ideally includes patients who are refractory to conservative medical management including: sacroiliac belt, NSAIDs, activity modification, radiofrequency ablation, and physical therapy, have >75% positive relief from sacroiliac steroid injection, or those with continued/recurrent SIJ pain.[11,42,43]

The difference in patient-reported outcomes between conservative management and surgical management is demonstrated in a randomized controlled trial that included 52 subjects who underwent either unilateral or bilateral minimally invasive sacroiliac arthrodesis using SI-Bone triangular titanium implants, and 51 subjects who received conservative medical management, which included physical therapy sessions for 6 months (2 subjects received additional sacroiliac corticosteroid injections and 1 subject received injections plus radiofrequency ablation).[44] The self-rated results demonstrated significant low back pain improvement at 6 months and 24 months in the surgical group compared to the conservative management group.[44]

Additionally, the arthrodesis group found significant improvement in leg pain and a 33% decrease in opioid use at 2 years.[44] Four adverse events were noted secondary to the device implantation or surgical procedure. This included 2 cases of increased sacroiliac joint pain, 1 case of gluteal hematoma, and 1 case of nerve root impingement.[44]

MECHANISM OF ACTION

The SIJ has several ligaments (anterior sacroiliac, interosseus, sacrospinous, and sacrotuberous) and muscles (gluteus maximus, pyriformis, and biceps femoris) to help stabilize the joint.[45] SIJ instability can produce pain both locally and refer pain to the lower extremities because the posterior surface of the joint is innervated by L3 and S4 dorsal rami collaterals, and the anterior surface of the joint is supplied by the L2 and S2 nerve.[45] The SIJ usually has a small range of motion (ROM) and displacement; however, if hypermobility or deterioration of the joint occurs then compression of innervated ligaments could arise.[46]

There are two main minimally invasive surgical approaches to achieve SIJ fusion: posterior or lateral transiliac.[47] The posterior approach requires dissection of the gluteal fascia and the lateral approach requires dissection through the lateral gluteus muscle to the ilium.[40,47] SIJ fixation may offer pain relief by providing joint stability and decreasing rotational movement and displacement of the joint, as well as removing innervated tissue for the implant.[46,48] On the other hand, prior surgical arthrodesis of the lumbar spine is also a cause for SIJ pain as fixation at one level can cause degeneration of an adjacent region.[40]

TECHNIQUE

Similar to other surgical procedures, SIJ fixation can be performed through open or percutaneous (minimally invasive) techniques- each with its own limitations and benefits (**Table 1**). The open technique can be performed through an anterior or posterior approach. The anterior open approach requires an incision in the lateral rectus abdominal muscles while the psoas major muscle, iliac muscle, and femoral nerve (L2, L3, L4) are retracted to reach the peritoneum.[49] The posterior open approach requires an incision from the posterior superior iliac spine (PSIS) down to the midpoint between the PSIS and the posterior inferior iliac spine that is then continued laterally for 5 cm.[50] Additionally, an incision of the gluteus medius superficial fascia and dissection of the gluteus maximus from the posterior ileum is performed with removal of the articular cartilage from the sacral and iliac surfaces, and finally the SIJ is disarticulated.[50] The minimally invasive technique to SIJ fusion can be performed through a posterior or lateral approach. For the posterior minimally invasive approach, the first step is to make a lateral incision on the buttocks and dissect the gluteal fascia to reach the ilium.[51]

A Steinmann pin is inserted through the ilium and SI joint to reach the sacrum, lateral to the sacral foramina.[51] Next, a broach is driven across the joint to form a channel for the first implant, and a x-ray or CT guide is used to verify correct placement.[51] Ideally, 2 or 3 implants across S1 and S2 sacral spinal levels are desired.[51] Important to note, greater stability can be achieved by placing the implants further from the SIJ, and greater reduction in movement is achieved by using a longer implant at S1.[51] The lateral minimally invasive approach consists of dissection through the lateral gluteus muscle to the ilium and then insertion of the device to fix the ilium to the sacrum across the SI joint.[47] There are several different devices and companies that can be used for the minimally invasive techniques.[51]

For instance, the iFuse implant system (SI-Bone) devices consist of porous titanium plasma spray-coated triangular titanium implants, and successful joint stabilization can be achieved through the unique shape, coating, and interference fit of these implants.[51] In more detail, the interference fit allows for accurate fixation, the shape reduces implant rotation, and the porous exterior augments ingrowth of bone resulting in stronger fusion.[51] All the fusions are obtained through the bony ingrowth, therefore no grafts are needed for this system.[51] One long-term prospective study observing 103 patients who underwent minimally invasive trans-iliac approach SI-Bone implants found at 3 years, mean SIJ pain score decreased to 26.2 (a 55-point improvement from baseline, $p<0.0001$), and a mean Oswestry Disability Index (ODI) was 28.2 (a 28-point improvement from baseline, $p<0.0001$).[53] Additionally, 82% of subjects were very satisfied with the procedure at 3 years and no adverse events definitively related to the study device or procedure were reported; one subject underwent revision surgery at year 3.7.[53] Important to note, 15 subjects experienced SIJ pain contralateral to the originally treated side of whom four underwent contralateral SIJ fusion and the proportion of subjects who were employed outside the home full- or part-time at 3 years decreased somewhat from baseline ($p=0.1814$).[53]

To compare devices within the same company, one randomized control trial aimed to study patient reported outcomes after undergoing arthrodesis with either SI-Bone triangular titanium dowel implants (TDIs) versus cylindrical threaded implants (CTIs).[41] The results demonstrated significantly longer procedure length for the cylindrical threaded implants (avg of 60 min) when compared to the triangular dowel implants (avg 41.2 min).[41] Favorably, Both groups found significant improvement in all patient-reported outcomes (Visual analog scale, Oswestry disability index, and Short Form-12) at 6 months when compared to preoperative values, and there was no significant difference between CTI and TDI patient-reported outcomes at 6 months and 1 year.[41] Another company, PainTEQ, has recently launched a study to investigate the function and motion of patients who have received a bilateral SIJ fusion using the LinQ Sacroiliac Joint Fusion System.[54] PainTEQ uses a minimally invasive outpatient posterior approach that involves implanting one small bone allograft into the SIJ through a single incision on the patient's back.[55] Alternatively, CornerLoc, is a corporation that performed a case series to explore patient characteristics, operating times, recovery times, adverse events, and patient satisfaction and improvement of 52 cases after minimally invasive SIJ fusion using CornerLoc grafts.[56]

Only 28 of the 52 patients offered a response and 24/28 indicated functional improvement after surgery and 4/28 indicated no improvement.[56] 79% of the patients who offered a response were satisfied with their results, and there were 0 neurologic, infections, adjacent fractures, hardware complications, or hospitalizations complications reported.[56] Another 12 month retrospective patient study us-

Table 1. Benefits and risks of open vs. minimally invasive surgical procedure

Study type	Author (year)	Groups studied and intervention	Results and findings	Conclusions
Review article	Joukar et al. (2020)[51]	55 studies that were reviewed to understand the efficacies of open versus minimally invasive SIJ fixation	Minimally invasive techniques involve less tissue damage, blood loss, and duration of hospitalization, leading to better clinical outcomes	Despite the satisfactory data on clinical outcomes of SIJ fixation surgery, the data on biomechanics of the SIJ in general and fixation techniques, in particular, are sparse.
Multi-center, retrospective comparative cohort study	Smith et al. (2013)[52]	149 patients treated with OS and 114 treated with MIS SI joint fusion. Operative measures including surgical operating time, length of hospitalization, and estimated blood loss (EBL) were collected along with demographics and medical history, surgical complications, and 12- and 24-month pain scores. Improvements in pain were compared after matching for age and gender and controlling for a history of lumbar spine fusion using repeated measures analysis of variance.	Compared to OS patients, MIS patients were on average 10 years older (mean age 57 vs. 46) and 69% of all patients were female. MIS operative measures of EBL, operating time, and length of hospitalization were significantly lower than open surgery ($p < 0.001$). Pain relief, measured as change from baseline to 12 months in VAS pain rating, was 3.5 points lower in the MIS vs. OS group (−6.2 vs. -2.7 points, $p < 0.001$). When matched for age, gender, and a history of prior lumbar spinal fusion, postoperative pain scores were on average 3.0 points (95% CI 2.1 – 4.0) lower in MIS vs. OS (rANOVA $p < 0.001$).	In this multi-center comparative study, patients who underwent either OS or MIS SI joint fusion showed postoperative improvements in pain score. Compared to OS patients, patients who underwent MIS SI joint fusion had significantly greater pain relief and more favorable perioperative surgical measures
Review article	Martin et al. (2020)[47]	Literature review of studies with the term "sacroiliac joint fusion" that had at least 12 months of clinical follow-up, reported on minimally invasive techniques and included patient-reported outcome measures.	Compared with open fusion, minimally invasive SI joint fusion was associated with shorter operative times (70 versus 163 minutes), lower estimated blood loss (33 versus 288 mL), and lower hospital length of stay (1.3 versus 5.1 days, all comparisons $P < .0001$) Operative complications occurred in 21% and 18% of the open and minimally invasive groups. At 12 months, pain scores improved by 2.7 points in the open group and 6.2 points in the minimally invasive group. The 2-year pain scores (available in only 96 patients) showed improvement of 2 points in the open group and 5.6 points in the minimally invasive group.	Minimally invasive SI joint fusion provides clinically significant improvement in pain scores and disability in most patients, across multiple studies and implant manufacturers.

ing CornerLoc was performed on 10 patients and found that the average pain reduction was 62.3% at 12 weeks and 79.2% at 12 months.[57] Every patient displayed improved posture and gait at follow-up, and the overall satisfaction with the procedure was 4.95/5.[57] Further results of these 10 patients include: 7 patients (70%) showed marked improvement in overall daily activity level, 1 patient (10%) show moderate improvement, and 2 patients (20%) showed limited to no increase in activity level due to other health factors unrelated to the procedure.[57]

To compare companies directly, Less Exposure Surgery Society performed a comparison study of mechanical pull-out strength of SacroFuse (Sacrix LLC) Gen II threaded implant versus SI-Bone iFuse triangular implants for SIJ fixation.[58] Pull-out strength is a critical element for screw fixation stability.[58] The pullout strength for SacroFuse Gen II implant was greater than the SI-Bone iFuse implant by 614.76 Newtons ($p<.05$), and the SacroFuse implant also showed a 400% increase in axial performance compared to iFuse.[58]

EFFICACY

In a retrospective study with up to a 6 year follow-up reports, patients treated with continued conservative management had no long-term improvement in pain (mean worsening of 1 point) or disability (mean Oswestry Disability Index worsened by 4-6 points), increased their use of opioids, and had poor long-term work status.[59] Minimally invasive techniques involve less tissue damage, blood loss, and duration of hospitalization leading to better clinical outcomes while open surgical fusion require longer operative time, blood loss, and procedure time.[51,52] One study aimed to narrow down these facts and discovered that compared with open fusion, minimally invasive SI joint fusion was associated with shorter operative times (70 versus 163 minutes), lower estimated blood loss (33 versus 288 mL), and lower hospital length of stay (1.3 versus 5.1 days, all comparisons $P < .0001$).[47]

In direct correlation to these details, the operative complications occurred in 21% and 18% of the open and minimally invasive groups.[47] At 12 months, pain scores improved by 2.7 points in the open group and 6.2 points in the minimally invasive group and the 2-year pain scores (available in only 96 patients) showed improvement of 2 points in the open group and 5.6 points in the minimally invasive group.[47] Another study directly compared minimally invasive surgery (MIS) joint fusion with triangular titanium implants to open surgery (OS) using SI joint fusion.[52] MIS operating time and length of hospitalization were significantly lower than open surgery ($p < 0.001$).[52] Pain relief, measured as change from baseline to 12 months in visual analog scale pain rating, was 3.5 points lower in the MIS vs. OS group (−6.2 vs. -2.7 points, $p < 0.001$).[52] When matched for age, gender, and a history of prior lumbar spinal fusion, postoperative pain scores were on average 3.0 points (95% CI 2.1 – 4.0) lower in MIS vs. OS (rANOVA $p < 0.001$).[52] The reoperation rate after open surgery ranged from 0% to 65% (mean 15%) and the reoperation rate after MIS ranged from 0% to 17% (mean 6%).[60]

ADVERSE EFFECTS

Adverse outcomes encountered after MIS include new-onset facet joint pain, trochanteric bursitis, deep wound infections, new onset of low-back or leg pain, and superficial cellulitis.[60] Other complications faced involved radiculopathy, vascular necrosis of the hip, piriformis syndrome, implant penetration into the sacral neural foramen, peripheral neuropathy, a nondisplaced fracture, and pulmonary emboli/deep vein thrombosis.[60] Fourteen studies of 720 patients (499 females/221 males) with a mean follow-up of 22 months reported ninety-nine patients (13.75%) underwent bilateral SI joint arthrodesis resulting in a total of 819 SI joints fused.[61] There were 91 reported procedural-related complications (11.11%) with the most common adverse event being surgical wound infection/drainage (n = 17) .[61] Twenty-five adverse events were attributed to placement of the implant (3.05%) with nerve root impingement (n = 13) being the most common and the revision rate was 2.56%.[61]

LIMITATIONS

The patient needing to be a suitable surgical candidate is the first limitation that is encountered in order to receive the minimally invasive SIJ fixation procedure. Surgical risk is a complex term that comprises disease-related factors, patient-related factors (anatomical variances, past surgical history, comorbidities, smoking status, and lifestyle), surgery-related factors, and system-related factors (quality of preoperative and postoperative care, follow-up care and compliance, and lifestyle modification).[62] An important question to also consider is if the SIJ is the true pain generator, or if it is pain secondary to another cause because the pain may not be irradicated if the pain generator was not correctly identified.[60] It is also imperative to identify the bone quality and density in order to determine if the implant will have successful stability achieved, and to consider that many patients may have had previous low-back surgery or underwent surgery during their follow-up period.[51,60]

Another limitation is there are unanswered questions regarding the effects of different implant devices and how their shapes impact structure, function, and motion of the SIJ as well as long-term patient outcomes.[51] For example, a review article reports a study that found an increased range of motion (ROM) when using one or two implanted devices compared to three implants for the iFuse System devices; however, the article also cited a study that found no significant difference in movement and translation when comparing the number of implants for RIALTO devices.[46,63] The same review article additionally reports conflicting evidence by citing a study that showed no significant difference in ROM for flexion-extension and axial rotations, but significant reduction measured in lateral bending for the Integrity-SI system devices and compared this with a study that found significant reduction in the ROM in all three directions.[46,64]

CONCLUSION

Sacroiliac joint pain is a considerable contributor to the common affliction of persistent lower back pain that diminishes the quality of life for patients by limiting daily activity and work capacity. Though conservative management through multi-modal pain control and physical therapy have their role as first line therapies, an increasing body of evidence supports the use of minimally invasive procedures, both as adjuvant treatments to conservative management and as second line therapies for patient's that fail first line treatment. Given the novelty of minimally invasive procedures in the SI joint pain space, there is a need for more clinical studies and comprehensive reviews to further elucidate their role in treatment pathways.

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