A prospective study on radiological & functional outcome of syndesmotic screw fixation in distal tibiofibular syndesmotic injuries associated with ankle injuries

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Abstract

Introduction and Purpose: Improper alignment, malreduction and neglecting to foresee syndesmotic injuries in ankle trauma led to persistent post operative ankle pain, delay in recovery and early arthritic changes of ankle joint. The treatment of distal tibiofibular syndesmotic injuries is a major concern in ankle injuries. The objectives of this study is to have Preoperative suspicious, assessment of mode of injury, stress x-rays and intraoperative test for all ankle injuries to avoid missing syndesmotic injuries and there by the treatment.

Materials and Methods: This is a prospective study of 28 ankle injuries diagnosed to have syndesmotic injury. All cases are due to RTA or fall while walking. Mostly of Weber type b and c. Compound grade I, II & III A were also included. After clinical and radiological investigations, diagnosis was confirmed and intraoperative test done and bimalleolar fracture fixed first then syndesmotic injury fixed with either single or double cortical screws and with 3 or 4 cortex purchase. Postoperative check x rays taken for checking proper reduction of the syndesmotic joint and level of screw placement. Post operative outcome were measured using AOFAS score chart.

Results and Discussion: Results of our study shows excellent (AOFAS 90-100) in 17 cases, good (AOFAS 80-89) in 9 cases, fair (AOFAS 70-79) in 1 case and poor (AOFAS less than 70) in 1 case. With this we come to the conclusion that (1) pronation external rotation injury is the common type. (2) Diagnosis of distal syndesmotic injuries and fixing it is very much important for having pain free stable ankle joint, early mobilization and preventing ankle joint arthritis. (3) Three cortical or four cortical purchase of syndesmotic screw is not significant in postoperative maintenance of reduction. (4) There is no definitive disadvantage if the syndesmotic screws were not removed.

Keywords: Prospective, radiological, functional, syndesmotic, fixation

Introduction

The lower extremity is the most common region of injury in road traffic accidents and other sports activities like running, jumping, twisting. One of the most common injuries faced by a practicing orthopaedic surgeon is the injuries of the ankle. We also see many numbers of cases treated by native bone setters and the patients present to our OPD with crippling disabilities. These ankle injuries are life challenging when coming to sports and athletes, for people working on uneven surfaces (our farmers). So, these ankle fractures are of utmost importance for being suspected, early diagnosed, and treated accordingly. For all these, we must be aware of the normal anatomy of the ankle joint, its biomechanics, its bony and ligamentous involvements, its pathology, clinical and radiological methods for diagnosing, and it’s potential for healing.

In 1950 Lauge-Hansen gave a classification with a simplified form that associates the fracture pattern, the mechanism of injury. Another classification is the Denis-Weber classification based on the fracture location compared to the distal syndesmotic joint. The AO/OTA classification of malleolar segment fractures is one of the most frequently used systems for classifying malleolar fractures. It takes the Danis-Weber classification into account and can be correlated to the Lauge-Hansen classification.
The management of these fractures are varying with time, and increasing availability of imaging modalities like MRI. Quenu E. Du [25] first published a case of tibiofibular diastasis after ligamentous disruption more than a century ago. This has increased the interest for further research studies on these injuries and controversies in treatment modalities raised.

**Aim of the study:** To evaluate the functional & radiological outcome of syndesmotic injuries associated with various ankle fractures treated with syndesmotic screw. Our objective is to evaluate the clinical and radiological measures by Assessing the syndesmotic injuries, Anatomical reduction, Biomechanics of syndesmotic ankle injuries.

**Epidemiology:** Ankle injuries account for 10% of all the fracture (Tim white, Kate bugler) [23] and is the second most common type in lower limb fractures next to hip fractures. In that, syndesmotic injuries occur in 1-18% of all ankle sprains (Angelo Del Buono et al.) [26]. The mean age of injury is about 45 years. It’s having a bimodal distribution with a peak incidence of ankle fractures in younger men and older women. The evidence for obesity as a risk factor comes from the international GLOW study of 60,393 women. It was found that obese women over the age of 55 years were significantly more likely to sustain an ankle fracture than nonobese women. Open injuries of the ankle are also common in low-velocity injuries. There is also specific epidemiology of specific fracture patterns. The AO/OTA type c fracture is more commonly due to fall from height or road traffic accidents while the AO/OTA type A or B is more common with simple fall. There is also a change in epidemiology with time. Between 1950 – 1980 there was an increased incidence in elderly females and younger males. In recent times, the incidence in young males is static while there is an increase in incidence among older females. The trabecular pattern of the distal tibia in elderly patients with ankle fracture are abnormal, depleted and the bone quality is much reduced when compared to uninjured controls. So, this fracture can be considered as true osteoporotic fracture. The highest risk appears to occur in high-velocity contact sports (football, kabaddi, etc) where there is a demand for the intensity of play, twisting, and risk of collision. Jones and Amendola [22] found that time lost from the sport because of these injuries varied with 10 to 14 days and up to 52 days. Boytim et al. [18] compared the return to play of high ankle sprains with routine ankle sprains and found that the individuals with high ankle sprains missed on average 1.4 games and 6.3 practices.

**Inferior Tibio Fibular Joint**

The inferior tibiofibular joint is a syndesmotic joint between the convex surface of the distal fibula and the concave surface of distal tibia. The distal fibula is firmly attached to the fibular notch of the tibia by syndesmotic ligaments. The stability of this joint is very important for the functioning of the entire limb.

**The ligaments are**
- Anterior inferior tibio-fibular ligament
- Posterior inferior tibio-fibular ligament
- The transverse ligament
- The interosseous ligament.

**Anterior Inferior Tibio-Fibular Ligament:** It is the strongest ligament in this syndesmotic joint. It is attached in the tubercle of Chaput present on the anterior aspect of the tibia and the other end on the tubercle of Wagstaff on the fibula. Fibers increase in length from proximal to distal. So, the distal Fibers are the longest. The function of this ligament is not only to hold the fibula tight into the incisura but also prevent excessive fibular movement and external talar rotation.

**Posterior Inferior Tibio-Fibular Ligament:** The posterior inferior tibiofibular ligament has two components. The superficial and deep components. The superficial fibers originate from the posterior tubercle of tibia and run obliquely, distally and laterally to the posterior aspect of lateral malleolus. This ligament holds the fibula close in the incisura. The deep component is the transverse ligament. It is thick and strong. Its fibres are twisted. It passes from the posterior tibial margin to the osteochondral junction on the posteros medial margin of distal fibula. The location of the transverse ligament below the posterior tibial margin prevents posterior talar translation. The ligament creates a posterior
The interosseus ligament pushes the desmosis, rupture of TF ligaments, the deltoid es accessory of gastrocnemius muscle. Syndesmotic association with other bony or ligamental on injuries, the talus is

Diastasis without fibular fracture can be classified into two ligament and the lateral malleolus fracture above the ankle. Injuries to the syndesmosis ligaments are mostly incomplete and occurs in association with other bony or ligamental injuries. Depending on the mechanism of force involved the ATFL can be sprained or even avulsed from the tibia or fibula. Continuous application of external rotation force can rupture the Tibiofibular ligaments and the interosseous membrane and possibly cause an oblique or spiral fracture of the fibula.

Mechanism of Injury
The most common type of injury causing syndesmotic disruption external rotation injury and hyperdorsiflexion injuries. In pronation external rotation injuries, the talus is unable to rotate within the mortise and tends to displace the lateral malleolus and thereby disrupting the ATFL and superficial PITFL, the transverse ligament, or a combination of all these. The twisting injury may also tear the interosseous membrane or even fracture the proximal fibula.

Injury to Tibiofibular Syndesmosis
A careful history taking, physical examination and a high degree of suspicion are important in getting a correct diagnosis of syndesmotic injury. When the force disrupts the congruency of ankle mortise, the syndesmotic injury occurs. Injury to syndesmosis can occur to any of the following structures. The first and the most common to be injured is the AITFL, followed by PITFL, the transverse ligament and the interosseous ligament.

External rotation is greatly increased by incising both anterior aspect of the deltoid ligament, the anterior tibiofibular ligament or the posterior talofibular ligament. Hence the rupture of the distal tibio fibular structures occurs only with external rotation injuries. ATFL injury alone is a rare and complete rupture of the distal TF structures are mostly combined along with it.

Isolated syndesmotic injuries, without bony injury, are thought to occur mainly from forced dorsiflexion and external rotation in combination with axial load. The syndesmotic ligaments are in fully taut position when the ankle is either in maximum dorsiflexion or plantar flexion. And when the external rotation force occurs at ankle causes the talus to press against the lateral malleolus. This rotational movement first ruptures the AITFL and if the rotational movement continues then it injures the Interosseous membrane and then the PITFL. In skirting and skiing the boot does not allow any sagittal plane movement and this results in excessive external rotation and injury to the syndesmosis. Ankle mortise is widened due to excessive dorsiflexion also. Normally dorsiflexion causes the interosseous ligament to become taut. Since the anterior aspect of talus is wider than the posterior part, the wider portion of the talus pushed the malleoli apart during the full dorsiflexion. This excessive force can rupture the syndesmosis ligaments. Hyper dorsiflexion type of injuries is seen in jumping and running sports activities where the foot is planted in ground and the person falls forward. In skirting the person falls forward and the ankle is hyper dorsiflexed on his board resulting in syndesmotic injury. The chance of hyper dorsiflexion type injury is low when the knee is in extended position due to the increased tightness of gastrocnemius muscle. Syndesmotic

In latent diastasis the mortise will not widened in normal x-ray but when stress view is taken the widening will be visualised.

In frank diastasis the widening of the mortise can be visualised in routine x ray.

The functional Anatomy and Biomechanics
The distal tibiofibular joint is a syndesmotic joint and its main function is to accommodate the talus while in dorsiflexion and plantar flexion. Dorsiflexion can be described as a movement of dorsum of foot towards anterior aspect of tibial shin. Plantar flexion is the movement of foot away from tibia. The normal range of movement at ankle is between 15 to 20 degrees in dorsiflexion and 45 to 55 degrees in plantar flexion. The trapezoidal-shaped talus requires accessory movements to gap and approximate the mortise during the sagittal plane movement of ankle. The anterior aspect of the superior talar surface is 3-4mm wider than it posterior aspect. The syndesmotic joint acts as a spring to widen the mortise to accommodate the talus while in dorsiflexion and then it recoils itself while in plantar flexion. Ankle stability is more in dorsiflexion and decreased in complete plantar flexion.

In spite of decreased bony stability in plantar flexion the posterior part of talus remains inside the mortise due to talar rotation. Inversion, eversion, supination and pronation are the movement at the subtalar joint. Inversion is called as inward movement of the sole of foot, and eversion is outward movement. Supination is the combination of foot adduction, calcaneal inversion and plantar flexion. Pronation is the combination of foot abduction, calcaneal eversion and dorsiflexion. Normal range of inversion 20 to 30 degrees, eversion 5 to 15 degrees.

The main function of the distal ankle ligaments is primarily to prevent the lateral displacement of fibula from incisura fibularis. When the diastasis occurs, there will be separation of the syndesmosis, rupture of TF ligaments, the deltoid ligament and the lateral malleolus fracture above the ankle. Diastasis without fibular fracture can be classified into two categories.
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Functional Anatomy and Biomechanics
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injuries can also occur in severe inversion/eversion of ankle sprains. Maximum eversion of the subtalar joint can rupture the deltoid ligament, and the force of the talus pushed the fibula laterally, there by damaging the syndesmotic ligaments. Severe inversion injuries cause the lateral ankle ligaments strain and can also disrupt the ankle mortise and stability of fibula. In the mechanism of inversion/eversion, the distal fibula the medial malleolus or the lateral malleolus usually get fractures before the rupture of the syndesmotic ligaments. Bony injury does not always reliably reveal the underlying ligamentous injury - stress tests including external rotation of the foot and stressing the fibula with a bone hook.

Clinical features will be
- Swelling of ankle and foot
- Tenderness over the swelling
- Ankle deformity
- Most of the cases have high soft tissue swelling but open injuries are comparatively low.

Usually, there will be adequacy of distal neuro vascularity. But have to be checked and documented.

| Clinical tests |
|---------------|
| **Weber A** = Lauge Hansen Supination adduction |
| **Weber B** = Lauge Hansen Supination external rotation |
| **Weber C** = Lauge Hansen Pronation external rotation |

Fig 7: Comparison of classification

Fig 5: Danis -weber classification

Fig 6: Lauge-Hansen classification

Fig 8: External rotation stress test

Squeeze test: This test is done by compressing the proximal part of the fibula to the tibia, this will separate the two bones distally and will cause pain if there is a syndesmotic injury.
**Forced dorsiflexion test:** The ankle is dorsiflexed forcefully either manually or with an athletic tape, there will be pain and this pain will decrease when the manoeuvre is repeated while compressing the distal end of the tibia and fibula. This suggests the presence of syndesmotic injury.

**Crossed-leg test:** It is done by crossing the injured leg over the uninjured leg while the patient is seated. A gentle downward pressure to the knee of the injured leg will cause pain suggesting syndesmotic injury.

**Intraoperative tests:** Hook test is done intraoperatively after fixation of fibula. The fibula is distracted using a bone hook separating from tibia, under fluoroscopy. If there is no displacement then the syndesmosis is intact if there is more than 3–4mm displacement then it suggests syndesmotic injury.

**Cotton test:** It is done by stabilising the distal tibia and fibula with one hand and a thrust is applied from medial to lateral side on the hindfoot. The test is said to be positive with syndesmotic injury if a lateral translation of more than 3–5mm.

**Radiological Findings in Normal Ankle Joint**
The common radiological investigation is x ray of ankle anteroposterior view, lateral view and mortise view.

**The normal findings are**
- Tibio fibular overlap of more than 5mm on AP view
- Tibio fibular clear space less than 5mm
- Medial and superior clear space should be equal

**Pre operative planning:** Radiolucent operating table, Supine positioning of the patient with a bolster under the ipsilateral buttock, Fluoroscopy located on the contralateral side.

**Materials and Methods**
Our study is a Prospective study over a period of One and
Half years (June 2020 to November 2021). 28 patients were included in our study. All the cases were from our RMMCH Emergency ward and Orthopaedic OPD. Proper history was recorded to find out the mode of injury. Clinical examination done with all stress tests. All required laboratory investigations are done and covid protocols are followed strictly to get anaesthesia fitness for surgery. Consent was obtained meticulously for performing surgery, Anaesthesis, And For inclusion in our study.

**Inclusion criteria**
1. Skeletally matured patients
2. 18 to 65 years old
3. Closed simple injuries
4. Grade I, Grade II, and Grade III A compound injuries
5. Those who give consent for surgery.

**Exclusion criteria**
1. Patients below 18 years
2. Compound grade III C.
3. Unacceptable High risk for surgery and anaesthesia
4. Severe comminutions and bone loss
5. Non-complaint patients.

Pre operative assessment is done for all patients. All haematological and radiological investigations were done.

**Radiological Investigation**
X ray of ankle: Antero-posterior view, Lateral view, Mortise view. Ct scan of the ankle for few cases with severe comminutions. Emergency stabilisation done with below knee pop slab with adequate padding.

Time interval between injury and surgery1 to 10 days. Mostly done under regional anaesthesia.

**Implants and Instrumentations:** K – wires, Ss – wires, 1/3rd tubular plates, Recon plates, Anatomical locking plates, Malleolar screws, Cortical screws 3.5mm, 4.5mm, Cannulated cancellous screws 4.0mm.

**Procedure Done**

**Fixation of lateral malleolus:** The patient is placed supine. Bolster is placed under the ipsilateral hip to allow foot to lie vertically. Under tourniquet control, the lateral malleolus is addressed first. An incision of 5 to 8cm is placed directly over the fibula and centered on the fracture. Blunt dissection is performed through subcutaneous tissue for avoiding injury to the superficial peroneal nerve. The fracture is identified. Periosteum and ligamentous interventions are cleared from the fracture edges. Reduction is achieved and held by the “lobster claw” clamp. If more force is necessary, inversion and distraction of foot and ankle is done. This will help in regaining length of fibula. A one-third tubular plate or anatomical locking plate of sufficient length is selected so as to allow the placement of three screws below and above the fracture.

**Fixation of fracture medial malleolus:** Incision of about 5 to 8cm placed over the medial malleolus, skin and subcutaneous tissue incised. Soft tissue interposing between the fracture sites is removed. Fracture reduced and fixed using 4.5 mm malleolar screws. If the fractured fragment is small then either K wire stabilization or Tension Band applied for transverse fracture. The syndesmotic injury is reduced first with a reduction clamp. During the reduction the ankle is kept in the neutral position or in slight dorsiflexion. Then the reduction is checked under fluoroscopy. After satisfactory reduction is achieved drilling is done. Screws are positioned at 2 – 3 cm proximal to the ankle joint line (tibial plafond), parallel to it and angled at 30 degrees from posterolateral surface of fibula to anteromedial surface of tibia.

**Use of reduction clamps:** Variations in the direction of reduction clamps and syndesmotic screw placement can cause iatrogenic syndesmotic mal-reduction.

- An angulation of 15 and 30 in the axial plane can displace the fibula in external rotation and cause over compression at the syndesmosis.
- Clamp placed in neutral anatomical axis reduces the syndesmosis most accurately
- Fixing of the fibula in as much as 30° of external rotation may go undetected even with use intraoperative fluoroscopy.

The most common malreduction was fibular malpositioning, followed by malreduction of the fracture. It was recommended to keep the ankle in maximal dorsiflexion, during syndesmotic fixation to prevent postoperative limitation of motion; however, there are data against this finding and the maximal dorsiflexion may induce an external rotation moment, risk ingmalreduction. However, while the strength of fixation, stabilizes the joint, it also eliminates normal motion between the tibia and fibula.

**Placement of syndesmotic screw**

- If the screw is placed too proximally, then it may deform the fibula and cause the mortise to widen.
- If the screw is not parallel to the joint, the fibula may shift proximally.
- If the screw is not perpendicular to the tibiofibular joint, the fibula may remain laterally displaced.

The AO group also recommend a fully threaded syndesmotic screw in a neutralization mode.

![Fig 14: Placement of screw](image)

![Fig 15: Placement of screw cross section view](image)
Post Operative Follow-Up
Dressing done on 3rd, 6th, 9th, and 12th pod. Suture removal on 12th POD after a healthy wound. Below knee, pop cast was given after that for 6 to 8 weeks with non-weight bearing walking. Check x ray for assessing the callous formation and union done every one-month interval. Follow up and evaluation for the joint made at 4th week, 8th week, and 6th month end. Active physiotherapy given for getting ankle mobility till full range of movement is achieved. Weight bearing allowed at 8 – 12 weeks. Postoperative scoring system given below.

![Fig 16: AOFAS Ankle-Hindfoot Scale (100 Points Total)](image)

AOFAS score grading (Scott J. Mubarak, MD et al. [37])

- **Excellent**: 90 – 100
- **Good**: 80 – 89
- **Fair**: 70 – 79
- **Poor**: less than 69

Case illustration

**Case -1**: A 35-year-old male patient sustained injury to his left ankle due to history of RTA and was diagnosed as Lateral malleolar fracture left ankle – with syndesmotic injury – Weber Type C

Preoperative x-ray

![Fig 17: Intra operative images](image)

**Case 1**: A 38-year-old female patient with history of RTA sustained injury to her left ankle and diagnosed to have Bimalleolar fracture left ankle – compound grade III B with ankle dislocation and syndesmotic injury – Weber B
Results

We had 28 patients in our study having ankle fractures associated with syndesmotic injury. All were operated within a range of 0 to 10 days from the date of injury. The longest follow up period was 16 months. Follow up analysis was made using the AOFAS score and AOFAS grading criteria.

In our study, we had 42% of patients with less than 40 years of age. In which, 53% of patients were male and there was no difference in the side affected.

| Age   | Number of cases | Percentage |
|-------|-----------------|------------|
| < 40  | 12              | 42.85      |
| 41 – 65 | 16            | 57.15      |
| Total | 28              | 100        |

| Sex   | Number of cases | Percentage |
|-------|-----------------|------------|
| Male  | 15              | 53.57      |
| Female | 13            | 46.43      |
| Total | 28              | 100        |

We had 17(61%) patients sustained injury due to RTA, and the remaining were by self-fall while walking in home.

Graph 1: Mode of Injury

| Mode of Injury | No. of cases |
|----------------|--------------|
| self fall      | 11           |
| RTA            | 17           |
This study aimed to evaluate the outcomes of syndesmotic injuries in 28 patients. Out of 28 patients, 18 patients developed syndesmotic injury due to pronation external rotation injury, 6 patients due to supination external rotation injury, and the remaining 4 patients due to pronation abduction injury. Hence in our study also it is proved that pronation external rotation injury is the most common type of ankle injury leading to syndesmotic injury as also stated by Mark J. Boytim et al. (18). Regarding the number of cortices purchased by syndesmotic screws, we had 3 cortex purchase in 29 syndesmotic screws placed. And 4 cortex purchase in 8 syndesmotic screws None of them experienced screw pull-out. There was also no screw breakage in our patients during our follow-up. We have not done any secondary procedure of syndesmotic screw removal.

In a prospective study, Hoiness and Stromsoe done any secondary procedure of syndesmosis fixation (17). Gaurav Kumar Sharma et al. (33) showed a higher incidence rate for ankle injury in males between 15-39 and in females over forty years old compared with their opposite-sex counterparts. In our study also we have 8 males out of 12 cases, with the age of less than 40 years. In more than 40 years patients, there were 9 females and 7 males, which corresponds to the above study.

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We had 3 patients who developed wound infection postoperatively. All 3 were compound injuries. They were treated with higher IV antibiotics and recovered.

### Discussion

Fractures around the ankle joint are not uncommon in our orthopaedic practice. The primary goal of our treatment is to obtain a pain-free, stable ankle joint with preservation of maximum function. The mean age of our study is agreeable with other studies of Davis et al. (4), Hasselman et al. (9). Though the inclination is towards older age, our study shows a wider range between 20 to 65 years. Our study shows the ratio of male vs female of 15:13. We have a little higher incidence in male patients. A higher incidence of young male patients shows mostly due to RTA while in female, it’s due to slip and fall in the home in their older age, similar to Davis et al. (4). Bridgman et al. (33) showed a higher incidence rate for an ankle injury in males between 15-39 and in females over forty years old compared with their opposite-sex counterparts. In our study also we have 8 males out of 12 cases, with the age of less than 40 years. In more than 40 years patients, there were 9 females and 7 males, which corresponds to the above study.

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In surgical technique the syndesmotic screw insertion should be done after the syndesmosis held together with reduction clamp to avoid shifting of the drill holes and all screws should be fully threaded. We don’t want a lag effect in our syndesmotic screws. The drill should be centered on the fibula to avoid fracture. And is directed at 25 to 30° oblique direction from posterolateral to anteromedial. Browner BD et al. (3) Gaurav Kumar Sharma et al. (29) in his article says that RTA is the most common mode of injury followed by fall and industrial accidents with a significant majority of fracture being open. The outcomes of severe injuries were similar to simple foot injuries. In our study also 60% of cases have RTA as a mode of injury. One of our patients developed early ankle arthritis at the 16th month of our follow-up. The most probable reason may be due to improper reduction of the syndesmotic joint during insertion of the syndesmotic screw. But longer
follow-up is needed for evaluating arthritis. We have achieved an AOFAS score of:
- More than 90 in 17 cases (60%)
- Between 80 to 90 in 9 cases (33%)
- Between 70 to 80 in 1 case (3.5%)
- Less than 70 in 1 case (3.5%)

In our follow up, we have not encountered any heterotopic ossification in the interosseous membrane of the affected ankles, or synostosis, in our study. It is recommended that posterior fragments greater than 25% of the size should be fixed, by Christain Bergman et al. [31]. In our study also we have fixed 5 cases of posterior malleolar fracture which has more than 25% of its articular size. Because of the low complication rate and much difficulty in treatment of late syndesmotic diastasis, a syndesmotic screw should be placed when in doubt of the indication. (Michel P.J van den Bekerom) [30]. In our study also few cases of Weber type B fractures were in doubt of stability and syndesmotic injury but we fixed the syndesmotic joint with a syndesmotic screw. Syndesmotic screw fixation with one or two screws need not compulsorily be removed for the fear of screw breakage on weight-bearing walking (Michel P.J van den Bekerom) [30].

**Conclusion**

Based on the results of our study, the following conclusions are made.

For all ankle fractures cases associated with syndesmotic diastasis, open reduction and internal fixation of the malleoli and diastasis should be fixed with syndesmotic screw, to achieve a fracture union, pain-free and stable ankle joint. A syndesmotic screw can be placed whenever there is a doubt about stability of inferior tibiofibular joint, intraoperatively.

In conclusion, treating the ankle fractures with syndesmotic diastasis, a syndesmotic screw should be placed in a high-fidelity cadaver model. J Bone Joint Surg Am. 2002;84-A(11):2029–2038.

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