Displaced Intra-articular Calcaneal Fractures: Classification and Treatment

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abstract

The calcaneus is the most commonly fractured tarsal bone. Displaced intra-articular calcaneal fractures are usually caused by a fall from height with one or both heels directly hitting the ground. Displaced intra-articular calcaneal fractures are complex and highly disabling injuries. There is ongoing debate regarding the optimal treatment for each type of displaced intra-articular calcaneal fracture. This review aims to summarize the classification of, various treatment options for, prevention of perioperative complications in, and management algorithms for displaced intra-articular calcaneal fractures. [*Orthopedics*. 2017; 40(6):e921-e929.]

The calcaneus is the most commonly fractured tarsal bone, and calcaneal fractures account for 1% to 4% of all adult fractures.[1,2] Most (60% to 80%) calcaneal fractures are intra-articular,[1,2] and the displacement of these fractures as little as 2 mm can alter contact pressures in the subtalar joint.[3] Displaced intra-articular calcaneal fractures are complex and highly disabling injuries.[4-7] The articular congruity of the subtalar joint must be restored to achieve optimal functional recovery.[8] However, the role of the subtalar joint as a major source of disability may have been overestimated,[9] as simply restoring the subtalar joint surface has not been shown to guarantee a symptom-free foot.[10] Loss of calcaneal height may result in anterior impingement and widening of the calcaneus, leading to compression of the peroneal tendon sheath and thus causing severe lateral hindfoot pain after fracture union.[11] Therefore, anatomic reduction of the subtalar articular surface may not be the critical factor impacting outcome, as restoration of calcaneal height, width, and alignment of the hindfoot are also important prognostic factors.[12,13] Displaced intra-articular calcaneal fractures can be treated nonoperatively or operatively. The appropriate surgical procedures, which may involve open reduction and internal fixation (ORIF), closed or percutaneous reduction and minimally invasive fixation, external fixation, or primary subtalar arthrodesis, must be carefully selected based on the type of fracture, the condition of the surrounding soft tissue envelope, and the characteristics and general medical condition of the patient.

Classification

In 1952, Essex-Lopresti[5] described a novel classification system that divided calcaneus fractures into 2 types: joint depression and tongue. The 2 patterns share a common primary fracture line and are

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distinguished from each other based on a secondary fracture line. The simplicity of the Essex-Lopresti classification makes it extremely useful in the emergency department. It relies solely on plain radiographs, specifically the lateral view, and can often assist the emergency physician in determining how to acutely manage the fracture. A tongue-type pattern predicts an impending or associated soft tissue injury in a unique way that other classification systems do not.[14] Unlike the Essex-Lopresti classification system, most other calcaneal fracture classification systems rely on computed tomography (CT).

The Sanders classification is based on coronal CT sections of the hindfoot and is one of the most commonly used systems.[15] This classification considers the number and location of fracture lines that enter the posterior facet of the calcaneus. Despite its prognostic value being confirmed by several studies,[16-18] the Sanders classification has had its reliability questioned because of low intra- and interobserver reproducibility.[19-21]

Treatment

Conservative Treatment vs Open Reduction and Internal Fixation

Operative treatment is recommended for displaced intra-articular calcaneal fractures involving the posterior facet with more than 2 mm of displacement, fracture-dislocations, and fractures with more than 25% involvement of the calcaneocuboid joint.[6] The current literature supports the judicious use of ORIF[1] via an L-shaped, extensile lateral approach.[22] Surgery can be performed when adequate reduction of swelling occurs, as indicated by a positive result on the wrinkle test.[23] However, the controversy regarding whether to use surgical or conservative interventions for displaced intra-articular calcaneal fractures persists. Some authors[24-26] have indicated that operative treatment may be superior to conservative treatment, whereas others[27-29] have claimed that there are no significant differences between the two methods.

Buckley et al[24] conducted a multicenter randomized controlled trial (RCT) with 424 enrolled patients (471 displaced intra-articular calcaneal fractures) that compared outcomes between ORIF and nonoperative treatment. They found that outcomes were significantly better for surgically treated patients after removing patients receiving workers' compensation. Agren et al[30] conducted a comparative prospective, multicenter RCT, in which operatively managing displaced intra-articular calcaneal fractures showed no superiority at 1 year of follow-up but seemed to have benefits at 8 to 12 years. In this series, operative treatment was associated with a higher risk of complications, but a reduced prevalence of posttraumatic arthritis was evident on follow-up radiographs.[30] In a post hoc analysis of the prospective, multicenter RCT comparing operative and nonoperative treatment, Agren et al[31] found that the factors associated with the superior long-term outcome included operative treatment, improved Böhler's angle and articular surface restoration, light labor or retirement, and absence of injury insurance. Jiang et al[32] reported a meta-analysis that examined 10 studies (6 RCTs and 4 clinical controlled trials) with a total of 891 participants. They confirmed that surgical treatment of displaced intra-articular calcaneal fractures can result in better recovery of Böhler's angle, more stable calcaneal height and width, and thus better functional recovery and an increased chance of resuming preinjury work. The function of conservatively treated displaced intra-articular calcaneal fractures may continue to deteriorate at long-term follow-up. Allmacher et al[33] reported that, at a 10-year follow-up, 63% of 19 patients with displaced intra-articular calcaneal fractures had good or excellent results on the Iowa calcaneal score and 37% had fair or poor results. At 20-year follow-up, only 47% had good or excellent results and 53% had fair or poor results. In another study, more subtalar arthrodeses were performed for the development of subtalar arthritis after conservative treatment than after surgical treatment.[29]

The L-shaped, extensile lateral approach is the most widely used approach for ORIF of a displaced intra-articular calcaneal fracture.[24] It is a modification of that described by Palmer[34] and Letournel.[35] The approach has been modified to include a full-thickness flap that protects the peroneal tendons, the sural nerve, and the vascularity of the flap. The primary concern with this approach is a high complication rate.[36-43] Some techniques can be employed to decrease the risk of complications related to this approach. For example, the corner of the incision should be curved to avoid significant wound complications. Direct dissection down to the bone and sharp elevation of the periosteum can be performed to maintain a full-thickness flap.[44] The full-thickness flap is retracted with three 2-mm Kirschner wires that are fixed in the fibula, talar neck, and navicular bones with the aim of avoiding excessive manipulation.

A medial approach has been described to treat displaced intra-articular calcaneal fractures.[45] The reported benefits of this approach include fewer wound complications and earlier weight bearing. However, this approach does not allow direct visualization of the posterior facet of the subtalar joint. The articular surface must be reduced indirectly with the aid of elevators inserted through the medial incision while assessing the appearance of the facet with Broden's views. Careful dissection will allow good exposure of the superomedial fragment and its interface with the tuberosity, but the major obstacle to achieving an adequate exposure is the neurovascular bundle.[46] The incision can be extended proximally to improve exposure of the entire tuberosity. In Burdeaux's[45] series of 61 patients (level IV evidence) treated through a medial approach, the average American Orthopaedic Foot & Ankle Society score was 94.7 at 4.4 years postoperatively. Romash[47] reported (level IV evidence) that all patients in his series were fully weight bearing and wearing shoes within 6 months after surgery, and 70% were able to return to their preinjury level of activity. However, in these 2 studies, 20% and 60% of patients, respectively, required an additional lateral incision to achieve a satisfactory reduction.

Open reduction and internal fixation via extensile approaches carries a greater risk of major complications when compared with conservative therapy.[32,41,48,49] Postoperative complications are common clinical problems that can be life-altering. Yu et al[36] analyzed 21 clinical studies that included 2046 displaced intra-articular calcaneal fractures treated by ORIF. The main complications were as follows: infection and skin flap necrosis (13.6%), neurovascular injury (2.8%), posttraumatic arthritis (1.2%), malreduction or implant problems (0.8%), and nonunion (0.1%). To prevent the well-documented soft tissue complications related to ORIF techniques, many authors have developed minimally invasive or percutaneous techniques to address displaced intra-articular calcaneal fractures.[50-60]

Internal Fixation of Displaced Intra-articular Calcaneal Fractures (With the Plates) via Minimally Invasive Approaches

Minimally invasive techniques have been proposed for displaced intra-articular calcaneal fractures with the aim of potentially lowering wound complication rates and improving overall outcomes.[42,61] Various minimally invasive approaches, such as the Palmer approach,[34] Smile incision,[62] Ollier approach,[63] sinus tarsi approach,[46,64,65] and minimally invasive longitudinal approach,[66] have been introduced to minimize the wound complication rate.

Among these, the sinus tarsi approach has been one of the most popular and widely used minimally invasive approaches. During the operation, the patient is placed on the operating table in the lateral decubitus position with the lateral malleolus of the affected foot facing up. A Steinmann pin 3.5 to 4.5 mm in diameter is drilled into the calcaneal tuberosity transversely. Distraction is applied via the pin to overcome the shortening of the calcaneus. The incision is made from the tip of the lateral malleolus to the calcaneocuboid joint in line with the fourth metatarsal.[50] The sinus tarsi approach provides a limited but adequate exposure to the posterior facet, anterolateral fragment, and lateral wall. Then, the impacted fracture fragments are elevated using the talus as a template. Kirschner wires are inserted for temporary fixation. After satisfactory reduction is achieved, a lateral plate is inserted via the transverse incision and fixed using cancellous screws with or without Steinmann pins. The sinus tarsi approach avoids the process of elevating the lateral flap, which can minimize damage to the blood supply of the hindfoot. Wound complication rates have been reported to range from 0% to 15.4% with the sinus tarsi approach,[42,65] being lower than those reported for the extended lateral approach (range, 10% to 37.1%).[36,41-43,67]

Kline et al[48] performed a retrospective review to compare the outcomes of displaced intra-articular calcaneal fractures treated with ORIF via an extensile approach vs a minimally invasive sinus tarsi approach. Clinical results were similar for the 2 approaches, but the minimally invasive approach had a significantly lower incidence of wound complications and secondary surgeries. However, insufficient restoration of the width and height of the calcaneus is considered an inevitable drawback of the sinus tarsi approach.

Zhang et al[11,66,68,69] introduced a new minimally invasive technique, termed internal compression fixation, for displaced intra-articular calcaneal fractures. It features a small, longitudinal lateral incision on the hindfoot, with placement of an anatomical plate and compression bolts with the aim of reducing the wound complication rate and maximizing functional recovery. The length of the calcaneus is first restored by distracting the Steinmann pin drilled transversely into the posteroinferior part of the calcaneal tuberosity. Under fluoroscopic guidance, 2 Steinmann pins are introduced percutaneously through the superoposterior portion of the tuberosity to lever the compressed fragments to reconstruct the overall shape of the heel. After satisfactory reduction is achieved, the pins are inserted into the anterior part of the calcaneus or through the posterior subtalar joint to gain temporary fixation. A 3.5-cm–long incision is made between the fibula and the Achilles tendon on the lateral hindfoot, and a subcutaneous tunnel is created on the lateral wall with a periosteal elevator. The anatomical plate is then inserted into the subcutaneous tunnel, and the plate position is confirmed by intraoperative imaging. Three compression bolts are drilled in a lateral–medial direction—2 into the posterior part of the hindfoot and 1 into the sustentaculum tali. Then, small incisions are made on the medial wall to expose the screws, being careful to avoid damaging neurovascular bundles and tendons. The nuts are tightened on the screws. This can generate enormous compression force to restore the width of the calcaneus to the utmost degree and to subsequently restore the height. The compression bolt is broken off at the site of the constricted area. Additional cancellous screws are inserted to fix the multifragmented fractures. Wang et al[70] conducted a biomechanical study to compare the stability obtained using an anatomical plate and compression bolts vs a conventional plate and cancellous screws in the fixation of intra-articular calcaneal fractures. During 20- to 200-N cyclic axial loading, the anatomical plate and compression bolts showed significantly lower irreversible deformation and a higher level of fixation failure than a conventional plate and cancellous screws.

Wang et al[66] treated 156 patients with 210 displaced intra-articular calcaneal fractures using this minimally invasive internal compression procedure. Anatomical or nearly anatomical reduction of the posterior articular facet, graded using an articular displacement of less than 3 mm, was achieved in 159 fractures (75.7%). According to the Maryland hindfoot score system, outcomes were excellent or good in 86% of the fractures, fair in 8%, and poor in 6%, with no wound infection, deep infection, or lateral impingement syndrome reported at follow-ups. Subtalar arthritis with radiological signs was present in 20 patients; however, pain in the subtalar joint was present in only 4 cases. Wu et al[68] conducted a comparative study to assess the clinical outcomes of displaced intra-articular calcaneal fractures treated using the minimally invasive internal compression procedure (181 patients; 213 feet) vs ORIF via an L-shaped, extensive lateral approach (148 patients; 170 feet). Functional outcomes of the minimally invasive treatment have been shown to be as good as or better than those of the open technique, with the benefit of a significantly lower complication rate.

Zhang et al[69] performed a prospective study to assess the clinical results for a minimally invasive longitudinal approach group (63 patients with 69 fractures) compared with a sinus tarsi approach group (67 patients with 72 fractures) in the surgical treatment of displaced intra-articular calcaneal fractures. During the minimally invasive longitudinal approach, a 3.5-mm Steinmann pin is drilled vertically to the calcaneal tuberosity, and the length of the calcaneus can be restored by percutaneous traction reduction using the pin.[66,71,72] The 2 groups were comparable in terms of age, sex, fracture type, and time from injury to operation. The operative time in the minimally invasive longitudinal approach group was significantly shorter than that in the sinus tarsi approach group. Wound-healing complications occurred in 2.9% of the minimally invasive longitudinal approach group and 12.5% of the sinus tarsi approach group. The 2 groups were comparable regarding good and excellent results for Sanders type II and type III calcaneal fractures, but the sinus tarsi approach group had a significantly higher rate of good to excellent results for Sanders type IV fractures.

Percutaneous Fixation of Displaced Intra-articular Calcaneal Fractures

Several techniques, including Schanz pins, Kirschner wires, cannulated screws, arthroscopically guided percutaneous fixation,[56] and intramedullary nails,[73-76] are available for percutaneous fixation of displaced intra-articular calcaneal fractures. Percutaneous reduction and fixation has been used to treat tongue-type fractures.[77,78] Percutaneously placed guidewires can be used as joysticks to lever the posterior facet into a reduced position. However, insufficient reduction and unreliable fixation can result from this technique. To achieve a reliable fixation, transfixation of the subtalar joint should be reserved for most calcaneal fractures. However, this is not routinely encouraged because it precludes functional recovery after treatment.[79] Regardless, it remains the best choice for displaced intra-articular calcaneal fractures that are open or that have a severely compromised soft tissue envelope. Stulik et al[80] reported the results of 287 displaced intra-articular calcaneal fractures treated by percutaneous reduction and Kirschner wire fixation following the modified 4-step Forgon and Zadravecz technique in a minimally invasive fashion. Using this technique, a satisfactory alignment (less than 2 mm of articular displacement) was achieved in 74% of cases, with a 4.5% rate of loss of reduction. However, Buch et al[81] reported obviously inferior results after percutaneous fixation compared with conservative therapy.

Multiple percutaneous screw fixation after closed reduction with percutaneous leverage and traction offers a successful treatment option for displaced intra-articular calcaneal fractures. Tomesen et al[57] reported excellent results using percutaneous screw fixation of displaced intra-articular calcaneal fractures according to the method of Forgon and Zadravecz, despite the fact that 46% of patients had undergone an uncomplicated removal of painful screws. Schepers et al[54] evaluated the outcomes of 50 patients with 61 displaced intra-articular calcaneal fractures treated by percutaneous screw fixation. At their final follow-up, the mean values for Maryland Foot Score, Creighton–Nebraska score, and American Orthopaedic Foot & Ankle Society score were 79, 76, and 83 of 100 points, respectively. The average range of motion of the ankle joint was 90% of normal, and the average subtalar joint movement was almost 70% compared with the uninjured, normal side. However, secondary arthrodesis of the subtalar joint was required in 9 patients (15%). Rammelt et al[52] found that percutaneous reduction and screw fixation was a reasonable alternative for moderately displaced fractures and provided adequate control of anatomical joint reduction with either subtalar arthroscopy or high-resolution (3-dimensional) fluoroscopy. Subtalar arthroscopy augments intraoperative fluoroscopy in the anatomical reduction of the posterior calcaneal facet of the subtalar joint following definitive fixation with 4 to 8 percutaneous cancellous screws, and it is most useful for Sanders type II or AO/OTA 82-C2 fractures.[82,83] The percutaneous approach further avoids soft tissue complications associated with open reduction. However, this procedure has a steep learning curve.[82]

A prospective randomized trial was undertaken to compare ORIF (n=23) with minimally invasive reduction and percutaneous fixation using cannulated cancellous screws (n=22) for the treatment of displaced intra-articular calcaneal fractures.[84] There was no statistically significant difference in radiological outcomes between the groups, as measured by Böhler's angle, Gissane's angle, and Score Analysis of Verona. Compared with ORIF, minimally invasive reduction and percutaneous fixation using cannulated cancellous screws was associated with fewer wound-healing problems, better functional outcome, and earlier return to work.[84]

An innovative reduction technique using percutaneous balloon-plasty and bone cement injection has been reported in recent years.[85-87] Surgeons should first use Kirschner wires for temporary fixation and place a balloon beneath the articular fragment. The balloon is inflated to produce fracture reduction. The plastic slabs can be applied laterally to the heel and then tightened with a bone clamp. It can both prevent the lateral wall from expanding outward and ensure that the bone is relatively stable when the balloon has been removed and polymethylmethacrylate bone cement has been injected. Percutaneous injection of viscous bone cement can effectively prevent leaking cement in the articular cavity. The surgical procedure is suitable for Sanders type II and type III fractures.

Jacquot et al[85] reported on 10 patients with 11 displaced intra-articular calcaneal fractures treated with balloon reduction and cement fixation. Reduction was obtained in all cases. The American Orthopaedic Foot & Ankle Society clinical results were rated good or excellent in 81.8% of the fractures, and the physical component of the Short Form-36 had a mean score of 74.6 at the latest follow-up (range, 3-5 years). All of the patients but one, who had retired but had resumed leisure walking, returned to their former professional activities at the same level as before the fracture. Labbe et al[86] studied 6 patients with a median follow-up of 12 months (range, 6-30 months). Fluoroscopic guidance was used to obtain optimal balloon positioning under the joint depression site. Reduction was achieved by balloon-plasty. Stabilization was achieved by injecting the cavity with resorbable tricalcium-phosphate cement for the younger patients and with polymethylmethacrylate cement for the 2 elderly patients with osteoporosis. This preliminary study showed that this technique was easy to perform, reproducible, and devoid of specific complications. High-quality reduction and stabilization until fracture healing were achieved. The time to recovery of self-sufficiency was short, even for elderly patients with osteoporosis. These results support the use of this minimally invasive technique.[86]

External Fixator

Elgamal et al[88] described the use of a temporary external fixator as an intraoperative aid in the ORIF of displaced intra-articular calcaneal fractures. The controlled distractive force provides numerous benefits, including improved exposure of the subtalar joint, correction of angulation, and maintenance of temporary stability prior to definitive fixation. Elgamal et al[88] found this technique to be applicable and easily reproducible.

In recent years, some authors have made the effort to apply external fixation in addressing closed calcaneal fractures, and some have successfully applied external skeletal traction to obtain closed reduction of displaced calcaneus fractures.[89-91] Forgonl[92] reported a 3-point distraction system that is located on the calcaneal tuberosity, talar trochlea, and cuboid, meaning that the main fragments can be manipulated separately. The width, height, and length of the hindfoot can be restored by distracting the main fragments, while broadening of the heel can be diminished using a Böhler clamp. This technique can be employed for the temporary reduction of severely displaced fractures with a severe soft tissue lesion until proper internal fixation can be achieved. It can also be a definitive treatment for calcaneal fractures.

Primary Subtalar Arthrodesis

The most severe Sanders type IV calcaneal fractures can lead to devastating long-term disability[5,6] and are often life-altering for patients.[7] Debate exists regarding the optimal treatment strategy for Sanders type IV fractures, with poor results and secondary surgical subtalar fusion rates as high as 73% reported.[93-96] As a result, open reduction and primary subtalar arthrodesis has been advocated as a surgical option to treat such injuries.[97-100] However, this method has not been universally adopted because it is technically demanding and has a high failure rate.

Factors Affecting Outcomes and Complications

Displaced Sustentacular Fragment

The sustentacular fragment in displaced intra-articular calcaneal fractures has historically been portrayed as a "constant fragment" that is bound to the talus by the interosseous and deltoid ligament complex. Operative treatment typically occurs through a lateral approach, with the remaining calcaneus being reconstructed back to the sustentaculum. However, in a review of CT scans, Berberian et al[101] reported that the sustentacular fragment was displaced in 42% of 100 displaced intra-articular calcaneal fractures. Among the 100 displaced intra-articular calcaneal fractures, there were 25 with sustentacular fragment angulation of greater than 10°, 24 with sustentacular translation of greater than 3 mm, 20 with fracture diastasis of the middle facet, and 21 with a displaced intra-articular fracture of the calcaneal middle facet. Fixation by means of a lateral approach may be compromised when the sustentaculum tali is fractured or subluxated. A medial approach, or combined medial and lateral approaches, may be considered in such circumstances. Therefore, special attention should be paid to the integrity and alignment of the sustentacular fragment prior to surgical fixation.[102]

Fibular Ligament Damage

Peroneal tendon displacements (subluxation or dislocation) accompanying displaced intra-articular calcaneal fractures are often undetected and undertreated. In a study by Toussaint et al,[103] peroneal tendon displacement based on CT scan evaluation was identified in 118 (28.0%) of 421 calcaneal fracture cases involving the posterior facet. The presence of tendon displacement was significantly associated with joint-depression fractures compared with tongue-type fractures ($P<.001$). Although 65 (55.1%) of the fractures with tendon displacement had been treated with internal fixation, the tendon displacement was treated surgically in only 10.8% of these cases.[103]

Bone Graft

In cases of severe subversion of the morphology of calcaneal fractures with trabecular defects, bone graft is often necessary to provide a mechanical buttress.[104] Singh and Vinay[105] reviewed 390 cases of displaced intra-articular calcaneal fractures treated with plate osteosynthesis with or without autologous iliac bone grafting, comparing outcomes and complications. There was an improved restoration of Böhler's angle, and the patients returned to full weight bearing earlier when bone grafting was used. The infection rate trended toward being higher in the bone grafting group than in the nongrafting group (8.3% vs 6.3%), although the difference was not statistically significant. No significant difference was found between the groups in terms of the rates of good reduction, postoperative osteoarthritis, and subtalar fusion. To avoid donor-site morbidity and complications associated with harvesting autologous bone graft, various bone substitutes have been developed. Mineralized collagen is a novel bone substitute developed by a biomimetic synthesis strategy that mimics the extracellular matrix of natural bone in structure and chemical composition. The promising results reported by Lian et al[104] justify and favor the use of mineralized collagen as a good autograft alternative in displaced intra-articular calcaneal fractures with trabecular defects. The effect of bone void fillers on the incidence of complications should receive more attention in future research.

Surgical Timing

To avoid producing marginal incision necrosis, dehiscence, and infection, it is important for surgeons to choose the proper surgical timing, waiting until there is a reduction in swelling and resolution of any fracture blisters. This usually requires delaying operative treatment at least 7 to 10 days after injury. Ho et al[106] performed a retrospective, single-surgeon, single-facility study to analyze the correlation between surgical timing and postoperative infection rates of displaced intra-articular calcaneal fractures treated with ORIF via the L-shaped, extensile lateral approach. However, they concluded that, for experienced surgeons, surgical timing may not affect postoperative infection rates in calcaneal fractures among strictly selected patients who do not have potential risk factors for wound complications. Therefore, early surgery may be helpful for these patients.[106] The inverse association between wound complications and the level of experience of the surgical team supports the need for the centralization of this complex injury.[22]

Incision Healing

Abidi et al[49] reported that smoking is harmful to the healing of incisions. A comparative study by Folk et al[37] showed that diabetes, smoking, and open fractures all adversely affected incision healing. For patients with superficial incision dehiscence and skin edge necrosis, changing the dressings frequently, administering antibiotics orally, and keeping the local wound clean can effectively promote wound healing. Patients should quit smoking before surgery, and their blood glucose levels should be strictly controlled.

Conclusion

The challenges regarding calcaneal fractures include fracture classification, treatment options, indications, surgical timing, and postoperative complications. With additional studies on biomechanics, pathological mechanisms, and the universal application of CT, the classification of calcaneal fractures should provide practical standards to guide treatment decisions. Patients' age, health, and type of fracture must be considered when determining treatment. If surgical treatment is chosen, surgeons must be aware of the operative indications, ensure careful planning and preparation are occurring before the operation, understand suitable surgical timing, and have the necessary surgical skill. To achieve a satisfactory outcome, any complications that occur should be addressed according to the specific situation.

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