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ULOGA I ZNAČAJ FIKSACIJE ZADNJEG MALEOLUSA KOD TRIMALEOLARNIH PRELOMA

Marko Mladenović (1), Predrag Stojiljković (1,2), Desimir Mladenović (2), Andrija Krstić (1), Vladimir Anđelković (3)

(1) KLINIČKI CENTAR NIŠ, KLINIKA ZA ORTOPEDSKU HIRURGIJU I TRAUMATOLOGIJU, NIŠ, SRBIJA.; (2) UNIVERZITET U NIŠU, MEDICINSKI FAKULTET, NIŠ, SRBIJA.; (3) ODELJENJE ZA ORTOPEDSKU HIRURGIJU I TRAUMATOLOGIJU, ZDRAVSTVENI CENTAR, LESKOVAC.

SAŽETAK: UVOD. Prelomi skočnog zgloba su na trećem mestu po učestalosti, posle preloma zgloba kuka i ručnog zgloba. Prelomi zadnjeg maleolusa su česti, oko 7% do 44% od svih preloma skočnog zgloba, a samostalno su veoma retki i to je prelom Volkmann-ovog trougla. Skočni zglob je noseći zglob u čovečjem telu, a prelomi uglavnom nastaju u okviru rotacije tela sa fiksiranim stopalom u različitim pozicijama. Zadnji maleolus je veoma važna struktura u stabilizaciji distalnog tibiofibularnog zgloba. **MATERIJAL I METODE** - retrospektivno prikazujemo grupu od 21 pacijenta koji su imali prelom skočnog zgloba a i operisani su u Klinici za ortopediju i traumatologiju u Nišu u periodu od januara 2013. do decembra 2015. godine. Osnovni kriterijum za operativno lečenje je veličina fragmenta, >25% od zglobne površine tibije i dislokacija >2mm. Sve prelome skočnog zgloba klasifikovali smo po Lauge-Hansen sistemu a koji se bazira na mehanizmu povrede. Efekat lečenja smo procenjivali prema Olerud-Molander klasifikaciji, praćeni su subjektivni i objektivni znaci. **REZULTATI** - etiološki razlozi preloma su: pad na istom nivou - sport, klizanje 11 (52,3%) pacijenata, pad sa visine 6 (28,6%) i saobraćajni udes 4 (21,1%). Prema Lauge-Hansen klasifikaciji bilo je 15 (71,4%) pacijenata sa prelomom tipa SER, 4 (19%) tipa PER i 2 (9,6%) tipa PA. Krajnji rezultat lečenja je odličan kod 13 (61,9%) bolesnika, dobar kod 7 (33,4%) i loš kod 1 (4,7%). Posttraumatski artritis (PTA) procenjivan je posle godinu dana od operacije i prisutan je kod 12 (57,1%) pacijenata - stepen 1 i 2. **ZAKLJUČAK** - veličina odlomljenog fragmenta zadnjeg maleolusa i stepen dislokacije određuju način lečenja preloma zadnjeg maleolusa. Operativno lečenje preloma daje odlične rezultate.

Ključne reči - skočni zglob, malleolus posterior, fiksacija, posttraumatski artritis.

UVOD

Prelomi skočnog zgloba relativno su česti, incidenca pojavljivanja je 187 prelomana 100.000 (1:800) stanovnika godišnje [1], tj. 3,92% u odnosu na sve prelome tela [2]. Prelomi zadnjeg maleolusa su česti, oko 7% do 44% od svih preloma skočnog zgloba [3,4], a samostalno su veoma retki i to je prelom Volkmann-ovog trougla [5]. Skočni zglob je noseći zglob u čovečjem telu, a prelomi uglavnom nastaju u okviru rotacije tela sa fiksiranim stopalom u različitim pozicijama. Destot [6] je 1911. godine prvi dao opis zadnjeg maleolusa, a Henderson [7] je 1932. godine prvi uveo termin trimaleolarni prelom. Trimaleolarni prelomi skočnog zgloba imaju lošiju prognozu od povreda bez preloma zadnjeg maleolusa, tzv. bimaleolarni prelomi [8,9] - tada nastaje frakturi displasman, poremećaj kongruencije artikularnih površina, tibiotalarna subluksacija i

nestabilnost skočnog zgloba. Cilj tretmana preloma skočnog zgloba je redukcija i obuzdavanje talusa u anatomskom položaju i njegovo uglavljanje u zglobnu viljušku.

Zadnji maleolus je veoma važna struktura u distalnom tibiofibularnom zglobu - pruža ograničenje distalne fibule i stabilizuje tibiofibularnu sindesmozu preko posteroinferiornog tibiofibularnog ligamenta (PITFL) i inferotransverzalnog ligamenta (ITL). Ogilvie-Harris i saradnici [10] navode da PITFL pruža 42% snage i stabilnosti sindesmoze. Integritet zadnjeg maleolusa i ligamentarnih pripoja je važan za prenos težine, zadnju stabilnost talusa i za rotatornu stabilnost. Ovaj tip preloma skočnog zgloba udružen je sa prelomom posteriornog tuberculum tibiae na kome se pripaja PITFL.

Indikacije za internu fiksaciju preloma zadnjeg maleolusa zavise od veličine i stepena

ROLE AND IMPORTANCE OF POSTERIOR MALLEOLUS FIXATION IN TRIMALEOLAR FRACTURES

Marko Mladenović (1), Predrag Stojiljković (1,2), Desimir Mladenović (2), Andrija Krstić (1), Vladimir Anđelković (3)

(1) KLINIČKI CENTAR NIŠ, KLINIKA ZA ORTOPEDSKU HIRURGIJU I TRAUMATOLOGIJU, NIŠ, SRBIJA.; (2) UNIVERZITET U NIŠU, MEDICINSKI FAKULTET, NIŠ, SRBIJA ;(3) ODELJENJE ZA ORTOPEDSKU HIRURGIJU I TRAUMATOLOGIJU, ZDRAVSTVENI CENTAR, LESKOVAC.

ABSTRACT: Introduction – ankle fractures are third when it comes to frequency, right after hip and wrist joint fractures. Posterior malleolus fractures are common, comprising 7% to 44% of all ankle fractures, and are very rare on their own; that is a Volkmann triangle fracture. Ankle is a supporting joint in the human body, and fractures generally occur within rotation of the body with different fixed foot positions. The posterior malleolus is a very important structure in distal tibiofibular joint. **Material and methods** - we retrospectively present a group of 21 patients who had a fracture of the ankle and were surgically treated at the Clinic for Orthopedics and Traumatology in Niš during the period from January 2013 to December 2015. The basic criterion for surgical treatment was the size of the fragment, > 25% from tibial joint surface and dislocation >2mm. We systemized all ankle fractures according to the Lauge Hansen system, which is based on the mechanism of injury. We evaluated treatment results according to the Olerud-Molander classification, followed by subjective and objective signs. We systemized posterior malleolus fractures into three types, according to the Haraguchi classification. **Results** - etiological causes of the fractures are: a fall at the same level - sport, skating in 11 (52.3%) patients, a fall from a height in 6 (28.6%) and traffic accident in 4 (21.1%) patients. According to the Lauge Hansen classification, there were 15 (71.4%) patients with a SER-type fracture, 4 (19%) of the PER type, and 2 (9.6%) of the PA type. End result of the treatment was excellent in 13 (61.9%) patients, good in 7 (33.4%) and poor in 1 (4.7%) patient. Post-traumatic arthritis (PTA) was assessed one year after the surgery and level 1 and 2 were present in 12 (57.1%) patients.

Keywords:– ankle, malleolus posterior, fixation, post-traumatic arthritis.

INTRODUCTION

Ankle fractures are relatively common, with an incidence of 187 fractures in 100,000 (1: 800) people per year [1], i.e. comprising 3.92% of all fractures in the body [2]. Posterior malleolus fractures are very common, comprising between 7% to 44% of all ankle fractures [3,4]; and are very rare on their own, and this is a fracture of the Volkmann triangle [5]. Ankle is a supporting joint in the human body, and fractures generally occur within rotation of the body with the foot fixed in different positions. Destot [6] was the first who described posterior malleolus in 1911, and Henderson [7] was the first who introduced the term trimaleolar fracture in 1932. Trimaleolar ankle fractures have a poorer prognosis than injuries without posterior malleolus fractures, so-called bimaleolar fractures [8,9] - fractured displacement,

disorder of articular surfaces congruence, tibiotalar subluxation and instability of the ankle joint occur in this situation. The aim of ankle joint fracture treatment is to reduce and restrain talus in its anatomical position and inserting it into the ankle fork.

Posterior malleolus is a very important structure in the distal tibiofibular joint - providing restriction for distal fibula and stabilizing tibiofibular syndesmosis via posterior inferior tibiofibular ligament (PITFL) and inferior transvers ligament (ITL). Ogilvie-Harris et al. [10] state that PITFL enables 42% of strength and stability of syndesmosis. Integrity of the posterior malleolus and ligamentous adhesions is important for weight transfer, posterior talus stability, and rotational stability. This type of ankle joint fracture is associated with posterior

dislokacije fragmenta. Za dijagnostiku preloma koristi se lateralna radiografija, mada se sve više preporučuje kompjuterizovana tomografija (CT). Ukoliko fragment zauzima više od 25% od plafona tibije i postoji dislokacija više od 2 mm, onda je prisutna nestabilnost skočnog zgloba sa udruženom povredom sindesmoze i perzistentne zadnje subluksacije talusa – tada postoji apsolutna indikacija za operaciju [11,12]. Na snimcima se određuje i ugao između bimalleolarne osovine i linije preloma zadnjeg maleolusa, koji iznosi do 400, a predstavlja stepen spoljne rotacije tibije [12]. Zadnji maleolus treba biti fiksiran iz više razloga: on predstavlja deo artikularne površine tibije, sa prelomom nastaje nekongruencija skočnog zgloba, remeti se kontakti pritisak između zglobnih površina - što je fragment veći pritisak je veći [13]. Zbog pripoja PITFL od fibule do zadnjeg maleolusa, nefiksirani zadnji maleolus sa vremenom dovodi do sekundarne dislokacije fibule iako je ona fiksirana, a to stvara mogućnost za postero-lateralnu nestabilnost talusa. Posle redukcije i fiksacije zadnjeg maleolusa, artikularna površina tibije je restaurirana, fibula nije skraćena, sindesmoza je stabilna i rehabilitacija pacijenta je brža [14]. Prelomi skočnog zgloba se događaju kada sila spoljašnje rotacije, abdukcije ili addukcije deluje na stopalo koje je fiksirano u supinaciji (u 70% slučajeva) ili pronaciji (u 30% slučajeva) [15]. Cilj rada je da prikazemo ulogu i značaj fiksacije zadnjeg maleolusa pri hirurškom tretmanu trimaleolarnih preloma.

MATERIJAL I METODE

Retrospektivno prikazujemo grupu od 21 pacijenta koji su imali prelom skočnog zgloba i operisani su u Klinici za ortopediju i traumatologiju u Nišu u periodu od januara 2013. do decembra 2015. godine. Urađena je i fiksacija zadnjeg maleolusa, a minimalno vreme praćenja je 18 meseci.

Kriterijumi za uključivanje povređenih u ovu studiju su: 1) definitivna dijagnoza preloma skočnog zgloba bazirana na kliničkom i radiološkom nalazu; 2) uključen je i prelom zadnjeg maleolusa; 3) fragment zadnjeg maleolusa zahvata >25% od zglobne površine tibije; 4) fragment je nestabilan i deplasiran >2mm; 5) urađena je redukcija i fiksacija maleolusa; 6) starost pacijenata od 18 do 70 godina; 7) kompletno kliničko praćenje na 3, 6, 12 i 18 meseci.

Klinički pregled i radiološko ispitivanje je neophodno, potrebno je uraditi i CT posle povređivanja i posle operacije, ako za to postoje uslovi.

Veličinu fragmenta zadnjeg maleolusa određivali smo na LL radiološkom snimku. Dobija se deljenjem dužine distalne artikularne površine tibije sa dužinom fragmenta – to je distanca od linije preloma do zadnjeg ruba tibije, izraženo u procenatima. Vertikalnu dislokaciju merimo na LL snimku, to je visina stepenika zadnjeg ruba tibije, izraženo u mm. Na istom snimku merili smo i stepen spoljne rotacije [12], (Slika 1).

Slika 1. Antero posteriorni i lateralni radiografski prikaz luksantne frakture sa kompletnom dislokacijom i trimaleolarnim prelomom.

tuberculum tibia fracture, to which the PITFL is attached.

Indications for internal fixation of posterior malleolus fracture depend on size and degree of fragment dislocation. Lateral radiography is used for fracture diagnostics, although computerized tomography (CT) is increasingly recommended. If the fragment comprises more than 25% of tibial ceiling and there is a dislocation larger than 2mm, then there is instability of ankle joint with associated syndesmosis injury, and persistent posterior talus subluxation – in this case there exists an absolute indication for surgery [11,12]. The images are also used to determine the angle between bimaleolar axis and posterior malleolus fracture line, up to 40°, representing the degree of external tibia rotation [12].

The posterior malleolus needs to be fixed for a number of reasons: it forms a part of articular tibia surface, with a fracture there occurs articular non-congruence of the ankle joint, contact pressure between joint surfaces is disrupted - the larger the fragment is, the larger the pressure [13]. Due to the attachment of PITFL from fibula to posterior malleolus, the non-fixed posterior malleolus eventually leads to secondary fibula dislocation, even though it is fixed, which creates a possibility for postero lateral talus instability. After reduction and posterior malleolus fixation, articular tibia surface is restored, fibula is not shortened, syndesmosis is stable and the patient's rehabilitation is faster [14].

Ankle joint fractures occur when external rotational force, abduction or adduction are applied to the foot that is fixed in supination (in

70% of occurrence) or pronation (in 30% of occurrence) [15].

The aim of this paper is to present the role and importance of posterior malleolus fixation during surgical treatment of trimaleolar fractures.

MATERIAL AND METHODS

We retrospectively present a group of 21 patients who had ankle joint fracture and were surgically treated at the Clinic for Orthopedics and Traumatology in Niš from January 2013 to December 2015. Fixation of posterior malleolus was also performed, with a minimum follow-up period of 18 months.

Criteria for including patients in this study are:

1) definitive diagnosis of a ankle joint fracture based on clinical and radiological findings, 2) fracture of posterior malleolus, 3) posterior malleolus fragment occupies >25% of tibial joint surface, 4) the fragment is unstable and misplaced > 2mm, 5) reduction and fixation of malleolus have been applied, 6) patients age is from 18 to 70 years, 7) complete clinical monitoring for 3,6,12 and 18 months.

Clinical and radiological examinations are necessary; post-injury and post-surgery CT should be performed, but we did not do it.

Size of the posterior malleolus fragment was determined in LL radiological image. It is obtained by dividing the length of distal articular surface of tibia by the length of the fragment - this is the distance from the fracture line to posterior edge of tibia, expressed in %. Vertical dislocation is measured in LL image, and it is the height of posterior tibia edge step, expressed in mm. We measured the degree of external rotation [12] in the same image (Figure 1).

Sve prelome skočnog zgloba klasifikovali smo po Lauge Hansen sistemu [16], koji se bazira na mehanizmu povrede. Prva reč opisuje poziciju stopala, a druga pokrete talusa u odnosu na ekstremitet. Postoji pet tipova preloma skočnog zgloba: supinaciono external rotacioni tip (SER), supinaciono addukcioni (SA), pronaciono external rotacioni (PER), pronaciono abdukcioni (PA) i pronaciono dorzifleksioni (PD) tip. Prelomi zadnjeg maleolusa najčešće nastaju (>70%) kod SER tipa preloma, u IV stadijumu, a potom kod PER [17,18].

Haraguchi et al. [19] su dali klasifikaciju preloma zadnjeg maleolusa, postoje tri tipa.

I tip – zadnje spoljašnja kosa linija preloma, fragment je klinast i obuhvata zadnje spoljašnji deo plafona tibije, odgovarajući hirurški pristup je posterolateralni,

II tip – transversalno unutrašnji prelom, frakturna linija obuhvata tibial notch (udubljenje za fibulu) pa sve do medijalnog maleolusa i obično postoje dva fragmenta, odgovarajući

hirurški pristup je medijalni ili produženi medijalni, a sa ciljem da se fiksira samo medijalni fragment koji je uvek veći,

III tip – mali ljuspasti prelom, zahvata zadnju ivicu tibije u vidu ljuspe, ovaj tip preloma ne zahteva hiruršku intervenciju.

Odmah posle pripreme bolesnika (treba težiti ranoj hirurškoj intervenciji) radili smo operativni zahvat u spinalnoj ili intravesnoj sprovodnoj anesteziji uz upotrebu Tourniquet-a. Za direktnu redukciju i fiksaciju zadnjeg maleolusa koristili smo posterolateralni pristup i plasirali šraf (1 ili 2) u postero-anterior (PA) projekciji, ploču nismo koristili. Indirektnu redukciju smo ostvarili posle osteosinteze lateralnog i medijalnog maleolusa uz transfiksaciju sindesmoze, potom uradimo Rtg snimak i odredimo poziciju zadnjeg maleolusa – ako je ona dobra, plasiramo šraf u AP ili PA poziciju (Slika 2). Kod jednog broja bolesnika nismo radili fiksaciju fragmenta zbog veličine, manji od 15% tibijalne zglobne površine.

Slika 2. Antero posteriorni i lateralni radiografski prikaz kombinovane osteosinteze zadnjeg, spoljašnjeg i unutrašnjeg maleolusa.

Posle operacije postavljali smo potkolenu gipsanu longetu za period od tri nedelje, a posle 6 nedelja dozvoljen je hod sa štakama i osloncem na operisanu nogu sa postupnim povećanjem opterećenja. Radi

provere redukcije zadnjeg maleolusa, posle operacije uradimo kontrolni radiološki snimak, a preporučuje se i CT. Redukcija može biti odlična (artikularni stepenik je <1mm) i tada je artikularna površina ravna, dobra (stepenik

Figure 1. Antero posterior and lateral radiographic presentation of a luxurios fracture with complete dislocation and trimaleolar fracture

We systematized all ankle fractures according to Lauge Hansen system [16], based on the mechanism of injury. The first word describes foot position, and the other describes movements of talus relative to the extremity. There are five types of ankle joint fractures: supinational external rotational type (SER), supinational adductional (SA), pronational external rotational (PER), pronational abductional (PA) and pronational dorsiflexional (PD) type. The posterior malleolus fractures most commonly occur (>70%) in SER type of fractures in stage IV, and subsequently in PER [17,18].

Haraguchi et al. [19] provided a classification for three types of posterior malleolus fractures.

Type I - posterior outer oblique fracture line, fragment is wedge-shaped and includes posterior outer part of tibial ceiling; appropriate surgical approach is posterolateral;

Type II - transversely internal fracture, the fracture line includes tibial notch (fibula dent) down to medial malleolus, and there are usually two fragments; appropriate surgical approach is

medial or prolonged medial, with the aim of fixing only the medial fragment which is always larger;

Type III - small flakey fracture, that includes posterior edge of the tibia in the form of flake; this type of fracture does not require surgical intervention.

Having prepared the patient (early surgical intervention should be endeavored), we immediately performed surgery in spinal or I.V. conductive anesthesia with Tourniquet.

For direct reduction and fixation of posterior malleolus posterolateral approach was used and the screw was placed (1 or 2) in postero-anterior (PA) projection; we did not use the plate. Indirect reduction was achieved after osteosynthesis of lateral and medial malleolus with transfixation of syndesmosis; then we made an Rtg image and determined the position of posterior malleolus - if it is good, we place the screw in AP or PA position (Figure 2). In a number of patients, we did not perform fragment fixation due to its size (less than 15% of the tibia joint surface).

<2mm) i loša repozicija (>2mm) kada je površina neravna [20].

Rezultate lečenja smo procenjivali prema Olerud-Molander klasifikaciji [21], praćeni su subjektivni i objektivni znaci. Posttraumatski artritis (PTA) određivali smo na Rtg snimcima u toku praćenja pacijenata, a prema sledećem skor: 0 – normalan zglobo, 1 – osteofiti bez suženja zglobnog prostora, 2 – suženje zglobnog prostora sa ili bez osteofita, 3 – nestajanje i deformacija zglobnog prostora (22).

REZULTATI

Prikazana je serija od 21 operisanog pacijenta. Bilo je 12 (57,1%) žena i 9 (42,9%) muškaraca, od 18 do 70 godina, (prosek 48,8). Etiološki razlozi preloma su: pad na istom nivou - sport, klizanje 11 (52,3%) pacijenata, pad sa visine 6 (28,6%) i saobraćajni udes 4 (21,1%).

Veličina fragmenta zadnjeg maleolusa bila je u proseku 27,3% (od 25% do 34%).

Stepen spoljašnje rotacije, tj. ugao između dve linije je bio od 00 do 400.

Prema Lauge Hansen klasifikaciji bilo je 15 (71,4%) pacijenata sa prelomom tipa SER, 4 (19%) tipa PER i 2 (9,6%) tipa PA.

Prema Haraguchi klasifikaciji preloma zadnjeg maleolusa bilo je 12 (57,1%) pacijenata sa prelomom tipa I, 6 (28,5%) tipa II i 3 (14,4%) tipa III.

Vreme proteklo od povrede do operacije, u proseku je 1,6 dana (1 – 5 dana).

Direktna redukcija i fiksacija šrafovima urađena je kod 6 pacijenata, indirektna redukcija i fiksacija kod 12 i kod 3 pacijenata urađena je fiksacija lateralnog i medijalnog maleolusa i tako je postignuta redukcija zadnjeg maleolusa koji nije fiksiran.

Postoperativna direktna redukcija odlična je kod 5 (83,3%) bolesnika, a dobra kod 1 (16,7%). Kod indirektno redukcije fragmenta odličan rezultat je kod 6 (50%) bolesnika, a dobra i loša kod po 3 (25%). Komparacijom ovih rezultata evidentno je da je kvalitet redukcije preloma signifikantno veći u grupi sa direktnom redukcijom u poređenju sa grupom gde je redukcija urađena indirektno ($p=0,039$).

Posle prosečnog praćenja od 16 meseci (od 12 do 18 meseci) ocenili smo rezultate prema Olerud – Molander skor. Bilo je odličnih rezultata (91% - 100%) kod 13 (61,9%) bolesnika, dobrih (61% - 90%) kod 7 (33,4%) i loših (0% - 30%) kod 1 (4,7%), (Slika 3 A,B).

Slika 3. Fotografija prikazuje anterolateralni aspekt plantarne (A) i dorzalne (B) fleksije stopala.

Postoperativno, pojavila se površna infekcija rane kod 2 (9,4%) bolesnika – tretirani su antibiotikom, parenteralno za 4 dana, i postoperativni tromboflebitis kod 1 (4,7%)

bolesnika – lečen je niskomolekularnim Heparinom. Nije bilo preloma šrafova i svi prelomi su zarasli do tri meseca.

Figure 2. Antero posterior and lateral radiographic presentation of combined osteosynthesis of posterior, external and internal malleolus.

After the surgery, we placed a lower leg plaster orthosis for three weeks, and after 6 weeks, we allowed the patients to walk with crutches and lean on the treated leg, with a gradual load increase.

We perform radiological control examination after surgery in order to check the posterior malleolus reduction, and CT scan is also recommended. The reduction can be excellent (articular step is <1mm), when the articular surface is flat, good (when the step is <2mm); and poor reposition (> 2mm), when the surface is uneven [20].

We evaluated treatment results according to the Olerud-Molander classification [21], subjective and objective signs were monitored.

Post-traumatic arthritis (PTA) was determined in Rtg images during the follow-up of patients, and according to the following score: 0 - normal joint, 1 - osteophytes without joint space narrowing, 2 - joint space narrowing with or without osteophytes, 3 - joint space disappearing and deformation [22].

RESULTS

A series of 21 operated patients was presented. There were 12 (57.1%) women and 9 (42.9%) men, 18 to 70 years old (average age 48.8). Etiological causes of fracture are: a fall at the same level - sports, skating 11 (52.3%) patients,

a fall from a height 6 (28.6%) and traffic accident 4 patients (21.1%).

The size of posterior malleolus fragment was 27,3% on the average (25% to 34%).

Degree of external rotation, i.e. angle between the two lines was 00 to 400

According to Lauge Hansen classification, there were 15 (71,4%) patients with fracture of type SER, 4 patients (19%) of type PER and 2 patients (9,6%) of type PA.

According to Haraguchi classification of posterior malleolus fracture, there were 12 (57,1%) of patients with fracture of type I, 6 patients (28,5%) of type II and 3 patients (14,4%) of type III.

Elapsed time from the moment of injury to surgery was 1,6 days (1-5 days) on the average.

Direct reduction and screw fixation was applied in 6 patients, indirect reduction and fixation in 12, and in 3 patients a fixation of lateral and medial malleolus was applied, and thus a reduction of non-fixed posterior malleolus was achieved.

Postoperative direct reduction was excellent in 5 (83.3%) patients and good in 1 (16.7%). As for indirect fragment reduction, we had excellent results in 6 patients (50%), good in 3, and bad in another 3 (25 %). By comparing these results, it is evident that fracture reduction quality was significantly higher in direct reduction group,

Posttraumatski artritis (PTA) procenjivan je posle godinu dana od operacije i dobili smo sledeće rezultate: stepen 0 kod 9 (42,9%) pacijenata, stepen 1 kod 10 (47,7%) i stepen 2 kod 2 (9,4%) pacijenta – ukupno, 12 (57,1%) pacijenata imalo je PTA.

DISKUSIJA

Prelomi skočnog zgloba su na trećem mestu po učestalosti, posle preloma zgloba kuka i ručnog zgloba. Krajnji funkcionalni ishod je bolji kod bimaleolarnih u odnosu na trimaleolarne prelome. Sreću se kod mladih i tada je trauma velike energije (udes, pad sa visine i sport), a kod starih osoba trauma niske energije izaziva prelome zbog osteoporoze. Kod mladih postoji rizik za razvoj posttraumatskog artritisa sa promenom kvaliteta života zbog redukcije funkcije skočnog zgloba i hroničnog bola. Kod starih pacijenata postoji rizik za infekciju, komplikacije rane i dezintegracije fiksacije [11].

Prelomi skočnog zgloba su intraartikularni, samim tim dolazi do povrede artikularnih površina, disrupcije osteohondralnog sloja, displasmana zglobnih površina i prisustva krvi i koštanog sadržaja u zglobu [23].

Sa biomehaničkog aspekta, zadnji maleolus igra značajnu ulogu u prenosu tibiotarnog opterećenja. On deluje preventivno na zadnji displasman talusa, a sa veličinom fragmenta raste i rizik za zadnju subluksaciju talusa, a posebno ako je fragment veći od 25% zglobne površine tibije [24,25]. Zadnji maleolus je važna struktura i u distalnom tibiofibularnom zglobo – on pruža koštano ograničenje distalnoj fibuli i stabilnost sindesmoze preko posterior inferior tibiofibular ligamenta (PITFL) i inferior transversum ligament (ITL).

Ramseyet al. i Lloyd et al. [26,27] ukazuju na veliki intraartikularni kontaktni pritisak kod displasmana talusa kao posledica povrede skočnog zgloba. Pomeranje talusa za 1mm i spoljašnja rotacija fibule od 30 dovode do opadanja tibiotarnog kontakta za 40%, nastaje inkongruencija zgloba, a pad kontaktne površine izaziva porast pritiska po jedinici merenja. Nastaje veliki stres koji oštećuje zglobnu hrskavicu, a to je odlučujući faktor u patogenezi PTA. Cilj hirurške intervencije kod preloma zadnjeg maleolusa je postići artikularnu kongruenciju, postići stabilnost i obnoviti funkciju skočnog zgloba. Iz ovih razloga, imperativ je postići anatomska redukciju i

obezbediti glatku i ravnu površinu hrskavice. Anatomska redukcija artikularnih površina je esencijalni faktor dobrog ishoda lečenja nestabilnih preloma zadnjeg maleolusa [28].

Ortopedska redukcija i fiksacija zadnjeg maleolusa može biti direktna i indirektna. Za direktni pristup i redukciju koristi se zadnje lateralni pristup, a indirektno može se redukovati i lateralni maleolus [29]. Zbog duboke pozicije zadnjeg maleolusa i tendo – neuro – vaskularnog snopa ove regije, ovaj pristup je zahtevan. Haraguchi et al. [19] ovaj pristup preporučuju za I tip preloma zadnjeg maleolusa. Za prelom tipa II preporučuje se medijalni prošireni pristup. Fiksacija fragmenta može biti direktna, a izvodi se šrafovim ili pločom [8]. Indirektna fiksacija se izvodi postavljanjem šrafa u AP ili PA pravcu, ali tek kada se uradi osteosinteza lateralnog i medijalnog maleolusa pa radiološki proverimo poziciju zadnjeg maleolusa [12]. Kod preloma zadnjeg maleolusa III tipa, repozicija fragmenta može se ostvariti na principu ligamentotakse jer posle repozicije lateralnog maleolusa i transfiksacije tibiofibularne sindesmoze dolazi do spontane repozicije zadnjeg maleolusa – povlači ga intaktni PITFL na svoje mesto [18,30]. Stepenn redukcije i stabilnost fiksacije su najveći kod direktne repozicije i osteosintezom pločom, a manja kod indirektna repozicije i stabilizacije [31]. Huber et al. [32] iznose da je indirektna redukcija i stabilnost postignuta u 27% slučajeva, a u 83% kod direktne redukcije i stabilizacije. I naši rezultati se kreću u ovim okvirima.

Odnos i povezanost zadnjeg maleolusa i tibiofibularne sindesmoze je veoma važan zbog PITFL i ITL. Ovi ligamenti se pripajaju na fibuli i zadnjem maleolusu i veoma su važne strukture distalnog tibiofibularnog zgloba jer pružaju stabilnost lateralnoj strani skočnog zgloba, tj. lateralnom delu talusa i fibuli. Ako je PITFL očuvan i uradi se otvorena repozicija i fiksacija zadnjeg maleolusa, stabilnost sindesmoze je veća od stabilnosti kada se uradi transsindezmalna fiksacija. PITFL kompleks je jezgro stabilnosti tibiofibularne sindesmoze. Prelom zadnjeg maleolusa menja stabilnost sindesmoze jer nastaje povređivanje i gubitak funkcije PITFL [33]. Rigidna fiksacija fibule i redukcija i fiksacija zadnjeg maleolusa mogu restaurirati ligamentarnu tenziju PITFL adekvatno i stabilisati sindesmozu bez transsindezmalne fiksacije. Gardner et al. [34]

compared to the group where reduction was performed indirectly ($p = 0.039$).

After follow-up period of 16 months (12 to 18 months) on the average, we evaluated the results according to the Olerud-Molander score.

There were excellent results (91% - 100%) in 13 (61.9%) patients, good (61% - 90%) in 7 (33.4%) patients, and poor (0% - 30%) in 1 (4.7%) patient (Figure 3A,B).

Figure 3. The photograph shows the anterolateral aspect of plantar (A) and dorsal (B) flexion of the foot.

Postoperatively, superficial wound infection occurred in 2 (9.4%) patients – it was treated with antibiotics, parenterally for 4 days, and postoperative thrombophlebitis in 1 (4.7%) patient – it was treated with low molecular Heparin. There were no fractured screws and all fractures healed in up to three months.

Post-traumatic arthritis (PTA) was evaluated one year after surgery and we obtained the following results: grade 0 in 9 (42.9%) patients, grade 1 in 10 (47.7%) patients, and grade 2 in 2 (9.4%) patients - in total, 12 (57.1%) patients had PTA.

DISCUSSION

Ankle joint fractures are the third in frequency, right after hip and wrist joint fractures. Final functional outcome is better in bimalleolar, compared to trimalleolar fractures. They occur in young people, and with high energy trauma (accident, fall from a height and sport), and in elderly persons low-energy trauma causes fractures due to osteoporosis. In young people there is a risk of developing post-traumatic arthritis causing changes in the quality of life, due to a reduction of ankle joint function and chronic pain. In elderly patients there is a risk of infection, wound complications and fixation disintegration [11].

Ankle joint fractures are intraarticular, resulting in articular surfaces injury, osteochondral layer disruption, joint surface displacement, and presence of blood and bone content in the joint [23].

From a biomechanical point of view, posterior malleolus plays a significant role in transmission of tibiotalar load. It has a preventive effect on posterior talus displacement, and with fragment size, the risk of posterior talus subluxation increases, especially if the fragment is larger than 25% of tibia joint surface [24,25]. Posterior maleolus is an important structure in distal tibiofibular joint - it provides bone restriction to distal fibula and syndesmosis stability via posterior inferior tibiofibular ligament (PITFL) and inferior transversum ligament (ITL).

Ramsey et al. and Lloyd et al. [26,27] indicate great intraarticular contact pressure in talus displacement as a result of ankle joint injury. Talus displacement by 1mm and external fibula rotation of 3° lead to a 40% decrease of tibiotalar contact, joint incongruence occurs, and decrease of contact surface causes increased pressure per unit of measurement. There is a great deal of stress that damages articular cartilage, which is the main factor in pathogenesis of PTA.

utvrdili su na kadaverima da je posle repozicije i stabilizacije zadnjeg maleolusa postignuta stabilnost distalnog tibiofibularnog zgloba 70%, a posle transindezmalne fiksacije 40%.

Funkcionalni ishod preloma skočnog zgloba udružen sa prelomom zadnjeg maleolusa zavisi od: veličine fragmenta zadnjeg maleolusa, od njegove kominucije, kvaliteta anatomske repozicije i stabilnosti fiksacije i od artikularne stabilnosti [18]. Naši klinički rezultati su dobri i slični su rezultatima koje objavljuju drugi autori [14,20,33].

Česta kasna komplikacija kod preloma zadnjeg maleolusa je posttraumatski artritis (PTA). Okidač za njegov nastanak su promene artikularnih površina izazvane traumom na distalnoj tibiji i talusu [35]. Rizični faktori za

nastanak PTA su: rezidualni artikularni depasman, nestabilnost ili subluksacija zgloba izazvana povredom, oštećenje artikularnih površina u vreme nastanka povrede [36]. Boist and Dust [37] u svojoj seriji imali su PTA gradus 2 i 3 u 67% slučajeva, i rezultati prikazani u našoj seriji bolesnika su slični.

ZAKLJUČAK

Prelomi zadnjeg maleolusa su česti u sklopu povreda skočnog zgloba. Fiksacija zadnjeg maleolusa je obavezna ako je fragment veći od 25% od tibijalne zglobne površine. U seriji prikazanih ispitanika dobijeni su odlični rezultati, a to nameće opravdanost i potrebu operativnog lečenja.

LITERATURA:

- Daly PJ, Fitzgerald RH Jr, Melton LJ, Ilstrup DM. Epidemiology of ankle fractures in Rochester, Minnesota. *Acta Orthop Scand* 1987;58:539-44.
- Salai M, Dudkiewicz I, Novikov I, Amit Y, Chechick A. The epidemic of ankle fractures in the elderly—is surgical treatment warranted? *Arch Orthop Trauma Surg*. 2000;120(9):511-513.
- Court-Brown CM, McBurnie J, Wilson G. Adult ankle fractures—an increasing problem? *Acta Orthop Scand*. 1998;69(1):43-47.
- Hai-lin XU, Li-min LIU, Bao-guo JIANG, et al. Multicenter follow-up study of ankle fracture surgery. *Chinese Medical Journal*. 2012;125(4):574-578.
- Neumaier Probst E, Maas R, Meenen NM. Isolated fracture of the posterolateral tibial lip (Volkman's triangle) *Acta Radiol*. 1997;38(3):359-362.
- Destot E. Traumatismes du poignet et rayons X. Paris: Masson; 1911; 109-134.
- Henderson MS. Trimalleolar fractures of the ankle. *Surg Clin North Am*. 1932;12:86.
- Anwar A, Zhang Z, Lv D, Lv G, Zhao Z, Wang Y, Cai Y, Qasim W, Nazir MU, Lu M. Biomechanical efficacy of AP, PA lag screws and posterior plating for fixation of posterior malleolar fractures: a three dimensional finite element study. *BMC Musculoskelet Disord*. 2018; 19: 73.
- Odak S, Ahluwalia R, Unnikrishnan P, Hennessy M, Platt S. Management of Posterior Malleolar Fractures: A Systematic Review. *J Foot Ankle Surg*. 2016;55(1):140-5.
- Ogilvie-Harris DJ, Reed SC, Hedman TP. Disruption of the ankle syndesmosis: biomechanical study of the ligamentous restraints. *Arthroscopy*. 1994;10:558-560.
- Duan X, Kadakia AR. Operative Treatment of Posterior Malleolar Fractures. *Open Orthop J*. 2017;11:732-742.
- Naoki H, Hiroki H, Hidekazu T, Fumio K. Pathoanatomy of posterior malleolar fractures of ankle. *J Bone Joint Surg Am*. 2006;88:1085-1092.
- Hartford JM, Gorczyca JT, McNamara JL, Mayor MB. Tibiotalar contact area. Contribution of posterior malleolus and deltoid ligament. *Clin Orthop Relat Res* 1995;320:182-187.
- Solan MC, Sakellariou A. Posterior malleolus fractures: worth fixing. *Bone Joint J*. 2017;99-B(11):1413-1419.
- Vasileios Lampridis, Nikolaos Gougoulas, and Anthony Sakellario. Stability in ankle fractures. Diagnosis and treatment. *EFORT Open Rev*. 2018; 3(5): 294-303.
- Lauge Hansen N. Ligamentous ankle fractures. Diagnosis and treatment. *Acta Chir Scand* 1949; 97: 544 - 50.
- Xing W, Wang Y, Sun L, Wang L, Kong Z, Zhang C, Zhang Z. Ankle joint dislocation treating dislocated trimalleolar fractures accompanied with the complex posterior malleolus fracture without separation of the tibiofibular syndesmosis. *Medicine (Baltimore)*. 2018;97(37):e12079.
- Fitzpatrick DC, Otto JK, McKinley TO, Brown TD. Kinematic and contact stress analysis of posterior malleolus fractures of the ankle. *J Orthop Trauma*. 2004;18:271-8.
- Haraguchi N, Haruyama H, Toga H, Kato F. Pathoanatomy of posterior malleolar fractures of the ankle. *J Bone Joint Surg [Am]* 2006;88-A:1085-1092.
- Xu HL, Li X, Zhang DY, Fu ZG, Wang TB, Zhang PX, Jiang BG, Shen HL, Wang G, Wang GL, Wu XB. Purpose A retrospective study of posterior malleolus fractures. *Int Orthop*. 2012;36(9):1929-36.
- Olerud C, Molander H. A scoring scale for symptom evaluation after ankle fracture. *Arch Orthop Trauma Surg* 1984;103:190-4.
- Domsic RT, Saltzman CL. Ankle osteoarthritis scale. *Foot Ankle Int* 1998;19:466-71.
- Olson SA, Furman B, Guilak F. Joint injury and post-traumatic arthritis. *HSS J*. 2012;8(1):23-5.
- McDaniel WJ, Wilson FC. Trimalleolar fractures of the ankle. An end result study. *Clin Orthop Relat Res*. 1977;122:37-45.
- De Vries JS, Wiggman AJ, Sierevelt IN, Schaap GR. Long-term results of ankle fractures with a posterior malleolar fragment. *J Foot Ankle Surg*. 2005;44:211-217.
- Ramsey PL, Hamilton W. Changes in tibiotalar area of contact caused by lateral talar shift. *J. Bone Joint Surg. Am*. 1976;58:356-357.

The goal of surgical intervention in posterior malleolus fractures is to achieve articular congruence, to achieve stability and restore ankle joint function. For these reasons, the imperative is to achieve anatomic reduction, and to provide a smooth and flat cartilage surface. Anatomical reduction of articular surfaces is essential factor for good treatment outcome of unstable posterior malleolus fractures [28].

Orthopedic reduction and posterior malleolus fixation can be direct and indirect. For direct access and reduction, posterior lateral approach is used, and lateral malleolus can be indirectly reduced [29]. Due to a deep position of posterior malleolus and tendon-neuro-vascular bundle of the area, this approach is very demanding and difficult. Haraguchi et al. [19] recommend this approach for type I posterior malleolus fracture. For type II fracture, a medially extended approach is recommended. Fragment fixation can be direct with screws or a plate [8]. Indirect fixation is performed by placing a screw in AP or PA direction, but only after performing lateral and medial malleolus osteosynthesis, and radiologically checking posterior malleolus position [12]. In posterior malleolus type III fractures, fragment repositioning can be achieved using the principle of ligamentotaxis, because after lateral malleolus repositioning and tibiofibular syndesmosis transfixation, there occurs a spontaneous posterior malleolus reposition – it is pulled to its place by intact PITFL [18,30]. The degree of fixation reduction and stability is the greatest in direct reposition and with the use of an osteosynthesis plate, and lower in indirect reposition and stabilization [31]. Huber et al. [32] report that indirect reduction and stability were achieved in 27% cases, while it was achieved in 83% in direct reduction and stabilization. Our results range within this frame.

Relationship and connection between posterior malleolus and tibiofibular syndesmosis is very important because of PITFL and ITL. These ligaments attach to fibula and posterior malleolus and are very important distal tibiofibular joint structures, as they provide stability to lateral ankle joint side, i.e. lateral part of talus and fibula. If the PITFL is preserved and

open reposition and fixation of posterior malleolus is performed, syndesmosis stability will be better than stability in case when transsyndesmal fixation is performed. PITFL complex is the nucleus of tibiofibular syndesmosis stability. The fracture of posterior malleolus alters syndesmosis stability, because of the injury and loss of PITFL function [33]. Rigid fibula fixation and posterior malleolus reduction and fixation can adequately restore ligamentous tension of PITFL, and stabilize syndesmosis without transsyndesmal fixation. Gardner et al [34] found, after performing posterior malleolus repositioning and stabilization on cadavers, that 70% of distal tibiofibular joint stability was achieved, while after transindezmal fixation it was 40%.

Functional outcome of ankle joint fracture associated with posterior malleolus fracture depends on: the size of posterior malleolus fragment, its comminution, the quality of anatomic reposition and fixation stability, and on articular stability [18]. Our clinical results are good and similar to those reported by other authors [14,20,33].

A common late complication in posterior malleolus fractures is post-traumatic arthritis (PTA). The trigger for its formation is the change of articular surfaces, caused by trauma to distal tibia and talus [35]. Risk factors for PTA are: residual articular displacement, joint instability or subluxation caused by an injury, damage on articular surfaces at the moment of injury [36]. Boist and Dust [37] had PTA grades 2 and 3 in 67% of cases in their series, and the results presented in our series of patients are similar to theirs.

CONCLUSION

Posterior malleolus fractures are common in ankle injuries. Posterior malleolus fixation is necessary if the fragment is larger than 25% of tibial joint surface. Direct reduction and fixation should be performed, as the results are better. Fixation restores articular surface, PITFL and syndesmosis stability is achieved. CT helps in classifying the fracture type, and after surgery helps in determining the degree of fragment and joint surface reduction.

REFERENCES

1. Daly PJ, Fitzgerald RH Jr, Melton LJ, Ilstrup DM. Epidemiology of ankle fractures in Rochester, Minnesota. *Acta Orthop Scand* 1987;58:539–44.
2. Salai M, Dudkiewicz I, Novikov I, Amit Y, Chechick A. The epidemic of ankle fractures in the elderly—is surgical treatment warranted? *Arch Orthop Trauma Surg*. 2000;120(9):511–513.
3. Court-Brown CM, McBirmie J, Wilson G. Adult ankle fractures—an increasing problem? *Acta Orthop Scand*. 1998;69(1):43–47.

27. Lloyd J, Elsayed S, Hariharan K, Tanaka H. Revisiting the concept of talar shift in ankle fractures. *Foot Ankle Int.* 2006;27:793-796.
28. Gougoulas N, Khanna A, Sakellariou A, Maffulli N. Supination-External Rotation Ankle Fractures: Stability a Key Issue. *Clin Orthop Relat Res.* 2010; 468(1): 243-251.
29. Talbot M, Steenblock TR, Cole PA. Posterolateral approach for open reduction and internal fixation of trimalleolar ankle fractures. *Can J Surg.* 2005;48(6):487-90.
30. Mak KH, Chan KM, Leung PC. Ankle fracture treated with the AO principle-an experience with 116 cases. *Injury.* 1985;16(4):265-72.
31. O'Connor TJ, Mueller B, Ly TV, Jacobson AR, Nelson ER, Cole PA. "A to p" screw versus posterolateral plate for posterior malleolus fixation in trimalleolar ankle fractures. *J Orthop Trauma.* 2015;29(4):e151-6.
32. Huber M, Stutz PM, Gerber C. Open reduction and internal fixation of the posterior malleolus with a posterior antilide plate using a postero-lateral approach-a preliminary report. *Foot Ankle Surg.* 1996;2(2):95-103.
33. Bilgehan Tosun, Ozgur Selek, Umit Gok, and Halil Ceylan. Posterior Malleolus Fractures in Trimalleolar Ankle Fractures: Malleolus versus Transyndesmal Fixation. *Indian J Orthop.* 2018; 52(3): 309-314.
34. Gardner MJ, Brodsky A, Briggs SM, Nielson JH, Lorch DG. Fixation of posterior malleolar fractures provides greater syndesmotic stability. *Clin Orthop Relat Res.* 2006;447:165-71.
35. van den Bekerom MP, Haverkamp D, Kloen P. Biomechanical and clinical evaluation of posterior malleolar fractures. A systematic review of the literature. *J Trauma* 2009;66:279-84.
36. Anderson DD, et al. Is elevated contact stress predictive of post-traumatic osteoarthritis for imprecisely reduced tibial plafond fractures? *J Orthop Res.* 2011;29(1):33-9.
37. Bois AJ, Dust W. Posterior fracture dislocation of the ankle: Technique and clinical experience using a posteromedial surgical approach. *J Orthop Trauma.* 2008;22:629-36.

4. Hai-lin XU, Li-min LIU, Bao-guo JIANG, et al. Multicenter follow-up study of ankle fracture surgery. *Chinese Medical Journal*. 2012;125(4):574–578.
5. Neumaier Probst E, Maas R, Meenen NM. Isolated fracture of the posterolateral tibial lip (Volkman's triangle) *Acta Radiol*. 1997;38(3):359–362.
6. Destot E. *Traumatismes du poignet et rayons X*. Paris:Masson;1911;109-134.
7. Henderson MS. Trimalleolar fractures of the ankle. *Surg Clin North Am*. 1932;12:86
8. Anwar A, Zhang Z, Lv D, Lv G, Zhao Z, Wang Y, Cai Y, Qasim W, Nazir MU, Lu M. Biomechanical efficacy of AP, PA lag screws and posterior plating for fixation of posterior malleolar fractures: a three dimensional finite element study. *BMC Musculoskelet Disord*. 2018; 19: 73.
9. Odak S, Ahluwalia R, Unnikrishnan P, Hennessy M, Platt S. Management of Posterior Malleolar Fractures: A Systematic Review. *J Foot Ankle Surg*. 2016;55(1):140-5.
10. Ogilvie-Harris DJ, Reed SC, Hedman TP. Disruption of the ankle syndesmosis: biomechanical study of the ligamentous restraints. *Arthroscopy*. 1994;10:558–560.
11. Duan X, Kadakia AR. Operative Treatment of Posterior Malleolar Fractures. *Open Orthop J*. 2017;11:732-742.
12. Naoki H, Hiroki H, Hidekazu T, Fumio K. Pathoanatomy of posterior malleolar fractures of ankle. *J Bone Joint Surg Am*. 2006;88:1085-1092.
13. Hartford JM, Gorczyca JT, McNamara JL, Mayor MB. Tibiotalar contact area. Contribution of posterior malleolus and deltoid ligament. *Clin Orthop Relat Res* 1995;320:182–187.
14. Solan MC, Sakellariou A. Posterior malleolus fractures: worth fixing. *Bone Joint J*. 2017;99-B(11):1413-1419.
15. Vasileios Lampridis, Nikolaos Gougoulas, and Anthony Sakellario. Stability in ankle fractures. Diagnosis and treatment. *EFORT Open Rev*. 2018; 3(5): 294–303.
16. Lauge Hansen N. Ligamentous ankle fractures. Diagnosis and treatment. *Acta Chir Scand* 1949; 97: 544 – 50.
17. Xing W, Wang Y, Sun L, Wang L, Kong Z, Zhang C, Zhang Z. Ankle joint dislocation treating dislocated trimalleolar fractures accompanied with the complex posterior malleolus fracture without separation of the tibiofibular syndesmosis. *Medicine (Baltimore)*. 2018;97(37):e12079.
18. Fitzpatrick DC, Otto JK, McKinley TO, Brown TD. Kinematic and contact stress analysis of posterior malleolus fractures of the ankle. *J Orthop Trauma*. 2004;18:271-8.
19. Haraguchi N, Haruyama H, Toga H, Kato F. Pathoanatomy of posterior malleolar fractures of the ankle. *J Bone Joint Surg [Am]* 2006;88-A:1085–1092.
20. Xu HL, Li X, Zhang DY, Fu ZG, Wang TB, Zhang PX, Jiang BG, Shen HL, Wang G, Wang GL, Wu XB. Purpose A retrospective study of posterior malleolus fractures. *Int Orthop*. 2012;36(9):1929-36.
21. Olerud C, Molander H. A scoring scale for symptom evaluation after ankle fracture. *Arch Orthop Trauma Surg* 1984;103:190-4.
22. Domsic RT, Saltzman CL. Ankle osteoarthritis scale. *Foot Ankle Int* 1998;19:466–71.
23. Olson SA, Furman B, Guilak F. Joint injury and post-traumatic arthritis. *HSS J*. 2012;8(1):23-5.
24. McDaniel WJ, Wilson FC. Trimalleolar fractures of the ankle. An end result study. *Clin Orthop Relat Res*. 1977;122:37–45.
25. De Vries JS, Wijgman AJ, Sierevelt IN, Schaap GR. Long-term results of ankle fractures with a posterior malleolar fragment. *J Foot Ankle Surg*. 2005;44:211–217.
26. Ramsey PL, Hamilton W. Changes in tibiotalar area of contact caused by lateral talar shift. *J. Bone Joint Surg. Am*. 1976;58:356–357.
27. Lloyd J, Elsayed S, Hariharan K, Tanaka H. Revisiting the concept of talar shift in ankle fractures. *Foot Ankle Int*. 2006;27:793–796.
28. Gougoulas N, Khanna A, Sakellariou A, Maffulli N. Supination-External Rotation Ankle Fractures: Stability a Key Issue. *Clin Orthop Relat Res*. 2010; 468(1): 243–251.
29. Talbot M, Steenblock TR, Cole PA. Posterolateral approach for open reduction and internal fixation of trimalleolar ankle fractures. *Can J Surg*. 2005;48(6):487-90.
30. Mak KH, Chan KM, Leung PC. Ankle fracture treated with the AO principle—an experience with 116 cases. *Injury*. 1985;16(4):265–72.
31. O'Connor TJ, Mueller B, Ly TV, Jacobson AR, Nelson ER, Cole PA. "A to p" screw versus posterolateral plate for posterior malleolus fixation in trimalleolar ankle fractures. *J Orthop Trauma*. 2015;29(4):e151-6.
32. Huber M, Stutz PM, Gerber C. Open reduction and internal fixation of the posterior malleolus with a posterior antiglide plate using a postero-lateral approach—a preliminary report. *Foot Ankle Surg*. 1996;2(2):95–103.
33. Bilgehan Tosun, Ozgur Selek, Umit Gok, and Halil Ceylan. Posterior Malleolus Fractures in Trimalleolar Ankle Fractures: Malleolus versus Transyndesmal Fixation. *Indian J Orthop*. 2018; 52(3): 309–314.
34. Gardner MJ, Brodsky A, Briggs SM, Nielson JH, Lorch DG. Fixation of posterior malleolar fractures provides greater syndesmotic stability. *Clin Orthop Relat Res*. 2006;447:165-71.
35. van den Bekerom MP, Haverkamp D, Kloen P. Biomechanical and clinical evaluation of posterior malleolar fractures. A systematic review of the literature. *J Trauma* 2009;66:279–84.
36. Anderson DD, et al. Is elevated contact stress predictive of post-traumatic osteoarthritis for imprecisely reduced tibial plafond fractures? *J Orthop Res*. 2011;29(1):33–9.
37. Bois AJ, Dust W. Posterior fracture dislocation of the ankle: Technique and clinical experience using a posteromedial surgical approach. *J Orthop Trauma*. 2008;22:629–36.