Universitat Autònoma de Barcelona

Arthroscopic treatment of ankle instability: anatomy, risks and complications

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ACKNOWLEDGEMENTS

Since the beginning of my orthopedic residency, I have been fascinated by ankle surgery and arthroscopy. My studies as surgeon and researcher on ankle arthroscopy began in 2015, thanks to the collaboration with amazing surgeons and anatomists. This PhD thesis is the result of this close collaboration, for which I am very grateful. I would especially like to thank:

- My parents, Barbara and Marco, this thesis is dedicated to them in particular. They have always supported me in my every decision I have taken and they taught me to be able to achieve everything I wished for through dedication, sacrifice and hard work.
- Prof. Rosa Mirapeix, co-director and tutor of this Thesis for her support and help throughout these years. Since 2013, when she welcomed me into the Department of Anatomy and Embryology of the Universitat Autònoma de Barcelona, allowing me to spend entire days in the dissecting room to perfect my anatomical knowledge and my arthroscopic techniques.
- Prof. Miki Dalmau-Pastor from the University of Barcelona, co-director of this thesis and friend who helped me finish this project and taught me the importance of surgical anatomy.
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importance of working in a team of friends and achieving every goal taking one step at a time. I owe him everything I know on ankle arthroscopy.

- The technical staff of the Dissecting Room of the Universitat Autònoma de Barcelona for always being very kind to me and constantly providing me with everything I needed.
- My highest gratitude to the Donors and their families, who donated their bodies to science. Without them the study of anatomy and anatomical research would not be possible.

INTRODUCTION

During the last few years, ankle arthroscopy has been an emerging field with a significant evolution of its indications, concepts, and techniques [1,2]. For this reason, the role of arthroscopy in treating ankle instability has rapidly evolved alongside arthroscopic stabilizing techniques [2]. These techniques have, as a working area, the anterolateral aspect of the ankle. In this area, there are several anatomical structures which may be at risk during the creation of the portals and the passage of the sutures. Due to this, to perform any of these techniques and in general to perform ankle arthroscopy, a thorough knowledge of both superficial and arthroscopic anatomy is mandatory to reduce the rate of complications and obtain successful outcomes.

Modern arthroscopic stabilizing techniques can be broadly divided into three groups: 1) an arthroscopic all-inside ligament repair, 2) an arthroscopically assisted percutaneous technique and 3) an arthroscopic ligamentoplasty.

Despite all being used in the treatment of ankle instability, these techniques are very different from each other. All of them have their own indications, advantages and pitfalls [2]. As often happens in orthopaedic surgery, there is no clear superiority of one technique over the other and often surgeons opt for the technique that they are more familiar with [3,4].

The all-inside repair, originally described by Vega et al. in 2013, is a fully arthroscopic technique which provides a repair of the lateral collateral ligament with a knotless anchor [5-7]. This technique provides an anatomic reattachment of

the injured ligaments into their original footprint. Regarding this technique, excellent clinical results have been observed in literature, and no major or neurological complications have been reported [3,5]. The absence of nerve-related complications may be explained by the fully intra-articular technique, while the excellent clinical outcomes by the perfect restoration of normal anatomy of the lateral ligaments. To our knowledge, there were no anatomic studies validating the arthroscopic all-inside lateral ligament repair.

The arthroscopically-assisted percutaneous technique, also known as Arthroscopic Broström (AB), aims to stabilize the ankle placing anchors into the fibula under arthroscopic vision while percutaneously grasping the lateral ligament and the inferior extensor retinaculum with sutures (IER) [8,9]. This technique has been popularized in the United States in particular, and although good clinical results have been reported, a high rate of complications have been observed (5.3% to 29%) [3]. This can be explained because of the percutaneous passage of the suture in the anterolateral aspect of the ankle. In this area, the superficial peroneal nerve (SPN) runs, and this has several anatomical variations and is at high risk of suture entrapment [9,10]. Moreover, this technique is not strictly an anatomic ligament repair, grasping with the same sutures the ligament, the capsule, the IER and/or the sural fascia. Grasping all of these anatomical structures with the sutures may create a large fibrosis in the anterolateral part of the ankle, causing stabilization but also a range of motion (ROM) limitation in some patients.

The arthroscopic ligamentoplasty is a reconstruction of the anterior talofibular ligament (ATFL) and/or the calcaneofibular ligament (CFL) with a graft tendon [11-14]. This technique has many disadvantages such as donor site morbidity, higher risk of intraoperative complications, sacrifice of the ligament remnants and their

proprioceptive function. In addition, there are no long-term studies favoring the reconstruction over the repair procedure. All of these considerations make this technique suitable only in selected patients with no available remnants present, that is not a common situation in primary cases. For this reason, this technique has not been studied in this thesis.

SUMMARY OF PUBLICATIONS

This compendium of publications is mainly composed of 4 articles and 2 book chapters.

ARTICLES:

2 papers as a first author and 2 papers as a co-author. All these articles have been published in peer-reviewed and indexed journals.

- **M. Guelfi**, J. Vega, F. Malagelada, M. Dalmau-Pastor. The arthroscopic all-inside ankle lateral collateral ligament repair is a safe and reproducible technique. Knee Surgery Sport Traumatol Arthrosc 2020 Jan;28(1):63-69. doi: 10.1007/s00167-019-05427-0. Epub 2019 Mar 4.
- **M. Guelfi**, G. Nunes, F. Malagelada, G. Cordieri, M. Dalmau-Pastor, J. Vega. Arthroscopic-assisted vs all-arthroscopic ankle stabilization technique. A comparative clinical study. 2020 Nov;41(11):1360-1367. doi: 10.1177/1071100720938672.
- M. Dalmau-Pastor, F. Malagelada, GM. Kerkhoffs, J. Karlsson, **M. Guelfi**, J. Vega. Redefining anterior ankle arthroscopic anatomy: medial and lateral ankle collateral ligaments are visible through dorsiflexion and non-distraction anterior ankle arthroscopy. Knee Surg Sports Traumatol Arthrosc. 2020 Jan;28(1):18-23. doi: 10.1007/s00167-019-05603-2. Epub 2019 Jul 10.

- J. Vega, F. Malagelada, J. Karlsson, GM. Kerkhoffs, **M. Guelfi**, M. Dalmau-Pastor. A step-by-step arthroscopic examination of the anterior ankle compartment. Knee Surg Sports Traumatol Arthrosc. 2020 Jan;28(1):24-33. doi: 10.1007/s00167-019-05756-0. Epub 2019 Oct 30.

BOOK CHAPTERS:

- M. Dalmau-Pastor, **M. Guelfi**, F. Malagelada, R. Mirapeix, J. Vega. Anatomy of the ankle joint and hindfoot. In F. Allegra et al. (eds.), Ankle Joint Arthroscopy. Springer-Verlag Berlin Heidelberg, 2020. Pag. 3-9. doi: 10.1007/978-3-030-29231-7.
- **M. Guelfi**, M. Dalmau-Pastor, R. Mirapeix, J. Vega. Gross anatomy of the subtalar joint. In F. Allegra et al. (eds.), Ankle Joint Arthroscopy. Springer-Verlag Berlin Heidelberg, 2020. Pag. 11-16. doi: 10.1007/978-3-030-29231-7.

PUBLICATIONS AS FIRST AUTHOR

M. Guelfi, J. Vega, F. Malagelada, M. Dalmau-Pastor. The arthroscopic all-inside ankle lateral collateral ligament repair is a safe and reproducible technique. Knee Surgery Sport Traumatol Arthrosc 2020 Jan;28(1):63-69. doi: 10.1007/s00167-019-05427-0. Epub 2019 Mar 4.

Background: Neurovascular structures around the ankle are at risk of injury during arthroscopic all-inside lateral collateral ligament repair for the treatment of chronic ankle instability. This study aimed to evaluate the risk of damage to anatomical structures and reproducibility of the technique amongst surgeons with different levels of expertise in the arthroscopic all- inside ligament repair.

Methods: Twelve fresh-frozen ankle specimens were used for the study. Two foot and ankle surgeons with different level of experience in the technique performed the procedure on 6 specimens each. The repair was performed following a standardized procedure as originally described. Then, an experienced anatomist dissected all the specimens to evaluate the outcome of the ligament repair, any injuries to anatomical structures and the distance between arthroscopic portals and the superficial peroneal nerve (SPN) and sural nerve.

Results: Dissections revealed no injury to the nerves assessed. Mean distance from the anterolateral portal and the SPN was of 4.8 (range 0.0–10.4) mm. The mean distance from the accessory anterolateral portal to the SPN and sural nerve was of 14.2 (range 7.1–32.9) mm and 28.1 (range 2.8–39.6) mm, respectively. The

difference between the 2 surgeons' groups was non-statistically significant for any measurement (mm). In all specimens both fascicles of the anterior talofibular ligament were reattached onto its original fibular footprint. The calcaneofibular ligament was not penetrated in any specimen.

Conclusions: The all-inside arthroscopic lateral collateral ligament repair is a safe and reproducible technique. The clinical relevance of this study is that this technique provides a safe and anatomic reattachment of the anterior talofibular ligament, with minimal risk of injury to surrounding anatomical structures regardless of the level of experience with the technique.

M. Guelfi, G. Nunes, F. Malagelada, G. Cordieri, M. Dalmau-Pastor, J. Vega. Arthroscopic-assisted vs all-arthroscopic ankle stabilization technique. A comparative clinical study. Foot Ankle Int 2020 Nov;41(11):1360-1367. doi: 10.1177/1071100720938672

Background: Both the percutaneous technique with arthroscopic assistance, also known as Arthroscopic Broström (AB), and the all-inside arthroscopic ligament repair (AI) are widely used to treat chronic lateral ankle instability. The aim of this study was to compare clinical outcomes of these two arthroscopic stabilizing techniques.

Methods: Thirty-nine consecutive patients were arthroscopically treated for chronic ankle instability by two different surgeons. The AB group comprised 20 patients with a mean age of 30.2 (range, 18-42) years and a mean follow-up of 19.6 (range, 12-28) months. The AI group comprised 19 patients with a mean age of 30.9 (range, 18-46) years and mean follow-up of 20.7 (range, 13-32) months. Functional outcomes using the American Orthopedic Foot and Ankle Society (AOFAS) hindfoot score and visual analog pain scale (VAS) were assessed pre- and postoperatively. Range of motion (ROM) and complications were recorded.

Results: In both groups AOFAS and VAS score significantly improved compared to preoperative values ($p<0.001$) with no difference ($p>0.1$) between groups. In the AB group the mean AOFAS improved from 67 (range, 44-87) to 92 (range, 76-100) and the mean VAS from 6.4 (range, 3-10) to 1.2 (range, 0-3). In the AI group the mean AOFAS changed from 60 (range, 32-87) to 93 (range, 76-100) and the mean VAS

from 6.1 (range, 4-10) to 0.8 (range, 0-3). At the final follow-up 8 complications (40%) were recorded in the AB group. In the AI group 1 complication was observed (5.3%). The differences in complication rates between groups were statistically significant ($p<0.05$).

Conclusion: Both the AB and the AI techniques are suitable surgical options to treat chronic ankle instability providing excellent clinical results. However, the AB presented a higher overall complication rate than the AI group, particularly involving a painful restriction of ankle plantarflexion and neuritis of the superficial peroneal nerve.

PUBLICATIONS AS CO-AUTHOR

M. Dalmau-Pastor, F. Malagelada, GM. Kerkhoffs, J. Karlsson, M. Guelfi, J. Vega. Redefining anterior ankle arthroscopic anatomy: medial and lateral ankle collateral ligaments are visible through dorsiflexion and non-distraction anterior ankle arthroscopy. Knee Surg Sports Traumatol Arthrosc. 2020 Jan;28(1):18-23. doi: 10.1007/s00167-019-05603-2. Epub 2019 Jul 10.

Purpose: A thorough understanding of the arthroscopic anatomy is important to recognize pathological conditions. Although some ankle ligaments have been described as intra-articular structures, no studies have assessed the full visibility of these structures. The purpose of this study was to assess arthroscopic visibility of medial and lateral ankle collateral ligaments.

Methods: Arthroscopy was performed in 20 fresh frozen ankles. The arthroscope was introduced through the anteromedial portal and the anterior compartment was explored in ankle dorsiflexion without distraction. Intra-articular structures were tagged using a suture-passer introduced percutaneously and they were listed in a table according to the surgeon's identification. After the arthroscopic procedure, the ankles were dissected to identify the suture-tagged structures.

Results: According to the suture-tagged structures, 100% correlation was found between arthroscopy and dissection. In the anterior compartment, the superior fascicle of the anterior talofibular ligament, the distal fascicle of the anterior tibiofibular ligament and the anterior tibiotalar ligament on the medial side were

observed. The deep fascicle of the posterior tibiofibular ligament and the intermalleolar ligament were tagged at the posterior compartment.

Conclusion: Ankle dorsiflexion and non-distraction arthroscopic technique allows full visualization of the medial and lateral ankle collateral ligaments: the superior fascicle of the anterior talofibular ligament, the distal fascicle of the anterior tibiofibular ligament and the anterior tibiotalar ligament. When using distraction, posterior structures as the deep fascicle of the posterior tibiofibular ligament and the intermalleolar ligament can be observed with anterior arthroscopy.

J. Vega, F. Malagelada, J. Karlsson, GM. Kerkhoffs, M. Guelfi, M. Dalmau-Pastor. A step-by-step arthroscopic examination of the anterior ankle compartment. Knee Surg Sports Traumatol Arthrosc. 2020 Jan;28(1):24-33. doi: 10.1007/s00167-019-05756-0. Epub 2019 Oct 30.

Purpose: Despite the increased use of ankle dorsiflexion without distraction, no reports have specifically addressed the arthroscopic anatomy of the ankle in this position. The purpose of this study was to describe the normal arthroscopic anatomy of the ankle joint, when using the ankle dorsiflexion and the dynamic distraction technique, and to propose an arthroscopic examination system for the anterior ankle compartment.

Methods: Ankle arthroscopy was performed in 20 fresh frozen specimens. Arthroscopic examination was performed with the arthroscope introduced through the anteromedial portal. The anterior compartment was examined in ankle dorsiflexion without distraction. The compartment was examined in four steps: (1) lateral area including the lateral gutter; (2) the central area of the anterior tibial rim; (3) the medial area including the medial gutter; (4) the talar neck. Next, distraction was applied to visualize the anterior compartment again and to examine the central and posterior ankle compartments.

Results: Anatomic intra-articular structures were visualized in all specimens. Four intra-articular fat pads, one anteromedial, two syndesmotic and another posteromedial, were constantly observed. A description of the normal arthroscopic anatomy of the ankle using the ankle dorsiflexion and the dynamic distraction technique is detailed for the anterior, central and posterior compartments.

Conclusion: The ankle arthroscopic procedure without distraction allows constant visualization of the ATFL's superior fascicle on the floor of the lateral gutter, the ATiFL's distal fascicle laterally and the most anterior margin of the deltoid ligament in the medial gutter (anterior tibiotalar ligament). However, ankle distraction is required to observe the central and posterior compartments, but it does not provide optimal visualization of the anterior ankle compartment structures.

BOOK CHAPTERS

M. Dalmau-Pastor, M. Guelfi, F. Malagelada, R. Mirapeix, J. Vega. Anatomy of the ankle joint and hindfoot. In F. Allegra et al. (eds.), Ankle Joint Arthroscopy. Springer-Verlag Berlin Heidelberg, 2020. Pag. 3-9. doi: 10.1007/978-3-030-29231-7.

M. Guelfi, M. Dalmau-Pastor, R. Mirapeix, J. Vega. Gross anatomy of the subtalar joint. In F. Allegra et al. (eds.), Ankle Joint Arthroscopy. Springer-Verlag Berlin Heidelberg, 2020. Pag. 11-16. doi: 10.1007/978-3-030-29231-7.

The two chapters book provide a thorough description of the anatomy of the ankle, the hindfoot and the subtalar joint. In these chapters, anatomy was specifically described in function of ankle arthroscopy and arthroscopic procedures.

HYPOTHESIS

The hypothesis of this Thesis is:

Ankle arthroscopic stabilizing techniques provide excellent clinical outcomes. Within these techniques, the all-inside ligament repair is a safe and reproducible technique for the treatment of chronic ankle instability, with minimal risk for surrounding anatomical structures. Comparing the two most popular techniques, the all-inside repair and the arthroscopic Broström, the all-inside is a fully arthroscopic procedure and avoids percutaneous passage of the suture. For this reason, it may be safer, providing better clinical outcomes and less complications.

OBJECTIVES

The objectives of this thesis are:

1. To describe the normal arthroscopic anatomy of the ankle joint when using the discretionary or dynamic distraction technique and how to safely and accurately identify the intra-articular ligamentous structures.

2. To assess the arthroscopic visibility of medial and lateral ankle collateral ligaments.

3. To evaluate the risk of damage and entrapment of neurological structures during the arthroscopic all-inside lateral collateral ligament repair.

4. To investigate the reproducibility of the all-inside lateral ligament repair among surgeons with varying levels of expertise in the technique.

5. To compare clinical outcomes and complications of the two most popular techniques for arthroscopic treatment of ankle instability: the all-inside repair and the arthroscopic Broström.

6. To propose a safe arthroscopic examination system for the visualization and evaluation of the anatomical structures in the anterior ankle compartment.

RESULTS

The results of the studies are reported in each publication. In the following section the original publications are included.

PUBLICATIONS

PUBLICATIONS AS FIRST AUTHOR

The arthroscopic all-inside ankle lateral collateral ligament repair is a safe and reproducible technique.

Authors: M. Guelfi, J. Vega, F. Malagelada, M. Dalmau-Pastor

Journal: Knee Surgery, Sports Traumatology and Arthroscopy

Impact Factor: 3.149 (2018)

Journal Impact Factor Quartile: Q1

Published online: 04 March 2019

Volume: 28

Issue: 1

Pages: 63-69

DOI: https://doi.org/10.1007/s00167-019-05427-0.

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Arthroscopic-assisted vs all-arthroscopic ankle stabilization technique. A comparative clinical study.

Authors: M. Guelfi, G. Nunes, F. Malagelada, G. Cordier, M. Dalmau-Pastor, J. Vega.

Journal: Foot and Ankle International

Impact Factor: 2.341 (2018)

Journal Impact Factor Quartile: Q1

Published online: 14 July 2020

Volume: 41

Issue: 11

Pages: 1360-1367

DOI: https://doi.org/10.117/1071100720938672

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PUBLICATIONS AS CO-AUTHOR

Redefining anterior ankle arthroscopic anatomy: medial and lateral ankle collateral ligaments are visible through dorsiflexion and non-distraction anterior ankle arthroscopy.

Authors: M. Dalmau-Pastor, F. Malagelada, GM. Kerkhoffs, J. Karlsson, M. Guelfi, J. Vega.

Journal: Knee Surgery, Sports Traumatology and Arthroscopy

Impact Factor: 3.149 (2018)

Journal Impact Factor Quartile: Q1

Published online: 10 July 2019

Volume: 28

Issue: 1

Pages: 18-23

DOI: https://doi.org/10.1007/s00167-019-05603-2.

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A step-by-step arthroscopic examination of the anterior ankle compartment.

Authors: J. Vega, F. Malagelada, J. Karlsson, GM. Kerkhoffs, M. Guelfi, M. Dalmau-Pastor.

Journal: Knee Surgery, Sports Traumatology and Arthroscopy

Impact Factor: 3.149 (2018)

Journal Impact Factor Quartile: Q1

Published online: 30 October 2019

Volume: 28

Issue: 1

Pages: 24-33

DOI: https://doi.org/10.1007/s00167-019-05756-0.

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BOOK CHAPTERS

Anatomy of the ankle joint and hindfoot.

Authors: M. Dalmau-Pastor, M. Guelfi, F. Malagelada, R. Mirapeix, J. Vega.

Book title: Ankle Joint Arthroscopy: A Step-by-step Guide

Editors: Francesco Allegra, Fabrizio Cortese, Francesco Lijoi

Publisher: Springer International Publishing

Pages: 3-9.

DOI: https:// 10.1007/978-3-030-29231-7

ISBN: 978-3-030-29230-0

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Gross anatomy of the subtalar joint

Authors: M. Guelfi, M. Dalmau-Pastor, R. Mirapeix, J. Vega.

Book title: Ankle Joint Arthroscopy: A Step-by-step Guide

Editors: Francesco Allegra, Fabrizio Cortese, Francesco Lijoi

Publisher: Springer International Publishing

Pages: 11-16.

DOI: https:// 10.1007/978-3-030-29231-7.

ISBN: 978-3-030-29230-0

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DISCUSSION

The most important contribution of this thesis is that the arthroscopic all-inside lateral collateral ligament repair is a safe and reproducible technique and, compared to other stabilizing techniques such as arthroscopic Broström, has less potential risk of complications.

Until today, the open Broström procedure was considered the gold standard technique for treating chronic ankle instability [15-17]. In the last decade, there has been a paradigm shift and the role of arthroscopy has gained widespread popularity in the surgical management of the condition [2]. This may be due to: 1) the constant research of less invasive surgery and better results; 2) the intra-articular pathology that is associated with ankle instability in up to 93% of cases, and requires an arthroscopic treatment even before performing an open stabilization [18,19].

The arthroscopy meets all these needs, providing minimally invasive surgery, a faster return to normal and sports activities and the possibility to treat other intra-articular pathologies. Although arthroscopic techniques are varied, clinical outcomes of the arthroscopic techniques have proven similar or superior to open procedures [3, 4].

However, in literature, the arthroscopic stabilizing techniques for ankle instability have shown a wide range of complication rates, ranging from a minimum

complication rate of 0% to a maximum of 35% [3,4,20-22]. This is explained by the fact that not all the techniques are similar and each one has its own characteristics and risks.

Modern arthroscopic stabilizing techniques can be broadly divided into three groups: 1) an arthroscopic all-inside ligament repair, 2) an arthroscopically assisted percutaneous technique and 3) an arthroscopic ligamentoplasty.

The arthroscopic all-inside lateral ligament repair is a fully arthroscopic technique that avoids percutaneous suture passage and, therefore, is inherently safer than its percutaneous counterparts [5,6,7,23]. In the first published study of this thesis, there were no cases of suture entrapment of any anatomical surrounding structures [24]. This is because the ligament is sutured within the ankle joint and under arthroscopic visualization, ensuring that no other anatomic structures or nerves are encountered. The results of this study explain and complement the clinical outcomes previously reported in literature and confirmed in the second paper of this thesis, which showed no neurological complications for the all-inside repair [25].

On the other side, the arthroscopic Broström is an arthroscopic-assisted technique with a percutaneous passage of the suture in the anterolateral aspect of the ankle [8]. Despite a risk-free zone being described for the passage of the suture, previous studies reported a high rate of complications for this technique (5.3% to 29%), almost double compared to open techniques. The high complication rate of the arthroscopies is due to the high risk of superficial peroneal nerve (SPN) entrapment during the percutaneous step [3,9,20-22]. The SPN is known to have multiple anatomical variants plus a mobile path that varies depending on ankle dorsiflexion

[10,28]. Anatomical variations in the nerve distribution pose higher risk of injury by the subcutaneous suture passing [28]. Moreover, the nerve moves approximately 2.4 mm laterally when the ankle is dorsiflexed when compared to a plantarflexed and inverted position [28]. In contrast to the AB, the AI is a fully arthroscopic procedure in which the ligament is grasped intra-articularly under direct arthroscopic vision, obviating any risk of subcutaneous nerve entrapment [24]. This pitfall was confirmed in the second publication of this thesis, with a significantly higher complication rate for the arthroscopic Broström compared to the all-inside repair (40% vs 5.3%; $p<0.05$) [25].

As for the post-operative stiffness, it is accepted that a mild deficit in range of motion (ROM) is to be expected as a consequence of the surgery itself which tightens the stabilizing structures. However, a ROM deficit greater than 10°, may compromise the functional outcome and sports activities [7]. In the second publication of this thesis, another concern highlighted for patients treated with the arthroscopic Broström technique was an ankle plantarflexion deficit greater than 10° present in 20% of patients (4 cases). This high rate of ROM limitation was not observed in the all-inside repair group, with only 1 case (5%) reported [25].

This difference could be explained for the characteristics of the tissue involved in each technique. As proved in the cadaveric study of this thesis, in the all-inside repair, sutures only grasp the ATFL and, if required, the CFL remnant, providing an anatomical repair of the ligaments. Contrarily, in the arthroscopic Broström, sutures grasp the ligament, the capsule, the IER and/or the sural fascia [9]. Therefore, grasping all these anatomical structures with the same sutures does not provide a strictly anatomic repair and may create a large fibrosis in the anterolateral part. This

results not only in the ankle stabilization but in some patients even in a ROM limitation.

In addition, the arthroscopic Broström is designed to include the IER to the ligament repair. This is a matter of controversy known from its open Broström counterpart [29,30]. The augmentation using the IER requires the presence of the superolateral IER band, only present in 25% of cases [30]. In addition, an anatomical study observed that the superolateral IER band is a thin and fragile band that may not add significant mechanical contribution to the ligament repair [30]. This could explain why incorporation of the IER in the traditional Broström procedure has not shown any mechanical advantage when compared to just a ligament repair without including the IER [29]. It is likely that during the percutaneous AB step what is actually tightened is not only the IER, but even subcutaneous fatty tissue that brings no real stability to the construct.

In addition, the all-inside repair is considered a moderately demanding technique, and as such, not ideal for novice arthroscopist. However, the cadaveric study showed it could be reproduced without difference in terms of complications and ligament repair even by 2 surgeons with different levels of experience in the technique [24]. The crucial point in performing the third-generation techniques is not the experience in the technique itself but a thorough knowledge of up-to-date arthroscopic anatomy. This explains the need in this thesis for the two-chapter book on anatomy related to ankle arthroscopy and 2 articles on specific arthroscopic anatomy [26,27].

The arthroscopic ankle anatomy described to date has traditionally been referred to as the constant distraction technique [31], which tightens the anterior capsule and intra-articular ligamentous structures, displaying a different view of anatomical structures when compared with that of the same structures when the dorsiflexion technique is used [32]. Despite the increasingly reported use of the dorsiflexion technique, no reports have specifically addressed the arthroscopic anatomy of the ankle in this position. The paper "A step-by-step arthroscopic examination of the anterior ankle compartment" present in this thesis, describes the normal arthroscopic anatomy of the ankle joint and proposes an arthroscopic examination system for the anterior ankle compartment when using the ankle dorsiflexion [33]. The use of dorsiflexion instead of constant distraction allows constant visualization of the ATFL's superior fascicle on the floor of the lateral gutter, the ATiFL's distal fascicle laterally and the most anterior margin of the deltoid ligament in the medial gutter (anterior tibiotalar ligament) [33]. This characteristic is fundamental in performing new ankle arthroscopic stabilizing techniques.

Most of the time, surgeons are used to studying anatomy in a general and static way that is useless for modern techniques, especially if minimally invasive. Instead of this common misunderstanding, anatomy is an evolving field which has to be studied and presented in a surgically-oriented description in order to provide useful knowledge for surgeons. In this regard, one of the strengths of this thesis is the close collaboration between anatomists and surgeons. This is essential because new arthroscopic techniques need specific anatomy description and knowledge.

CONCLUSIONS

1. The lateral and medial gutters along with the talar neck can be observed only when using discretionary distraction technique.

2. The anterior part of both the lateral and medial ankle collateral ligaments is observed through anterior ankle arthroscopy when using dorsiflexion and non-distraction technique. The intra-articular ligamentous structures seen arthroscopically correspond to the ATFL's superior fascicle, the ATiFL's distal fascicle and the anterior tibiotalar component of the deltoid ligament in the anterior compartment.

3. The arthroscopic all-inside lateral collateral ligament repair is a safe technique with minimal risk of damage to surrounding neurological structures.

4. The arthroscopic all-inside lateral collateral ligament repair is a reproducible technique regardless of the surgeon's level of experience.

5. Both the arthroscopic Broström and the all-inside repair are suitable surgical options to treat chronic ankle instability providing excellent clinical outcomes. However, the arthroscopic Broström has a higher rate of

complications, particularly involving neuritis of the superficial peroneal nerve and restrictions in range of motion.

6. A safe arthroscopic seven-point examination system of the ankle's anterior compartment is possible. This enables the accounting for all structures that are best and safely visualized when using a dorsiflexion technique.

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APPENDIX

NON-INDEXED JOURNALS' ARTICLES

Title:

Trattamento artroscopico dell'instabilità laterale di caviglia con tecnica all-inside

Arthroscopic all-inside lateral ligament repair for chronic ankle instability.

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