

**The impact of foot and ankle radiographs
in the diagnosis and management of
patients with ankle pain**

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2018

Dissertation submitted in partial compliance with the requirements for the

Master's Degree in Technology: Chiropractic

Durban University of Technology

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DECLARATION

I, Andrew Revell, declare that this dissertation is representative of my own work in both conception and execution, except where indicated via references.

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DEDICATION

I dedicate this dissertation to my mom, Sarah Revell. Without her love, support and sacrifice throughout my academic career I wouldn't be in the position I am in today. Thank you for everything, words cannot describe how much I appreciate everything.

ACKNOWLEDGEMENTS

Dr Keseri Padayachy, thank you for the guidance during this study. The hours sacrificed towards my study to make it happen have not gone unnoticed.

Dr Angela Pastellides, thank you for all help during the study and for always trying your best to make the procedure as quick as possible.

Dr Charmaine Korporaal, thank you to all your hard work in the program, without you the six years would've been a lot different. Your dedication to chiropractic is inspirational.

Deepak Singh, thank you for working so hard on my statistics. The sacrifice you made during such a busy time of the year to get my work back is greatly appreciated.

Dr Richard Steele, thank you for fitting my study in for proof reading.

The Radiography Department, without your agreement, sacrifice and willing to help this study wouldn't be possible.

The Chiropractic Day Clinic, thank you for your support during the last 2 years.

My brother and sister, Scott and Tessa Revell. You two have always been there for me and without your support I wouldn't be where I am today.

Christie Garlick, my amazing girlfriend. You have been here for me from the beginning of this study. Your love and support mean the world to me and I wouldn't have been able to finish without you. Thank you.

ABSTRACT

Background:

Foot and ankle problems are highly prevalent in the general population. An accurate diagnosis is often difficult despite a careful and detailed clinical history as well as physical examination. Identifying the cause of ankle pain is essential for timely and adequate treatment although it is often challenging for the physician due to the complexity of the joint. The initial assessment typically involves the use of radiographs which play a key role in the diagnosis and management of ankle pain. Although radiographs play a key role in the assessment of foot and ankle pain the overutilization of radiographs worldwide emphasises the need to investigate the correlation between clinical conditions and the outcome of the radiographic examination. Literature is currently limited on the role of foot and ankle radiographs and their influence on the diagnosis and management for patients with foot and/or ankle pain.

Aim:

This study aimed to investigate any correlation between clinical and radiographic diagnosis of the foot and ankle. The impact the radiological diagnosis had on the clinical diagnosis and management was determined for patients that presented with foot and/or ankle pain at the Durban University of Technology (DUT) Chiropractic Day Clinic (CDC).

Method:

The picture archiving and communication system (PACS) at the Radiography Department at the Durban University of Technology (DUT) was searched for all available foot and ankle radiographs with their corresponding patient files at the CDC regarding foot and/or ankle pain. The ABCS (alignment, bone, cartilage, soft tissue) system was utilized to record data of the radiographs without any knowledge of the patient's main complaint. The corresponding patient files were then evaluated with selected clinical variables being recorded. Statistical analysis and interpretation included frequency counts, percentages, mean, standard deviation and ranges for

the descriptive objectives. The radiographic and clinical diagnoses were then compared in a two-by-two table to determine any possible relationship in diagnoses of patients with foot and/or ankle pain.

Results:

A total of $n = 26$ clinical files and their corresponding foot or ankle radiographs were analysed in this study. The average age of the patients was 38.12 years with a gender distribution of 53.80% males and 46.20% females. The majority of foot and ankle radiographs (57.69%) were requested at the initial consultation. The most common reason for radiographic examination referral was trauma, check for fracture at 20.80%, pain on palpation at 16.70% and no response to conservative management at 16.70%. The primary clinical diagnosis changed in a total of 7.70% of patients following radiographic examination. Most patients were diagnosed with non-specific mechanical causes of foot and ankle pain. A wide variety of treatment modalities were utilized before and after radiographic examination, including soft tissue therapy, electro modalities, extremity manipulative therapy (EMT) and dry needling. A total of 38.00% of cases in this study had a change in management protocol post radiographic examination.

Conclusion:

Foot and ankle radiographs have little impact on the diagnosis and management of patients with foot and/or ankle pain as the majority of clinical diagnoses were non-specific mechanical causes of foot and ankle pain. Foot or ankle radiographs were influential in the diagnosis of 7.70% and in 38.00% of management of cases. Foot and ankle radiographs may therefore be over utilized at the DUT CDC.

TABLE OF CONTENTS

DECLARATION.....	ii
DEDICATION	iii
ACKNOWLEDGEMENTS	iv
ABSTRACT	v
TABLE OF CONTENTS	vii
LIST OF TABLES.....	x
LIST OF FIGURES.....	xi
LIST OF APPENDICES.....	xii
LIST OF DEFINITIONS	xiii
LIST OF ABBREVIATIONS AND SYMBOLS	xv
CHAPTER 1: INTRODUCTION.....	1
1.1 INTRODUCTION TO THE STUDY	1
1.2 AIMS AND OBJECTIVES	3
1.2.1 Research problem	3
1.2.2 Aim of the study	3
1.2.3 Objectives of the study	3
1.3 SCOPE OF THE STUDY	4
CHAPTER 2: LITERATURE REVIEW.....	5
2.1 INTRODUCTION	5
2.1.1 Chiropractic and foot and ankle pain	5
2.1.2 Anatomy of the foot and ankle	6
2.2 THE AETIOLOGY AND DIAGNOSIS OF FOOT AND ANKLE PAIN	12
2.2.1 Foot and ankle joint dysfunction	13
2.2.2 Ankle sprains	14
2.2.3 Chronic ankle instability	16
2.2.4 Plantar fasciitis	19
2.2.5 Stress fractures	20
2.2.6 Pes planus (flat feet).....	21

2.2.7	Cuboid syndrome	22
2.2.8	Bunion formation	22
2.2.9	Arterial calcification.....	23
2.2.10	Club foot (Talipes eqinovarus).....	24
2.2.11	Osteochondral lesions	24
2.2.12	Systemic Diseases	25
2.3	FACTORS ASSOCIATED WITH THE DIAGNOSIS OF FOOT AND ANKLE PAIN	26
2.4	THE ROLE OF RADIOGRAPHS IN THE DIAGNOSIS	34
2.4.1	Foot and Ankle projections	36
2.4.1.1	Anterior to posterior of the ankle (AP ankle).....	36
2.4.1.2	Medial oblique ankle projection	37
2.4.1.3	Lateral ankle projection	39
2.4.1.4	AP foot projection	41
2.4.1.5	Lateral foot projection	43
2.5	CLINICAL APPROACH TO RADIOGRAPHIC REFERRAL	44
2.6	OVERVIEW OF THE MANAGEMENT OF PAIN	45
2.7	CONCLUSION.....	48
CHAPTER 3:	MATERIALS AND METHODS	49
3.1	STUDY DESIGN.....	49
3.2	PATIENT CONFIDENTIALITY	49
3.3	SAMPLING METHOD AND SAMPLE SIZE	49
3.4	INCLUSION AND EXCLUSION CRITERIA	50
3.4.1	Inclusion criteria.....	50
3.4.2	Exclusion criteria	50
3.5	RESEARCH PROCEDURE	50
3.6	ETHICAL CONSIDERATIONS	52
3.7	STATISTICAL ANALYSIS.....	53
CHAPTER 4:	RESULTS – STATEMENT OF FINDINGS, INTERPRETATION AND DISCUSSION OF THE DATA.....	54
4.1	INTRODUCTION	54
4.2	DISTRIBUTION OF AGE AND GENDER	55

4.3	THE RELATIONSHIP BETWEEN THE CLINICAL AND THE RADIOLOGICAL DIAGNOSIS OF PARTICIPANTS	55
4.4	THE CONSULTATION WHEN FOOT AND/OR ANKLE RADIOGRAPHS WERE REQUESTED AND THE REASONS THEREFORE.....	59
4.5	SUSPECTED CLINICAL DIAGNOSES AND MANAGEMENT	63
4.5.1	Prior to referral for foot or ankle radiographs	63
4.5.2	Changes in the clinical diagnoses and management after radiographic evaluation	66
4.6	INCIDENTAL FINDINGS ON RADIOGRAPHS.....	70
CHAPTER 5: DISCUSSION OF RESULTS		73
5.1	INTRODUCTION	73
5.1.1	Age and gender	73
5.2	THE RELATIONSHIP BETWEEN THE PRE-RADIOGRAPHIC AND RADIOLOGICAL DIAGNOSES OF PATIENTS WITH FOOT AND/OR ANKLE PAIN.....	74
5.3	THE CONSULTATION WHEN FOOT AND ANKLE RADIOGRAPHS WERE REQUESTED AND REASONS THEREFOR.....	77
5.4	SUSPECTED CLINICAL DIAGNOSES AND MANAGEMENT PRIOR TO REFERRAL FOR FOOT OR ANKLE RADIOGRAPHS.....	79
5.5	CHANGES IN THE CLINICAL DIAGNOSIS AND MANAGEMENT AFTER FOOT OR ANKLE RADIOGRAPHS	79
5.6	INCIDENTAL RADIOGRAPHIC FINDINGS.....	80
CHAPTER 6: CONCLUSION AND RECOMMENDATIONS.....		82
6.1	CONCLUSION	82
6.2	LIMITATIONS OF THE STUDY	83
6.3	RECOMMENDATIONS.....	84
REFERENCES.....		85
APPENDICES		98

LIST OF TABLES

Table 2.1: Grading method to the extent of damage to a single ligament	15
Table 2.2: Grading method in relation to the number of ligaments involved	15
Table 2.3: Grading method in relation to the clinical features.....	15
Table 2.4: Adult foot and ankle disorders for which radiographs are recommended	29
Table 3.1: Recorded data and source	52
Table 4.1: The pre-radiographic primary clinical diagnosis and the primary radiological diagnosis.....	57
Table 4.2: The pre-radiographic primary clinical diagnosis and the secondary radiological diagnosis.....	58
Table 4.3: The reasons for radiographic referral and at which consultation	60
Table 4.4: The most common reasons for radiographic referral	62
Table 4.5: The suspected clinical diagnosis and management prior to radiographic evaluation	64
Table 4.6: Clinical diagnosis and the corresponding radiographic findings	67
Table 4.7: Incidental findings related to the pre-radiographic clinical diagnosis and post-radiographic clinical diagnosis	71
Table 4.8: Incidental findings and the effect on the post-radiographic management	72

LIST OF FIGURES

Figure 2.1: Anterior and posterior views of the ankle joint.....	7
Figure 2.2: Lateral ankle ligaments	8
Figure 2.3: Medial ankle ligaments.....	9
Figure 2.4: Lower leg musculature	10
Figure 2.5: Anatomy of the foot	12
Figure 2.6: Lateral foot radiograph showing heel spur	20
Figure 2.7: Lateral foot radiograph showing calcaneal stress fracture	21
Figure 2.8: Radiograph showing pes planus: the long axis of the talus is angled plantar forward in relation to the first metatarsal	22
Figure 2.9: Radiograph showing the malalignment in the presence of a bunion	23
Figure 2.10: Radiograph of arterial calcification of the foot	24
Figure 2.11: Ottawa foot and ankle rules to improve the diagnosis of fractures without imaging studies.....	28
Figure 2.12: AP radiographic view of the ankle	36
Figure 2.13: Medial oblique view of the ankle	37
Figure 2.14: Lateral ankle projection	39
Figure 2.15: AP projection of the foot.....	41
Figure 2.16: Lateral projection of the foot.....	43
Figure 4.1: Gender distribution of participants.....	55
Figure 4.2: The management prior to radiographic referral	65
Figure 4.3: The impact radiographs had on the clinical diagnosis.....	66
Figure 4.4: The impact the radiologic referral had on management	68
Figure 4.5: The management post radiographic referral	69
Figure 4.6: The change in management post radiographic referral	70
Figure 4.7: The number of incidental findings on radiographs.....	71

LIST OF APPENDICES

Appendix A: Approval to access the PACS system.....	98
Appendix B: Permission to record data from the CDC	99
Appendix C: Ethics Approval.....	100
Appendix D: The DUT CDC indemnity form highlighting permission for utilization of clinical information for research purposes.....	101
Appendix E: File capture sheet	102
Appendix F: Data capture sheet.....	103

LIST OF DEFINITIONS

Chiropractic:

A health care profession that is involved with the diagnosis, treatment and prevention of neuromuscular skeletal system disorders and the effects these disorders have on general health. Manual techniques, including joint manipulation/adjustments, are the primary emphasis in the profession (World Federation of Chiropractic, 2012).

Incidental findings:

An abnormality that is not related to the illness or causes that prompted the diagnostic imaging (Lumbreras *et al.*, 2010).

Modalities:

A form of therapeutic agent or regimen to aid in the healing of a condition (Stedman's Medical Dictionary, 2008).

Radiograph:

An image produced on a sensitive plate or film by X-rays, gamma rays, or similar radiation, and typically used in medical examination (English Oxford Dictionary, 2018a).

Red Flags:

Features of potential serious underlying pathology and are recognised through subjective and objective assessments (Henschke *et al.*, 2013).

Referred pain:

Pain felt in a part of the body other than its actual source (English Oxford Dictionary, 2018).

Ankle pain:

Ankle pain is defined as pain on the inside or outside of your ankle or along the Achilles tendon (Edwards, Harms and Berg, 2016).

Foot Pain:

Foot pain is defined as pain that affects any part of the foot, from toes to the Achilles tendon at the back of the heel (Edwards, Harms and Berg, 2016).

Extremity manipulative therapy:

This movement is accomplished with a high-velocity, low amplitude manipulative thrust which may create a characteristic cavitation (Bergman and Peterson, 2011).

LIST OF ABBREVIATIONS AND SYMBOLS

ABCS	Alignment, bone, cartilage and soft tissue
AP	Antero-posterior
ATFL	Anterior tibiotalar ligament
CFL	Calcaneofibular ligament
CDC	Chiropractic Day Clinic
DUT	Durban University of Technology
EMT	Extremity Manipulative Therapy
IFC	Interferential current
MRI	Magnetic resonance imaging
n	Sample size or count
PNF	Proprioceptive neuromuscular facilitation
PTFL	Posterior talofibular ligament
SD	Standard deviation
SOAPE	Subjective, objective, assessment, plan and education
TENS	Transcutaneous electrical nerve stimulation
US	Ultrasound

CHAPTER 1: INTRODUCTION

1.1 INTRODUCTION TO THE STUDY

Foot and ankle problems are highly prevalent in the general population affecting between 16% to 50% of adults over the age of 50 (Thomas *et al.*, 2011). Literature from several studies revealed that foot and/or ankle pain affects approximately 1 in 5 middle-aged to older people, with an increased prevalence in females (Thomas *et al.*, 2011). According to Hiller *et al.*, 2012, the general community presents with between 2.2 to 7.0 ankle sprains per year per 1000 people and 1.1 per 1000 people per year for an ankle fracture to the emergency department. Furthermore, 22% of all sporting injuries that presented to a hospital emergency room were ankle injuries, with a ratio of eight sprains to each fracture (Hiller *et al.*, 2012).

The ankle joint is a hinge-type synovial joint located between the distal ends of the tibia and fibula and the superior part of the talus. It is the most frequently injured major joint in the body (Moore, Dalley and Agur, 2010). Ankle pain is defined as pain on the inside or outside of your ankle or along the Achilles tendon (Edwards, Harms and Berg, 2016). Due to the complexity of the joint (Wong and Tan, 2016), an accurate diagnosis is often difficult despite a careful, detailed clinical history and physical examination (Ahn and El-Khoury, 2007). It is useful to know the mechanism of injury when obtaining the history as higher energy injuries are likely to result in articular damage (Griffith and Brockwell, 2006). Ankle joint effusion and local tenderness over one or more periarticular regions, including the anterolateral and anteromedial joint line, are common examination findings. Neurological examination (Bussi res Peterson, and Taylor, 2007) as well as varus alignment, instability of the ankle and subtalar joints should be assessed as well as the anterior drawer test and standard inversion manoeuvres (O'loughlin, Heyworth and Kennedy, 2010). The initial assessment typically involves the use of radiographs, playing a key role in the diagnosis and management of ankle pain (Ahn and El-Khoury, 2007; Nugent, 2004).

Radiography is a common image modality for ankle injuries (Bindiya *et al.*, 2014), typically used as an initial assessment, playing a key role in the diagnosis and management of ankle pain (Ahn and El-Khoury, 2007; Nugent, 2004). Radiography is frequently used for assessments as it is widely available and inexpensive (Ahn and El-Khoury, 2007). According to Bussi res *et al.* (2007), indications for radiographic imaging include; the patient being unable to give a reliable history, crippling phobia to cancer and back pain, whether it may impact on an individual's career or athletic future, legal evaluation or a history of significant abnormalities from other investigations. The most necessary documented reasons for radiographs is the need to confirm a pathology, follow the progression of a pathology which may influence treatment, or to identify suspected contra-indications to an intervention (e.g. manipulative therapy) (Bussi res *et al.*, 2007). Radiographs are not indicated for non-specific hip, knee, ankle or foot pain initially, but are indicated after blunt trauma or if there is no improvement after four weeks of conservative treatment (Bussi res *et al.*, 2007).

Due to the complexity of the ankle joint (Wong and Tan, 2016), an accurate diagnosis is often difficult despite a careful, detailed clinical history and physical examination (Ahn and El-Khoury, 2007), but it is essential for timely and adequate treatment (Wong and Tan, 2016). Foot and ankle pain often responds well to home treatments although it is advisable to consult a doctor for severe foot and ankle pain, especially following an injury (Edwards, Harms and Berg, 2016). Hiller *et al.* (2012) found that subsequent to an ankle sprain, up to 15% of people that returned to work have an impairment; 6% were unable to maintain any occupational activity, and 72% of the participants could not maintain their previous activity level. According to Hiller *et al.* (2012) posttraumatic ankle osteoarthritis may result in long term consequences such as ankle fractures, sprain, osteochondrosis and cartilage damage. Approximately 25% of people have poor to fair self-reported outcomes at 2, 5 and 14 years post fracture with residual problems including pain, decreased range of motion and impaired function (Hiller *et al.*, 2012). Foot pain has also been identified as an independent risk factor for impaired balance, functional activities, locomotive disability, and an increased risk of falling (Thomas *et al.*, 2011).

Chiropractic management incorporates passive and active care, addressing the acute inflammatory/pain phase and the chronic/rehabilitation/injury prevention phase (Hoskins *et al.*, 2006). Chiropractic management incorporates a multimodal approach involving various manual therapy procedures emphasising high velocity techniques, massage and stretching and rehabilitation exercises which include proprioceptive exercises, motor pattern correction and sports specific training (Hoskins *et al.*, 2006). Modalities such as strapping, ice and heat, electrotherapies, acupuncture, gait retraining, nutrition, footwear/ergonomic/training advice, and exercise/cross training programs may also be used (Hoskins *et al.*, 2006).

This study will address the impact that foot and/or ankle radiographs have on the clinical diagnosis and management of patients that presented to the CDC at DUT with foot and or ankle pain.

1.2 AIMS AND OBJECTIVES

1.2.1 Research problem

It is unknown if any correlation exists between clinical and radiological diagnosis in patients with foot and ankle pain that presented to the Chiropractic Day Clinic (CDC) at the Durban University of Technology (DUT) and if the radiological diagnosis leads to a change in the patients' initial management plan.

1.2.2 Aim of the study

The aim of this research was to determine whether a correlation exists between the clinical and radiographic diagnosis of foot and ankle pain and the impact of the radiographic diagnosis on the clinical diagnosis and management of patients with foot and ankle pain at DUT.

1.2.3 Objectives of the study

- To determine the clinical diagnosis and management of the selected patients prior to referral for foot or ankle radiographs.
- To record the consultation at which foot or ankle radiographs were requested by the student or clinician and the reasons therefore.

- To determine the relationship between the clinical and the radiographic diagnosis of patients with foot or ankle pain.
- To determine the number of incidental radiographic findings in the selected patients' foot or ankle radiographs.
- To determine any change in clinical diagnoses and management following radiographic reporting of the selected patient's foot or ankle radiographs.

1.3 SCOPE OF THE STUDY

In this retrospective study, a total of 26 foot and ankle radiographs with their corresponding patient files that satisfied the inclusion and exclusion criteria were extracted from the DUT Radiography Department PACS system from January 2013 to April 2018, and CDC archives respectively. Purposive sampling was used and all the radiographs and corresponding patient files are discussed in this dissertation. A standardized DUT CDC consent for (Appendix C) which allows access to clinical information for research purposes after IREC approval would need to have been signed. Patient confidentiality was maintained by the utilization of an alpha numerical coding system (Appendix E) as well as limiting access to the patient files and radiographs to only the researcher and supervisors. The supervisors verified the clinical and radiographic findings that were recorded by the researcher.

CHAPTER 2: LITERATURE REVIEW

2.1 INTRODUCTION

This chapter includes an in-depth review of the foot and ankle literature. This literature relates to the foot and ankle anatomy and the prevalence and causes of foot and/or ankle pain. Additionally, clinical findings revealed during patient history and physical examination and the importance of such findings are discussed. Lastly, indications for radiograph referral and the recommended patient management for ankle and/or foot pain have been included.

2.1.1 Chiropractic and foot and ankle pain

Chiropractic is the most popular drug-free, primary contact health care profession in the world and is growing at a fast pace (World Federation of Chiropractic, 2012). Chiropractors mainly focus on the diagnosis and treatment of neuro-musculoskeletal conditions in a conservative manner without the utilization of medicine or surgery (World Federation of Chiropractic, 2012).

Foot and ankle disorders can manifest as a result of one or both local and systemic disease processes (Montgomery and Davies, 2016). Ankle pain is defined as pain on the inside or outside of the ankle or along the Achilles tendon, while foot pain is defined as pain that affects any part of the foot, from toes to the Achilles tendon at the back of the heel (Edwards, Harms and Berg, 2016).

A considerable amount of time is devoted to the foot by primary healthcare physicians and the ankle is the most frequently injured major joint in the body (Moore, Dalley and Agur, 2010), therefore, it is one of the most common presenting acute injuries to emergency departments' (Yazdani, Jahandideh and Ghofrani, 2006). Although chiropractic is generally associated with back pain, only a minority of practitioners perceive themselves as solely spine specialists (Kollasch *et al.*, 2005).

Foot and ankle problems are highly prevalent in the general population affecting 16% to 50% of adults over the age of 50 (Thomas *et al.*, 2011). Data collected from

several different studies revealed that foot and/or ankle pain affects approximately one in five middle-aged to older people, with an increased prevalence in females (Thomas *et al.*, 2011). According to Hiller *et al.* (2012), the general community presents with between 2.2 to 7.0 ankle sprains per year per 1000 people with a ratio of 8 sprains to 1 fracture (Daniels, Welk and Enix, 2016). Furthermore, 22% of all sporting injuries that presented to a hospital emergency room are ankle injuries, with a ratio of eight sprains to each fracture, which is the same as the general population (Hiller *et al.*, 2012; Daniels, Welk and Enix, 2016). Fong *et al.* (2007) identified that ankle injuries are the most common type of injury in 24 out of 70 types of sport. Furthermore, Saxena and Eakin (2007) documented osteochondral lesions of the ankle as an increasingly common injury as they may occur in up to 50% of acute ankle sprains and fractures, particularly in association with sport (Tol *et al.*, 2000; Saxena and Eakin, 2007). A study conducted at DUT over three different years (2000, 2006 and 2011) found that ankle injuries were, on average, the most common lower extremity complaint treated at the DUT CDC (McDonald, 2012).

2.1.2 Anatomy of the foot and ankle

The ankle is located proximally from the malleolar parts of the distal leg to its distal landmark which is just proximal to the dorsum of the heel. It is described as a hinge-type synovial joint located between the distal ends of the tibia and fibula and the superior part of the talus (**Figure 2.1**) (Moore, Dalley and Agur, 2010) as well as all the articular surfaces covered by hyaline cartilage (Gosling *et al.*, 2008). **Figure 2.1** demonstrates the articular surfaces of the proximal aspect of the ankle comprising the distal ends of the tibia and fibula (Gosling *et al.*, 2008) along with the inferior transverse part of the posterior tibiofibular ligament which form the malleolar mortise into which the pulley shaped trochlea of the talus fits (Moore, Dalley and Agur, 2010).

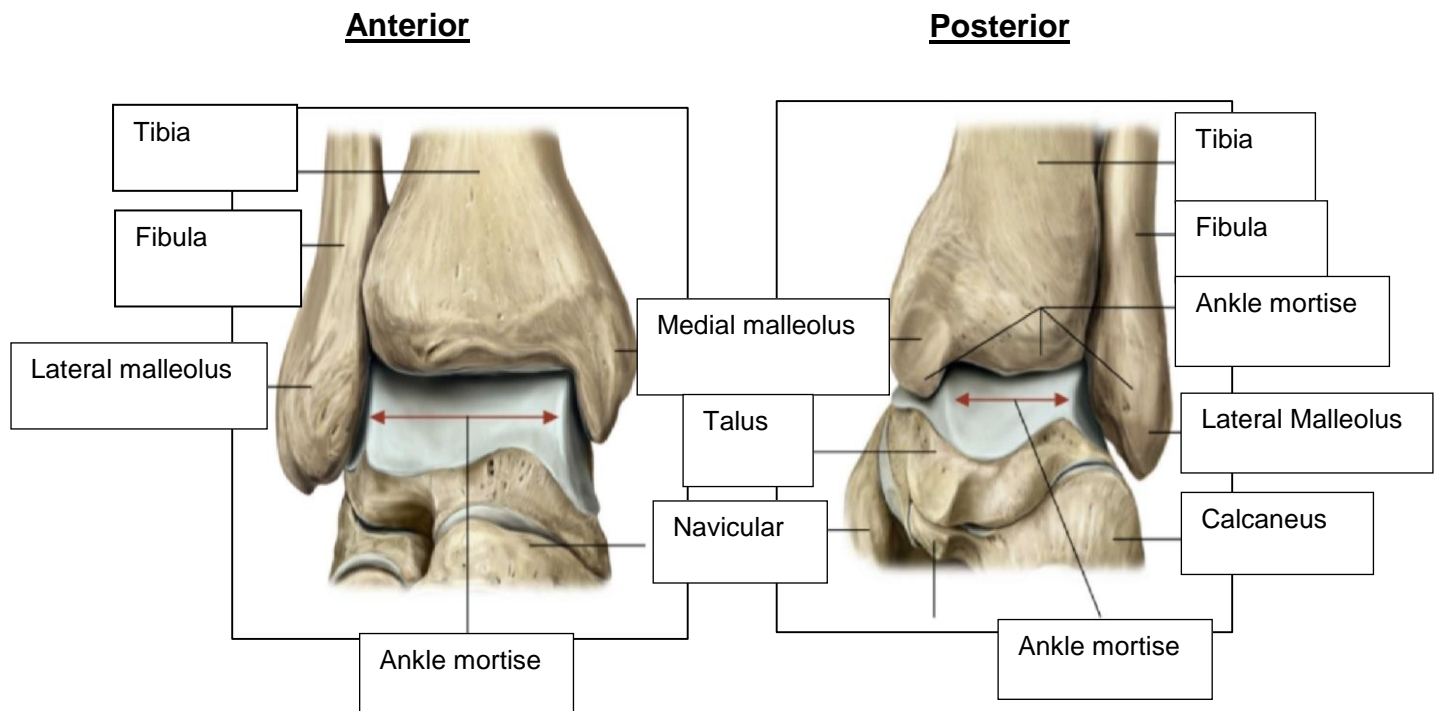


Figure 2.1: Anterior and posterior views of the ankle joint

Source: Scheunke, Schulte and Schumacher (2014)

The trochlea is described as the rounded superior articular surface of the talus (**Figure 2.1**). The lateral aspect of the talus articulates with the medial aspect of the lateral malleolus and the tibia articulates with the talus in two separate places (Moore, Dalley and Agur, 2010). The first articular surface is described as the inferior surface of the tibia forming the roof of the malleolar mortise which transfers body weight to the talus. The second articulation is at the medial malleolus and the medial surface of the talus (Moore, Dalley and Agur, 2010). The lateral articular subsurface of the talus is more extensive than that of the medial surface (Gosling *et al.*, 2008).

The ankle joint capsule is thin anteriorly and posteriorly but is supported by strong lateral and medial ligaments (Moore, Dalley and Agur, 2010). The attachments of the fibrous capsule extend along the margins of the articular surfaces anteriorly onto the neck of the talus (Gosling *et al.*, 2008). The loose synovial membrane lines the fibrous layer of the capsule (Moore, Dalley and Agur, 2010). The synovial cavity frequently extends superiorly between the tibia and the fibula as far as the interosseous tibiofibular ligament (Moore, Dalley and Agur, 2010).

There are two collateral ligaments (Gosling *et al.*, 2008). Laterally the ankle joint is reinforced by the lateral ligament of the ankle (Moore, Dalley and Agur, 2010). This is a compound structure consisting of three completely separate ligaments (**Figure 2.2**):

1. Anterior talofibular ligament: a weak, flat band that extends anteromedially from the lateral malleolus to the neck of the talus (Moore, Dalley and Agur, 2010).
2. Posterior talofibular ligament: a reasonably strong, thick band which runs horizontally medially and slightly posteriorly from the malleolar fossa to the lateral tubercle of the talus (Moore, Dalley and Agur, 2010).
3. Calcaneofibular ligament: A round cord-like ligament which passes posteroinferiorly from the tip of the lateral malleolus to the lateral aspect of the calcaneus (Moore, Dalley and Agur, 2010)

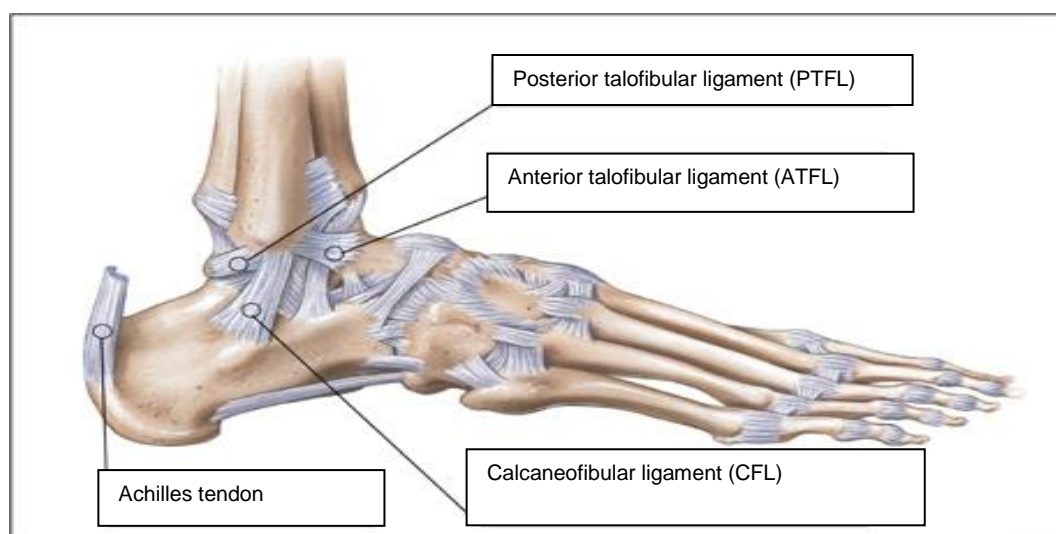


Figure 2.2: Lateral ankle ligaments
Source: Dynamic Physiotherapy (2016)

Medially the ankle joint is stabilised by the deltoid ligament (Gosling *et al.*, 2008). It is a large, strong ligament that attaches proximally to the medial malleolus (Moore, Dalley and Agur, 2010). It fans out from the malleolus, attaching distally to the talus, calcaneus, and navicular via four adjacent and continuous parts (**Figure 2.3**) (Moore, Dalley and Agur, 2010).

1. Tibionavicular part

2. Tibiocalcaneal part
3. Anterior tibiotalar part
4. Posterior tibiotalar part

The role of the medial ligament is to stabilize the ankle joint during eversion and to prevent subluxation of the joint (Moore, Dalley and Agur, 2010).

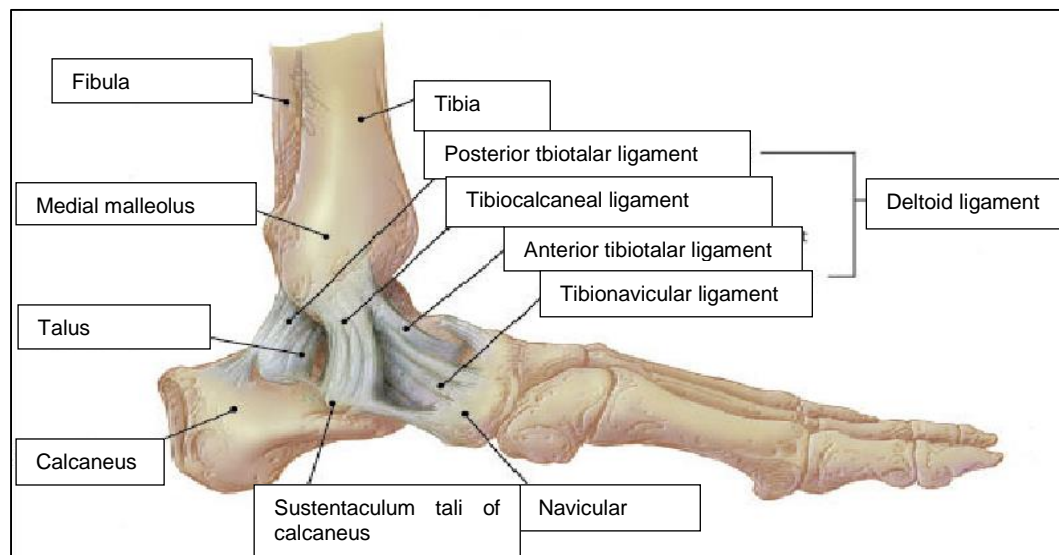


Figure 2.3: Medial ankle ligaments
Source: Physiopedia (2017)

Dorsiflexion and plantar flexion of the foot are the predominant movements of the ankle joint (Moore, Dalley and Agur, 2010). These movements occur around a transverse axis passing through the talus (Moore, Dalley and Agur, 2010). Approximately 20 degrees of movement occurs in dorsiflexion while 40 to 50 degrees of movement occur during plantar flexion (Loveless, 2017). Tibialis anterior, extensor hallucis longus, extensor digitorum longus and fibularis tertius are responsible for dorsiflexion (Gosling *et al.*, 2008). The soleus and gastrocnemius muscles, with the assistance of tibialis posterior, flexors hallucis longus and digitorum longus, and fibularis longus and brevis, are responsible for plantar flexion (Gosling *et al.*, 2008). **Figure 2.4** displays the muscles necessary for plantar and dorsiflexion to occur.

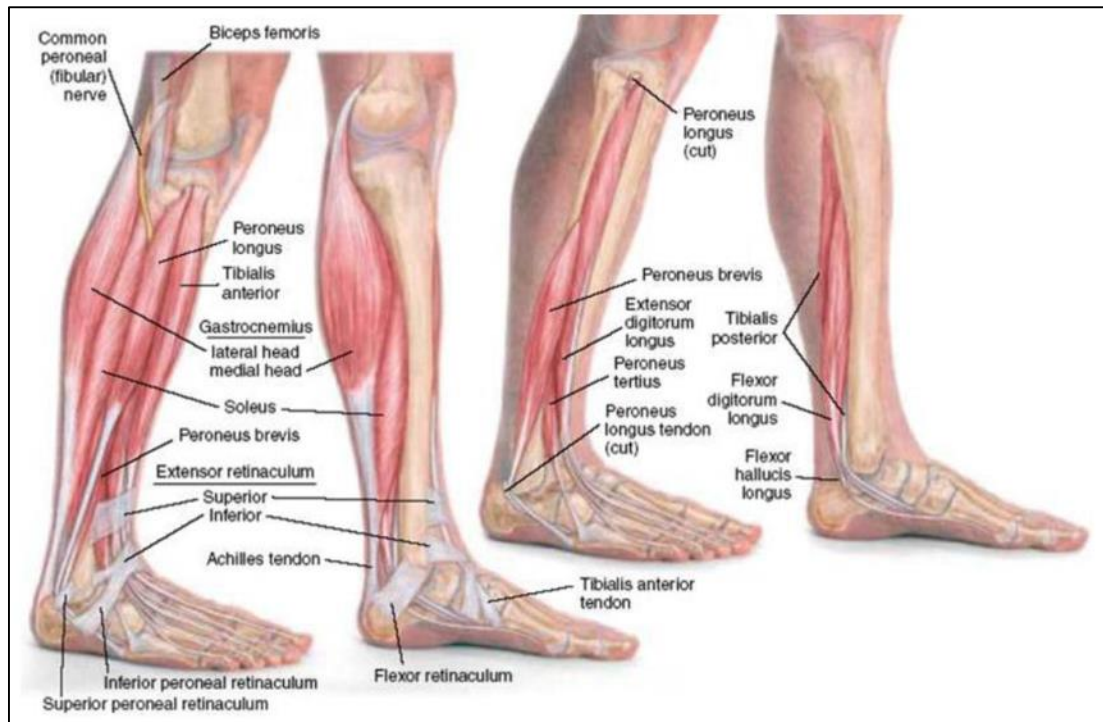


Figure 2.4: Lower leg musculature

Source: Mountain Peak Fitness (2017)

Due to the wedge shape of the articular surfaces and the strong collateral ligaments, the ankle joint is very stable (Gosling *et al.*, 2008). The bones are the primary stabilisers while the ligaments are secondary stabilisers (Loveless, 2017). During standing or walking, body weight tends to displace the tibiofibular socket forwards which results in it being closely packed against the wider anterior part of the talus, which increases stability during dorsiflexion (Gosling *et al.*, 2008). Excessive forward displacement of the fibula and tibia on the talus is prevented by the posterior fibres of the deltoid ligament, the calcanofibular and posterior talofibular ligaments (Gosling *et al.*, 2008). During plantar flexion of the ankle joint, “wobble” (small amounts of abduction, adduction, inversion and eversion) may occur due to the narrow end of the trochlea of the talus lying loosely between the malleoli which will result in an unstable position (Moore, Dalley and Agur, 2010).

The foot is divided into three different compartments, namely, hindfoot, midfoot and forefoot. The hindfoot is made up of the talus and calcaneus, the mid foot of the tarsals and the forefoot by the metatarsals and phalanges (Loveless, 2017). All the joints in the foot are synovial and are shaped according to their movements (Gosling *et al.*, 2008). The subtalar joint and the transverse tarsal joint are considered the

main intertarsal joints (Moore, Dalley and Agur, 2010). The joint capsule is weak but supported by medial, lateral, posterior and interosseous talocalcaneal ligaments (Moore, Dalley and Agur, 2010). Within the sinus tarsi lies the especially strong interosseous talocalcaneal ligament which separates the subtalar and talocalcaneonavicular joints (Moore, Dalley and Agur, 2010). The term subtalar joint refers to the compound functional joint consisting of the anatomical subtalar joint as well as the talocalcaneal part of the talocalcaneonavicular joint (Moore, Dalley and Agur, 2010). It is impossible for the two separate parts to function independently hence they function as a compound unit (Moore, Dalley and Agur, 2010). The function of the subtalar joint is for shock absorption and to accommodate to uneven surfaces (Loveless, 2017). Foot eversion and inversion occurs predominantly at the subtalar joint (Moore, Dalley and Agur, 2010).

The transverse tarsal complex is formed by two separate joints aligned transversely (Moore, Dalley and Agur, 2010). It is made up of the talonavicular part of the talocalcaneonavicular joint (**Figure 2.5**) (Moore, Dalley and Agur, 2010). The transverse tarsal complex is where the mid-foot and the forefoot rotate as a unit on the hind foot around a longitudinal axis. This enhances the inversion and eversion movements occurring at the subtalar joint (Moore, Dalley and Agur, 2010). Compound movements of the foot and ankle include pronation and supination (Loveless, 2017). During weight-bearing pronation there will be ankle joint dorsiflexion, subtalar eversion and forefoot abduction (Loveless, 2017). During weight-bearing supination there will be ankle joint plantarflex, subtalar inversion and forefoot adduction (Loveless, 2017).

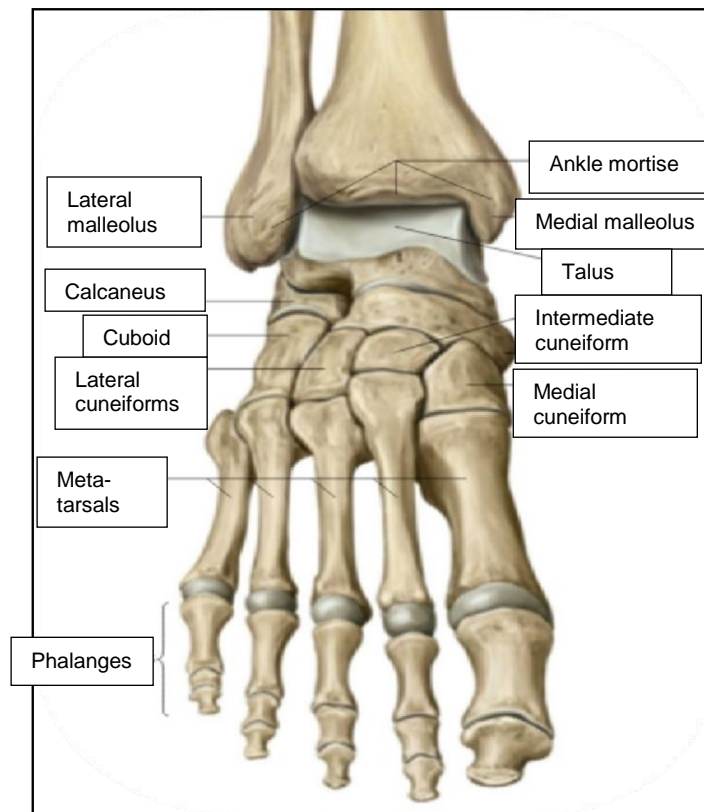


Figure 2.5: Anatomy of the foot

Source: Scheunke, Schulte and Schumacher (2014)

2.2 THE AETIOLOGY AND DIAGNOSIS OF FOOT AND ANKLE PAIN

Foot and ankle problems range from minor to more serious disorders (Akbaba *et al.*, 2016). Identifying the cause of ankle pain is essential for timely and adequate treatment although it is often challenging for the physician due to the complexity of the joint (Wong and Tan, 2016).

Common clinical conditions causing foot and ankle pain include posterior impingement, Achilles tendon pathology, medial flexor pathology, peroneal pathology, retrocalcaneal bursitis, posterior subtalar tarsal coalition, sinus tarsi, tarsal tunnel syndrome (Wong and Tan, 2016), tibial nerve entrapment, hallux valgus, hammer toe, claw toes, pes planus and talipes equinovarus (Moore, Dalley and Agur, 2010). Furthermore, pathologies that can cause posterior ankle pain may occur primarily or co-exist with other pathologies (Wong and Tan, 2016).

2.2.1 Foot and ankle joint dysfunction

A joint dysfunction syndrome diagnosis is referred to as a clinical diagnosis. It is defined by a collection of signs and symptoms that are assumed to identify dysfunction of the spinal, pelvic, or peripheral joints. It is not seen as a structural diagnosis, but rather as a functional diagnosis (Bergman and Peterson, 2011) of hypomobility (Vernon and Mrozek, 2005).

The nature and extent of an individual joint motion is determined by the structure of the joint, and specifically the shape of the opposing joint surfaces. There are no two perfectly uniform joint surfaces, nor are they perfectly geometric. All joint surfaces have a degree of curvature which is not constant but changing from point to point. Due to the incongruence of joint surfaces, some joint space and “play” must be present to allow free movement (Bergman and Peterson, 2011).

Osteokinematic movement refers to the physiologic movement possible at a joint when muscles contract or when gravity acts on the bone to move it. Osteokinematic movement describes the relationship between two joints and the movements that occur at these joints. Two perspectives of joint movements can be considered: the proximal segment can rotate against the relatively fixed distal segment, or against a series of articulated segmental links such as the shoulder, arm, forearm, wrist and hand. These can be referred to as an open or closed kinematic chain (Bergman and Peterson, 2011).

An open kinematic chain is defined by the distal segment, such as the foot in the lower extremity, which is not fixed to an immovable object and is free to move. A closed kinematic chain is the opposite circumstance, where the distal segment is fixed to an immovable object. When the patient is fully weight-bearing on the lower extremity then the lower extremity is in a closed packed position (Bergman and Peterson, 2011).

There must be five movement qualities present for normal joint function. These five qualities are: joint play, active range of motion, passive range of motion, end feel and paraphysiologic movement. In a neutral closed pack position, joint play should be present (Bergman and Peterson, 2011). The palpatory experience during joint play

should be matched with a feeling of smooth motion of a normal joint ending in a feeling of “play” or “spring” at the end of the passive range (Vernon and Mrozek, 2005). This is followed by active range of movement under the control of musculature. The examiner produces the passive range of motion and includes the active range, plus a small degree of movement, into the elastic range of movement. This causes an elastic barrier of resistance which exhibits the characteristic of end feel. The paraphysiologic movement is the minor movement past the elastic barrier and is typically encountered post cavitation of the joint (Bergman and Peterson, 2011).

Joint play and end feel movements are thought to be a necessity for normal joint function. A loss in either movement may result in a restriction of movement, pain, and most likely, both. Active movements may be influenced by exercise and mobilization and passive movements may be influenced by traction and some forms of mobilization. End feel movements are affected when the joint passes the elastic barrier, creating a sudden yielding of the joint with a characteristic cavitation (cracking noise). This movement is accomplished with a high-velocity, low amplitude manipulative thrust (Bergman and Peterson, 2011).

2.2.2 Ankle sprains

Ankle sprains are the most common muscular skeletal injury, occurring 1 in 10000 people daily (Bindiya *et al.*, 2014). They are considered to be a very common sports injury (Fong *et al.*, 2007). The mechanism of injury is often due to plantar flexion and inversion of the foot and ankle complex (Loveless, 2017). Depending on the severity, the excessive stress placed on the lateral ligaments and joint capsule may result in a disruption of some or all of these structures, concomitant pain, swelling and joint dysfunction (Denegar and Miller, 2002; Hertel, 2002; Bonnel *et al.*, 2010).

Lateral ankle sprains are graded according to the degree of injury. There are three grades of injury (**Table 2.1**). Grade one occurs when there is ligament stretch without tear and on examination laxity will not be present. Grade two presents as a partial ligament tear and will present with laxity on examination. Grade three is a complete tear of the ligament, on examination there will be laxity as well as no end point in the

range of motion (Caulfield, 2000; Pellow and Brantingham, 2001; Lynch, 2002; Loveless, 2017). **Table 2.2** shows the extent for grading of sprains according to the number of ligaments involved. **Table 2.3** shows the grading method of sprains in relation to their clinical presentation.

Table 2.1: Grading method to the extent of damage to a single ligament

Grade	Description
I	Microscopic damage without any macroscopic damage.
II	Macroscopic damage/stretching, ligament still intact.
III	Complete tear of the ligament.

Sources: Caulfield (2000), Pellow and Brantingham (2001), Lynch (2002)

Table 2.2: Grading method in relation to the number of ligaments involved

Grade	Description
I	Stretching of the anterior talofibular ligament (ATFL).
II	Tearing of the ATFL with/without tearing the calcaneofibular ligament (CFL).
III	Tearing the ATFL and CFL with a capsular tear or tear of the posterior talofibular ligament (PTFL).

Source: Chan *et al.* (2011)

Table 2.3: Grading method in relation to the clinical features

Grading	Description
I	Mild sprain, mild ligament damage, no haemorrhage or bruising, minimal oedema, point tenderness and no gross instability.
II	Moderate sprain, partial tearing of the ligaments, minimal haemorrhage and bruising, localised oedema and minimal instability if at all.
III	Severe sprain, complete rupture of the ligaments, early haemorrhage and bruising, diffuse oedema on both sides of the Achilles tendon, tenderness laterally and possibly medially and gross instability.

Sources: Reid (1992), Caulfield (2000), Pellow and Brantingham (2001), Lynch (2002), Ajis and Maffulli (2006), Chan *et al.* (2011)

Sprains present with similar symptoms to ankle fractures (Daniels, Welk and Enix, 2016). Symptoms include: pain, tissue swelling, ecchymosis, ligament laxity and decreased range of motion (Daniels, Welk and Enix, 2016). Generally, ankle fractures are a straight forward diagnosis. The Ottawa ankle rules are a tool which aid in the diagnostic decision between sprain and fracture and limits the need for imaging studies (Daniels, Welk and Enix, 2016).

One of the complications of ankle sprains is chronic ankle instability (CAI) (Bindiya *et al.*, 2014) which is the primary residual deficit after a sprain to the ankle joint (Delahunt, McGrath and Doran, 2010) and may be developed through repetitive ankle sprains and persistent symptoms after the initial ankle sprain. However, there are no clear indications that are important to differentiate between people with or without CAI (Hubbard *et al.*, 2007).

2.2.3 Chronic ankle instability

Chronic ankle instability syndrome is a debilitating condition with a negative impact on everyday life (Waterman *et al.*, 2010). It is associated with arthrogenic muscle inhibition and resultant weakness of the soleus and peroneal muscles therefore making the ankle joint susceptible to re-injury (McVey *et al.*, 2005; Palmieri-Smith, Hopkins and Brown, 2009). Subsequent to acute ankle trauma, 40% of people are at risk of developing chronic symptoms (Bindiya *et al.*, 2014) such as pain, joint instability, restriction and loss of function (Ivins, 2006; Wolfe *et al.*, 2001). There are numerous conditions that may mimic CAI that need to be ruled out to make a clinical diagnosis. These conditions include: fractures of the foot and ankle, peroneal tendonitis, osteoarthritis of the ankle joint, ankle impingement syndrome, Achilles tendonitis, lateral malleolar bursitis, tarsal coalition, posterior tibialis tendon dysfunction, sinus tarsi syndrome and osteochondritis dissecans (de Bie *et al.*, 2003; Chan, Ding and Mroczek, 2011).

Ankle instabilities are complex and difficult to understand (Bonnel *et al.*, 2010). They are classified as functional and mechanical instabilities (Bonnel *et al.*, 2010). Risk factors for the development of chronic ankle instability may either be intrinsic or extrinsic. Intrinsic risk factors relate to the individual and their morphology, as there may be bone, ligament and postural variations. Extrinsic factors relate to the environment, and the mechanism of injury. The interrelation of these factors may explain the pathogenesis to the development of chronic ankle instability (Bonnel *et al.*, 2010).

Mechanical instability may be due to bone structure abnormalities of the tibiotarsal complex, ligament laxity, and impairment of range of motion of the tibiotarsal joint

related to dorsiflexion deficits. These do not often respond positively to conservative treatment (Bonnell *et al.*, 2010).

Mechanical instabilities leading to CAI include pathological laxity, arthrokinematic impairments and synovial and degenerative changes (Denegar, Hertel and Fonseca, 2002; Hertel, 2002; Bonnell *et al.*, 2010).

1. Pathological laxity

Subsequent to an ankle sprain there is disruption and poor healing of the ligaments supporting the ankle. The extent of injury is dependent on the degree of disruption. Ankle instability is best demonstrated when the foot and ankle complex are placed into vulnerable positions (inversion, supination and plantar flexion) during activity (Bonnell *et al.*, 2010).

2. Arthrokinematic impairments

These result from joint dysfunction or bony changes that disrupt the normal arthrokinematics of any joints that make up the ankle joint complex. It has been shown that hypomobility of the joint, particularly dorsiflexion of the talocrural joint, may lead to CAI (Denegar, Hertel and Fonseca, 2002; Hertel, 2002; Bonnell *et al.*, 2010).

3. Synovial and degenerative changes

Degenerative changes as well as synovial swelling due to inflammation within the ankle joint complex may contribute to CAI (Hertel, 2002; Bonnell *et al.*, 2010).

Functional instability is a result of postural defects and abnormalities of the muscles and tendons. These are typically due to injury and respond positively to conservative treatment (Hertel, 2002; Bonnell *et al.*, 2010). Functional instabilities are commonly inter-related, and may occur in isolation or together (Hiller *et al.*, 2012).

Functional instabilities include impaired proprioception, neuromuscular firing, impaired postural control, strength deficits and muscular imbalances (Lentell *et al.*, 1995; Hertel, 2002; Kaminski and Hartsell, 2002; Konradsen, 2002; Riemann, 2002; Delahunt, Monaghan and Caulfield, 2006; Hopkins *et al.*, 2009).

1. Impaired proprioception

Impaired proprioception sensation is found in individuals that experience repetitive ankle sprains. This is most likely due to the disruption of mechanoreceptors found within the articular surfaces, ligaments, and surrounding musculature of the ankle (Konradsen, 2002; Riemann, 2002; Lentell *et al.*, 1995).

2. Impaired neuromuscular firing

Patients suffering from CAI have been found to have impaired peroneal muscle response. This may be a result of proprioceptive deficits, decreased nerve conduction velocity or impairments in neuromuscular recruitment (Hertel, 2002; Vaes, Duquet and Van Gheluwe, 2002; Hopkins *et al.*, 2009).

3. Impaired postural control

Postural impairment has been found in patients with CAI. This is particularly noticeable during single leg standing (stank standing) (Delahunt, Monaghan and Caulfield, 2006; Bonnel *et al.*, 2010). These postural impairments may be attributed to disruptions in proprioception and neuromuscular control (Hertel, 2002).

4. Strength deficits and muscular imbalances

There is a correlation of strength deficits of the peroneal muscles and incidences of recurring ankle sprains, although this correlation can vary between patients (Hertel, 2002; Kaminski and Hartsell, 2002). There are many possibilities that lead to strength deficits, but the exact cause is unclear. Possibilities include muscle damage, atrophy, and/or impaired neuromuscular recruitment (Hertel, 2002). There is a stronger link between muscle imbalances and CAI than muscular strength deficits (Kaminski and Hartsell, 2002). The most prominent muscle imbalance is that of weak ankle evertor muscles and strong/normal invertor muscles (Vizniak and Carnes, 2004).

2.2.4 Plantar fasciitis

Plantar fasciitis is a common cause of heel pain, affecting over 1 million people per year in both sedentary and athletic populations (James, Goff and Crawford, 2011). Plantar fasciitis is thought to be caused by biomechanical overuse (James, Goff and Crawford, 2011). Risk factors include obesity, excessive foot pronation, prolonged standing, high arch, leg length discrepancy and excessive running (James, Goff and Crawford, 2011).

A comprehensive case history and physical examination is important in the diagnosis of plantar fasciitis. Most patients will present with heel pain and tightness when getting out of bed in the morning or after being seated for a prolonged period (James, Goff and Crawford, 2011). The pain typically subsides with ambulation but may intensify by the days' end if the individual continues to walk or stand for a prolonged time (James, Goff and Crawford, 2011).

During the physical examination, patients may avoid applying pressure on the painful heel. The medial plantar calcaneal region is painful to palpate; palpation will elicit a sharp, stabbing type pain (James, Goff and Crawford, 2011). Other causes of heel pain should be sought if the history and physical examination findings are atypical for plantar fasciitis (James, Goff and Crawford, 2011).

Imaging studies can aid in the diagnosis. Although not routinely requested, radiographs can confirm recalcitrant plantar fasciitis or rule out other heel pathologies (James, Goff and Crawford, 2011). Radiographs can confirm bony lesions of the foot such as subcalcaneal heel spurs (**Figure 2.6**) (James, Goff and Crawford, 2011). Subcalcaneal heel spurs do not necessarily confirm the diagnosis of plantar fasciitis as studies have shown that subcalcaneal heel spurs can occur without plantar fasciitis, however, they can predispose to the development of plantar fasciitis (James, Goff and Crawford, 2011).



Figure 2.6: Lateral foot radiograph showing heel spur
Sourced from James, Goff and Crawford (2011)

2.2.5 Stress fractures

According to Welck *et al.* (2017), the foot and ankle are subjected to numerous stress fractures. Microscopic fracture injuries sustained when bone is subjected to repeated submaximal stresses may result in stress fractures (Welck *et al.*, 2017). Macro-structural failure and frank fractures will occur with repeated cycles of loading (Welck *et al.*, 2017). Stress fractures of the foot and ankle may include; tibia, navicular, calcaneus, metatarsal, fibular, talus, medial malleolus, sesamoid, cuboid and cuniforms (Welck *et al.*, 2017). It is important that these fractures are diagnosed as the diagnosis is often missed resulting in the appropriate treatment being delayed. Delayed treatment has complications such as non-union, protracted pain and disability (Welck *et al.*, 2017).

Calcaneal stress fractures (**Figure 2.7**) are reported to be the second most commonly seen stress fractures of the foot in males and most frequently observed in females (Aldridge, 2004; Welck *et al.*, 2017). There is often a history of sudden increase in physical activity (Barret and O'Malley, 1999). The condition often presents with exercise induced heel pain, often difficult to localise, and tenderness during the “squeeze test” (compression of the medial and lateral aspects of the calcaneus) (Toomey, 2009; Alghadir, 2006; Sormaala *et al.*, 2006; Aldridge, 2004).

Calcaneal stress fractures are commonly misdiagnosed as a heel spur or plantar fasciitis due to their similar presentation (Sormaala *et al.*, 2006).



Figure 2.7: Lateral foot radiograph showing calcaneal stress fracture

Sourced from: University of Virginia (2013)

2.2.6 Pes planus (flat feet)

There are three types of flat feet: flexible, rigid and acquired. Flexible flat foot is the more common of the two and is characterised by a normal medial arch appearance when non-weight-bearing but during weight bearing the arch collapses resulting in a flat foot (Moore, Dalley and Agur, 2010). Flexible flat foot commonly presents in childhood but resolves with age as the ligaments grow and mature, but may continue into adulthood (Moore, Dalley and Agur, 2010).

Rigid flat foot is characterised by a flat arch when non-weight-bearing or weight-bearing. It may be a result from a bony deformity, such as fusion of adjacent tarsal bones (Moore, Dalley and Agur, 2010).

Acquired flat feet are often a result of trauma, degeneration or denervation causing a dysfunction of the tibialis posterior (dynamic arch support) (Moore, Dalley and Agur, 2010). In the absence of dynamic or passive support, the plantar calcaneonavicular ligament fails to support the head of the talus. A consequence of this is that the head of the talus displaces infero-medially and becomes prominent. As a result, there is flattening of the medial longitudinal arch as well as lateral deviation of the foot (Moore, Dalley and Agur, 2010). **Figure 2.8** shows a radiograph of pes planus.



Figure 2.8: Radiograph showing pes planus: the long axis of the talus is angled plantar forward in relation to the first metatarsal
Sourced from: Escobedo *et al.*, (2016)

2.2.7 Cuboid syndrome

Cuboid syndrome is defined by a collection of signs and symptoms (Durell, 2011; Patterson, 2006) including pain when weight-bearing over the cuboid, which may radiate into the plantar medial arch or distally along the fourth metatarsal (Patterson, 2006). Secondary to pain, weakness may occur during toe-off during the gait cycle as well as there being a decrease in range of motion of the foot and ankle. There are several contributing factors to the development of cuboid syndrome (Durell, 2011; Patterson, 2006). A disruption of the calcaneal cuboid joint may stem from an abnormal inversion force acting on the rearfoot when the forefoot is loaded in a close kinematic chain, the incorrect use or construction of orthotics, or as a complication of heel spur surgery (Durell, 2011; Patterson, 2006).

2.2.8 Bunion formation

The fundamental problem of a bunion deformity is deviation of the hallux at the metatarsophalangeal joint and deviation of the tarsometatarsal joint (Santrock and Smith, 2018). A comprehensive understanding of the mechanism by which the deformity develops is essential for successful correction (Almalki *et al.*, 2013).

Bunions may result from constant friction against the inside of a shoe due to biomechanical variation. Variation may be caused by pronation of the foot, prolonged

pronation during gait, contractures of the Achilles tendon, arthritis, and generalised ligamentous laxity between the first and second metatarsal heads (Charrette, 2009). Anterior to posterior radiographs are typically requested (Santrock and Smith, 2018), as shown in **Figure 2.9**.



Figure 2.9: Radiograph showing the malalignment in the presence of a bunion
Sourced from: Kemp (n.d.)

2.2.9 Arterial calcification

Peripheral arterial disease is an increasingly prevalent condition (Chowdhury *et al.*, 2017) which affects millions of people worldwide. In the United States alone, it is estimated that eight million people suffer from peripheral arterial disease (Medtronic, 2018). General awareness of the disease is poor thus there are many people who go undiagnosed and are untreated (Medtronic, 2018).

At rest the condition is often asymptomatic but may emerge during walking or other physical activity (Medtronic, 2018). Symptoms include: pain, fatigue, sores or breaks in the skin, decrease in skin temperature and throbbing in toes or feet (Medtronic, 2018). **Figure 2.10** shows a radiograph of arterial calcification of the foot.

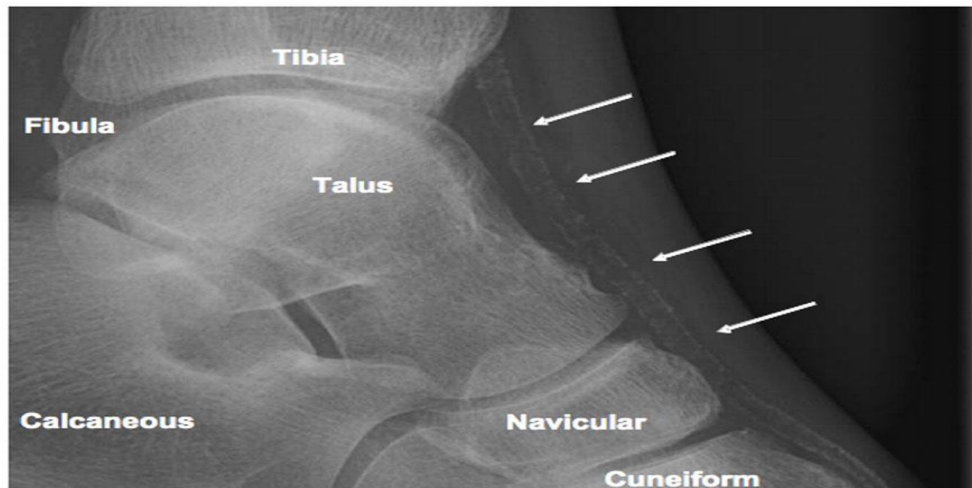


Figure 2.10: Radiograph of arterial calcification of the foot
Sourced from: Towler (2008)

2.2.10 Club foot (Talipes equinovarus)

Talipes equinovarus is defined as inversion of the foot, plantar flexion of the ankle and adduction of the forefoot (Moore, Dalley and Agur, 2010). The condition is congenital and affects 2 per 1000 infants. It affects boys twice as often as girls. A person with an uncorrected talipes equinovarus will experience pain when walking as the individual is unable to place the heel and sole of the foot on the ground therefore the individual will have to bear weight on the lateral aspect of the foot. The main abnormality is due to shortness and tightness of muscles, tendons and joint capsules on the medial and posterior aspect of the foot and ankle (Moore, Dalley and Agur, 2010).

2.2.11 Osteochondral lesions

Osteochondral lesions (OCL) of the ankle are now recognised as a more common source of ankle pain than previously thought. There is no precise pathophysiology of the condition, but a variety of etiological factors have been recognised to play a role (O'loughlin, Heyworth and Kennedy, 2010). These lesions are induced by traumatic injuries or by diseases which affect the cartilage surface and the subchondral bone (Vilela *et al.*, 2018).

Cartilage has limited ability to regenerate and self-repair which may result in these lesions gradually worsening and progressing towards osteoarthritis (Vilela *et al.*, 2018). Although most patients with OCLs complain of ankle pain after a traumatic event, other patients present with chronic ankle pain (Santrock *et al.*, 2003) and associated swelling, stiffness, and weakness. Prolonged weight-bearing or high-impact activities typically exacerbate the pain (O'loughlin, Heyworth and Kennedy, 2010).

Osteochondral lesions of the talus are most commonly found at the anterolateral and posteromedial shoulder of the talus (Montgomery and Davies, 2016). The variations in size and depth determines the description of chondral or subchondral lesions with a possibility of an underlying cystic lesion (Montgomery and Davies, 2016).

2.2.12 Systemic Diseases

As with local conditions of the foot and ankle joint, pain and inflammation are common presentations in individuals with a systemic disease, however, symptoms can present initially as pain in the heel (Barret and O'Malley, 1999). A thorough, detailed history and physical examination is essential to detect signs and symptoms of systemic disease (Aldridge, 2004; Barret and O'Malley, 1999). Early imagining such as radiographs, bone scans, MRIs or CT scans are important to rule out any systemic diseases (Barret and O'Malley, 1999).

In comparison to neoplasms of the breast, colon or lungs, tumours of the musculoskeletal system are rare and the aetiology is unknown (Toepfer, 2017). Although the foot and ankle only occupy 3% of body mass, approximately 5% to 8% of musculoskeletal tumours are located in the foot and ankle. Due to neoplasms not often being considered, diagnostic error or delayed diagnosis is common in the diagnosis of foot and ankle tumours, despite its compact and thin soft tissue coverage (Toepfer, 2017). This may be due to the highly variable clinical presentation (Toepfer *et al.*, 2012).

A differential of tumour processes should always be considered if there is unclear, persistent swelling or bone lesion as any tumour entity of the musculoskeletal system may be located at the foot or ankle (Toepfer, 2017). Osteosarcoma,

chondrosarcoma and Ewing's sarcoma are the three most common primary malignant bone tumours and are also most frequent bone sarcomas of the foot and ankles (Toepfer, 2017).

2.3 FACTORS ASSOCIATED WITH THE DIAGNOSIS OF FOOT AND ANKLE PAIN

There are many causes of foot and ankle symptoms that will cause an individual to seek care from a physician (Delzell *et al.*, 2017). Disorders may manifest as both local and systemic disease processes (Montgomery and Davies, 2016). Some conditions may be easy to diagnose by physical examination, others may have nonspecific examination findings thus optimal treatment decisions may be difficult (Delzell *et al.*, 2017). Clinical examination together with radiographs can frequently illuminate the correct diagnostic or even provide a definitive diagnosis (Delzell *et al.*, 2017).

Although chiropractic is primarily associated with treatment of the back, chiropractors routinely diagnose and treat extremity conditions (Brantingham *et al.*, 2012). A complete history and physical examination (Chauhan *et al.*, 2014) are conducted to exclude red flags and serious injuries (Bussi res *et al.*, 2007). The history includes questions regarding the onset of the pain, mechanism of injury, duration and location of the pain, associated clicking, sensation of "giving out", numbness and tingling, and persistent or shooting pain (Chauhan *et al.*, 2014). Determining if the patient can bear weight immediately following injury is important during the history of the foot and ankle (Chauhan *et al.*, 2014). The history is helpful to distinguish the origin of the pain, that is, neuropathic, vascular or musculoskeletal (Bussi res *et al.*, 2007). Compared to other neuromuscular skeletal conditions, the history gained from foot pain is unique. The history should be directed to exclude red flags such as fractures and dislocations (Bussi res *et al.*, 2007), and will query the cause of the pain as the patient often will be able to pin point the exact anatomical location (Cailliet, 1997). Location of the pain may be diagnostic (Griffith and Brockwell, 2006). It is useful to know the mechanism of injury when obtaining the history as higher energy injuries are likely to result in greater articular damage (Griffith and Brockwell, 2006).

Neurological screening is important during the physical examination (Bussi res *et al.*, 2007). This consists of inspection, palpation, swelling, crepitus, ankle and subtalar range of motion, talar tilt and anterior draw sign (Chauhan *et al.*, 2014). A comparison between the injured and the uninjured foot and ankle is important in the assessment (Chauhan *et al.*, 2014). Although sensory abnormalities and muscle atrophy are rare, the physician should still rule them out (Chauhan *et al.*, 2014). Ankle joint effusion and local tenderness over one or more periarticular regions, including the anterolateral and anteromedial joint line are common examination findings. Neurological examination (Bussi res *et al.*, 2007), varus alignment, and instability of the ankle and subtalar joints should be assessed, and the anterior drawer test and standard inversion manoeuvres (O'loughlin, Heyworth and Kennedy, 2010). Tuning forks are useful in the detection of fractures but are not sufficiently reliable for widespread clinical use (Daniels, Welk and Enix, 2016). The Ottawa ankle rules (**Figure 2.11**), which are internationally validated (Paradis *et al.*, 2018), may help with initial screening to determine a diagnosis between ankle fractures and sprain. (Daniels, Welk and Enix, 2016). These rules help clinicians make a clinical decision regarding whether a radiographic investigation is necessary (Paradis *et al.*, 2018; Abela *et al.*, 2018; Daniels, Welk and Enix, 2016). Local tenderness and pain on weight-bearing confirms the need for radiographs (Paradis *et al.*, 2018; Abela *et al.*, 2018; Daniels, Welk and Enix, 2016).

Figure 2.11 explains the Ottawa ankle rules which aid in the common clinical practice to establish whether or not radiographs are indicated. (Yazdani *et al.*, 2005). These rules effectively reduced the amount of radiograph referrals by 33%, which is a must in the current situation where health care systems are increasingly more focussed on cost effective methods (Yazdani *et al.*, 2005). Not only was there a decrease in radiographic referrals but a reduction in cost, radiation exposure and time for hospital staff and patients (Yazdani *et al.*, 2005).

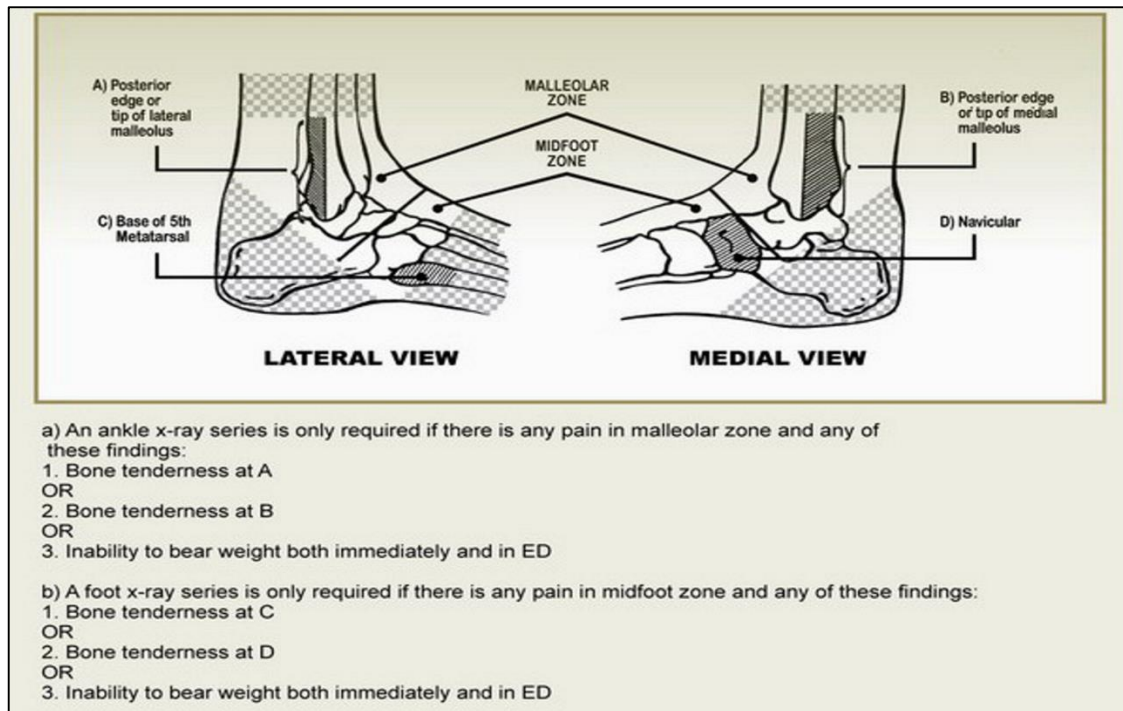


Figure 2.11: Ottawa foot and ankle rules to improve the diagnosis of fractures without imaging studies

Source: Adapted from Yazdani *et al.* (2005)

Initially radiographs are not indicated for non-specific hip, knee, ankle or foot pain but conventional radiographs are indicated following blunt trauma or if there is no improvement after four weeks of conservative care, increasing disability or the presence of red flags (Bussi res *et al.*, 2007). A careful correlation of a patient's radiographs to their history, physical examination and consideration of the anatomical position of injury may help the physician administer the appropriate treatment (Ahn and El-Khoury, 2007). **Table 2.4** shows the common foot and ankle conditions and the recommendations for each condition with regards to diagnostic imaging.

Table 2.4: Adult foot and ankle disorders for which radiographs are recommended

Patient Presentation	Comments
<p>Adult with acute ankle and foot injury but negative findings on the Ottawa ankle rules (OAR) which has a high sensitivity for fractures.</p> <p>Radiographs are not routinely indicated; however, should be considered only of patients excluded from the OAR presenting with:</p> <ul style="list-style-type: none"> • Multiple injuries • Isolated skin injury • 10 days since injury • Obvious deformity of the ankle or foot • Altered sensorium: neurologic deficit, head trauma, intoxicated. 	<p>Only rarely are radiographs of foot and ankle indicated together.</p> <p>Patient satisfaction does not appear to be related to the decision to order ankle radiographs.</p>
<p>Adult with acute toe injury in the presence of significant metatarsal pain.</p>	<p>Radiographs indicated.</p>
<p>Adult with chronic ankle and tarsal pain.</p>	<p>Routine radiography for exclusion of arthritis, infection, fracture and tumor.</p> <p>Specific indications for radiographs include:</p> <ul style="list-style-type: none"> • Suspected osteochondral lesion/stress fracture • Suspected tendinopathy with possible inflammatory arthritis • Possible ankle instability: Single-leg jump test assessment • Non-investigated chronic ankle and tarsal pain • Multiple sites of degenerative joint disease as visualized on radiographs • Possible operative candidate <p>Normal radiograph with abnormal clinical examination may necessitate MRI or diagnostic anaesthetic injection</p>
<p>Specific clinical diagnoses:</p> <ul style="list-style-type: none"> • Impingement syndromes • Anterolateral tenderness • Swelling • Pain with single leg squat. 	<p>Radiographs may appear normal as soft tissue can cause impingement, such as synovial hypertrophy.</p> <p>Additional investigations are necessary with positive radiographs or lack of symptomatic relief following 4 weeks of conservative care.</p>
<p>Anterolateral impingement.</p> <p>Pain and localized tenderness in the region of the anteroinferior</p>	<p>Findings on X-ray may include:</p> <ul style="list-style-type: none"> • Small osteophytes on anterior tibial margin.

tibiofibular and/or anterior talofibular ligament following inversion injury. Positive impingement sign.	<ul style="list-style-type: none"> • 50% have increased anterior translation of the talar dome on stress radiograph.
<p>Anterior impingement.</p> <p>Due to supination or repeated dorsiflexion injury. Complaint of anterior pain with painful with restricted dorsiflexion.</p>	<p>Findings on X-ray may include:</p> <ul style="list-style-type: none"> • Osteophytes involving the distal tibia and the talar neck. • Seen best on mortise views.
<p>Anteromedial impingement.</p> <p>Due to inversion injury or ankle/talar fracture. Anteromedial pain and tenderness with swelling. Pain and restriction present on dorsiflexion and supination.</p>	<p>Findings on X-ray may include:</p> <ul style="list-style-type: none"> • Osteophytes involving the anteromedial talus.
<p>Posterior impingement.</p> <p>Consists of impingement of the os trigonum between the talus and the posterior tibia. Commonly occurs in ballet dancers.</p> <p>Presentation of pain in full plantar flexion weight bearing position and with passive plantarflexion. Tenderness posterior to lateral malleolus.</p>	<p>Findings on X-ray may include:</p> <ul style="list-style-type: none"> • Possible os trigonum (congenital bone defect of the calcaneus).
<p>Peroneal tendinosis.</p> <p>Lateral hind foot pain.</p> <p>Cavovalgus foot deformity.</p> <p>Frequently affected in RA.</p>	<p>Radiographs are not routinely indicated unless unrelieved by 4 weeks of conservative care or there is reason to suspect inflammatory arthritis.</p> <p>MRI or US is indicated if there are signs of clicking or popping with foot eversion.</p>
<p>Adult with chronic foot pain.</p> <p>Differential diagnoses:</p> <ul style="list-style-type: none"> • Complications of diabetes mellitus: neuroarthropathy and foot infection • Arthritis: Most of the common forms of arthritis affect the feet and can cause foot pain • Vasculitis • Neurologic involvement: Polyneuropathies, cervical myelopathies, sciatica, mononeuritis multiplex 	<p>Medial oblique helps evaluate forefoot and lateral oblique the tarsal and Chopart joints.</p> <p>In suspected RA, foot radiographs may show erosions even when symptomatic hand(s) appear normal.</p> <p>High prevalence of midfoot and forefoot involvement in RA (53%–92%). Hindfoot and ankle affected later.</p> <p>Laboratory investigations (blood and synovial fluid) recommended: MRI, US, arthrography may be useful.</p>
<p>Hindfoot-heel pain.</p> <p>Differential diagnoses:</p> <ul style="list-style-type: none"> • Plantar fasciitis (common) • Calcaneal stress fracture • Tarsal tunnel syndrome 	<p>Radiographs indicated only in specific circumstances including exclusion of trauma to the calcaneus and tarsal coalition.</p> <p>MRI if unrelieved by 4 weeks of conservative care or before orthopaedic or paediatric referral.</p> <p>Achilles enthesopathy: power Doppler sonography may show</p>

<ul style="list-style-type: none"> • Diabetes mellitus • Long-term hemodialysis • Achilles or plantar enthesopathy • Inflammatory arthritis: Consider reactive arthritis (Reiter syndrome) with bilateral heel pain in young patient (second decade) with heel pain and toe inflammation. 	neovascularization that may be the cause of pain.
<p>Plantar fasciitis (PF) and calcaneal enthesophyte (spur).</p> <p>PF is one of the most common soft tissue foot disorders and presents with hyperesthesia over the plantar fascia.</p> <p>Risk factors include:</p> <ul style="list-style-type: none"> • Decreased ankle dorsiflexion ($\leq 0^\circ$) • Prolonged periods of standing • Obesity (body mass index ≥ 30 kg/m²) 	<p>Radiographs not routinely indicated except in young athletes.</p> <p>Plantar spurs are common incidental findings.</p> <p>The cause of the pain is seldom detected on radiograph. Most patients can be managed without imaging.</p> <p>Consider ankle dorsiflexion night splinting for treatment of recalcitrant PF.</p> <p>US may be initial step for advanced imaging (readily available, highly sensitive, low-cost, and radiation-free).</p> <p>Doppler/power US improves US value.</p> <p>US, MRI, and bone scan are more sensitive in demonstrating inflammatory changes and thickening of the plantar aponeurosis in PF.</p>
<p>Midfoot pain (nontraumatic).</p> <p>Midfoot pain is usually self-limiting. However, consider differential diagnoses:</p> <ul style="list-style-type: none"> • RA • Psoriatic arthritis • Reactive arthritis (Reiter disease) • Gout • Diabetic neuroarthropathy • Diabetic infection 	<p>Radiographs indicated if unrelieved by 4 weeks of conservative care or in suspected inflammatory arthritis.</p> <p>Consider further investigations if radiography is positive.</p> <p>Midfoot erosive disease is difficult to assess on radiographs.</p> <p>CT or MRI warranted in suspected or proven disease, but negative/equivocal radiographs. White blood cell tagged bone scan to differentiate between infection and diabetic neuroarthropathy.</p>
<p>Acquired flat foot with posterior tibial tendon dysfunction/rupture.</p> <p>Posterior tibial tendon rupture results in an acquired flatfoot, valgus hindfoot and forefoot abduction</p> <p>Clinical features include:</p> <ul style="list-style-type: none"> • Medial ankle/foot pain initially • May lead to disabling weight bearing symptoms • Talonavicular subluxation • Difficulty or inability to perform single-limb heel rise 	<p>Radiographs indicated if unrelieved by 4 weeks of conservative care or in suspected inflammatory arthritis.</p> <p>Consider other causes of flatfoot:</p> <ul style="list-style-type: none"> • Inflammatory arthritis • Tarsometatarsal OA • Tarsal coalition • Neuropathic arthropathy • Traumatic ligament disruption

<ul style="list-style-type: none"> Weak resisted inversion of fully flexed foot. 	<ul style="list-style-type: none"> Neuromuscular diseases <p>MRI better at differential diagnosis of medial ankle/foot pain. US may be useful.</p>
<p>Navicular tuberosity pain and tenderness.</p> <p>Potential painful normal variants such as accessory navicular bone (4%–21% of the population) have been described.</p>	<p>Radiographs indicated if unrelieved by 4 weeks of conservative care.</p> <p>MRI to differentiate accessory navicular from an avulsion fracture.</p> <p>NM may be useful to help identify or confirm site of pain.</p>
<p>Complex regional pain syndrome</p> <p>Also known as reflex sympathetic dystrophy and Sudek's atrophy</p> <p>Clinical features:</p> <ul style="list-style-type: none"> Pain Tenderness Swelling Diminished motor function 	<p>Diffuse osteopenia seen in 70% of cases.</p> <p>Advanced imaging and orthopedic referral recommended.</p> <p>MRI is useful in detecting numerous soft tissue and earlier bone and joint processes that are not depicted or as well characterised with other imaging modalities.</p>
<p>Forefoot pain.</p> <p>Common site of foot pain. Aetiologies are not easily identifiable by physical examination.</p>	<p>Radiographs not routinely indicated unless unresponsive after 4 weeks of conservative treatment or if inflammatory or infectious aetiology suspected.</p> <p>MRI useful in differential diagnosis of forefoot pain such as stress fracture, metatarsophalangeal synovitis, and intermetatarsal bursitis.</p>
<p>Metatarsal bursitis</p> <p>Possible causes:</p> <ul style="list-style-type: none"> MTP overstrain and repetitive trauma Infection RA Gout 	<p>Radiographs not routinely indicated unless unresponsive to conservative treatment or inflammatory or infectious cause suspected.</p>
<p>Morton Neuroma</p> <p>Clinical features:</p> <ul style="list-style-type: none"> Commonly between the 3rd and 4th web space. Differentiating metatarsophalangeal arthritis may be difficult. Pain hyperesthesia or paresthesia radiation to the toes. Positive forefoot neuroma squeeze test. 	
<p>Stress fracture.</p> <p>High risk patients are athletes (runners, dancers, walkers, weight bearing sportsmen) and the middle aged and elderly (if they participate in weight</p>	<p>If radiograph is inconclusive, re-radiograph after 6 weeks of restricted use before proceeding to advanced imaging.</p>

bearing activities or are on long term corticosteroid treatment). Clinical features include: Pain and tenderness in the: <ul style="list-style-type: none"> • 1st, 2nd, and 3rd metatarsal • Calcaneus • Medial sesamoid • Navicular 	
Osteonecrosis of the metatarsal head (Freiberg infraction). Clinical features include: <ul style="list-style-type: none"> • Adolescent patient • Pain/tenderness • Swelling • Limitation of movement at metatarsal head • Second or third head most commonly affected 	Radiographic findings (metatarsal head): <ul style="list-style-type: none"> • Increased density • Flattening, collapse • Cystic changes • Widening of the MTP joint
Hallux rigidus and hallux valgus	
Sesamoiditis	

Adapted from: Bussières *et al.*, (2007)

2.4 THE ROLE OF RADIOGRAPHS IN THE DIAGNOSIS

Radiographic examination of a joint requires a minimum of two separate views perpendicular to one another (Yochum and Rowe, 2005). It is important that one of these views demonstrates the opposing articular surfaces. Under normal circumstances a joint will not be fully visible unless the central beam is parallel to these joint surfaces. To observe fine detail of articular anatomy film quality must be at an optimum. The evaluation of a radiograph is crucial. Radiographs demonstrate alignment, bone, cartilage and soft tissue (ABCS) (Yochum and Rowe, 2005).

- **Alignment**

It is important to evaluate joint relationships as a diagnostic procedure because subtle misalignments and deformities may be overlooked. Orthopaedic lines and measurements must be applied during visual inspection of the radiograph (Yochum and Rowe, 2005).

- **Bone**

The subchondral bone plate, consisting of the articular cortex and underlying cancellous bone, is a key osseous structure analysed in joint disease. The articular cortex is distinctively thin in comparison to cortices in other locations. The subarticular cancellous bone consists of trabeculae which help support against stresses traversing the joint. Within a single bone the articular region of the epiphysis appears as the most radiolucent. Density, periosteal response and changes at bone-ligament or bone-tendon junctions of the metaphysis and diaphysis should be evaluated (Yochum and Rowe, 2005).

- **Cartilage**

Although cartilage is not typically visible on radiographs, the distance of the joint cavity between the two opposing articular surfaces is a direct correlation of the cartilage thickness. Recognition of altered joint space is a key diagnostic tool as joint diseases act to destroy intra-articular cartilage in a variety of ways (Yochum and Rowe, 2005).

- **Soft tissue**

Important structures to be observed are the articular and periarticular soft tissues. Although the capsule and synovium are not typically visible, a layer of peri-capsular fat often renders the capsule margin, particularly when intra-articular effusion is present. After trauma, infection, and inflammatory changes, fat between muscle planes and tendons may be identified. Soft tissue can be distended and obliterated with oedema. The overall thickness and density should also be assessed (Yochum and Rowe, 2005).

Consideration of patient preference should be taken into account in the decision to use imaging and be judged in an unbiased approach with the best available evidence and experience of a clinician (Bussi res *et al.*, 2007). The circumstance for every individual patient should be taken into account. These circumstances may be due to fear, communication issues, or career orientated (Bussi res *et al.*, 2007). It is important to acknowledge these circumstances to influence the reduction of unnecessary radiographs but maintain an ethical practice (Bussi res *et al.*, 2007).

Imaging studies of the foot and ankle are a common procedure (Doody and Hopper, 2014). Although there is a wide range of modalities for imaging investigations (Doody and Hopper, 2014), radiographs typically are used as the initial assessment for ankle injuries (Ahn and El-Khoury, 2007; Chauhan *et al.*, 2014). They are easily available, most cost effective and play a key role in the diagnosis and management of ankle injuries (Ahn and El-Khoury, 2007).

Typically, two radiographic views are requested, conventionally in the anteroposterior (AP) and the lateral planes. As the anatomy of the foot and ankle is complex this is frequently modified depending on the clinical concern (Doody and Hopper, 2014). There are numerous techniques such as weight bearing, non-weight bearing, having every possible aspect of extremity positioned against the film (Baron, Stugielski and Christman, 2003), or active and passive stress views may be used for foot and ankle radiographs (Doody and Hopper, 2014).

2.4.1 Foot and Ankle projections

2.4.1.1 Anterior to posterior of the ankle (AP ankle)



Figure 2.12: AP radiographic view of the ankle

- Alignment

In the anterior-posterior (AP) ankle projection shown in **Figure 2.12**, the opposing articular surfaces of the distal tibia and talar dome should be congruous and parallel. Normal limits of tibiotalar tilt variation is from 0 to 6 degrees (Yochum and Rowe, 2005).

- Bone

In the AP ankle projection (**Figure 2.12**), the diaphysis of the distal tibia gradually expands to the metaphysis. This is noticed by the progressive thinning of the cortex. The medial malleolus curves inferiorly with a groove visible at its tip. The deep flexor tendons are housed in the groove. The plafond (inferior articular surface of the tibia) may be seen parallel to the residuals of the growth plate. The bulbous lateral malleolus has a distinct groove called the peroneal groove. This is where the peroneal tendons pass. It extends approximately one centimetre inferior to the medial malleolus and marginally overlaps the talus. The talar dome

has three articular facets: the trochlear for the articulation between the tibial plafond, and the lateral and medial facets for the articulation with the adjacent malleoli (Yochum and Rowe, 2005).

- Cartilage

In the AP ankle projection (**Figure 2.12**), the mortise joint space is congruent for the entire articulation from medial to lateral. The medial and lateral clear space should be the same distance as that at the superior joint and should not deviate from the distance of five millimetres (Yochum and Rowe, 2005).

- Soft tissue

In the AP ankle projection (**Figure 4.2.1**) it is important to notice the close proximity of the overlying skin line to the underlying malleoli (Yochum and Rowe, 2005).

2.4.1.2 Medial oblique ankle projection



Figure 2.13: Medial oblique view of the ankle

- Alignment

Figure 2.13 shows the medial oblique projection of the ankle. The opposing articular surfaces of the talar dome and tibia should be parallel but may deviate up to six degrees. The depth of the joint remains the same throughout its length of about five millimetres (Yocham and Rowe, 2005).

- Bone

The medial oblique ankle view (**Figure 2.13**) demonstrates both lateral and medial malleoli as well as the talocrural joint space, talus and tibial plafond. The distal tibia and fibula overlap is reduced in this view. The navicular, cuboid, calcaneus and proximal metatarsals are also visible in this projection (Yochum and Rowe, 2005).

- Cartilage

The entire mortise joint space is visible in the medial oblique projection. The important variation of the medial oblique view to the AP ankle view is the two millimetre separation of the distal tibiofibular joint. A measurement of greater than five millimetres demonstrates diastasis (Yochum and Rowe, 2005) (**Figure 2.13**).

- Soft tissue

It is important to note the underlying malleoli to the overlying skin line. The concave contour below the malleolar tips should be viewed for abnormalities (Yochum and Rowe, 2005) (**Figure 2.13**).

2.4.1.3 Lateral ankle projection



Figure 2.14: Lateral ankle projection

- Alignment

During the lateral ankle projection (**Figure 2.14**) it is important to note the position of the tibia and the talus. There is a superior angle of the calcaneus known as the “calcaneal pitch”. The longitudinal arch of the foot is formed by the configuration of the calcaneus, tarsals, and inferior sloping metatarsals (Yochum and Rowe, 2005).

- Bone

In the lateral ankle projection, the fibula overlaps the tibia and the talar dome. The talus divisions are recognised by the dome (forms the talocrural joint), neck (narrow segment anterior to the joint) and head (has a convex surface to articulate with the navicular). The posterior plantar aspect of the calcaneus is typically thick and dense due to a normal compressive stress reaction. Note the trabecular pattern (Yochum and Rowe, 2005) (**Figure 2.14**).

- Cartilage

The surfaces between the concave surface of the tibial plafond and the reciprocal surface of the convex talus should be congruent. In the midsection where the subtalar joint may be observed, the sinus tarsi is located. The convex talonavicular joint is uniform (Yochum and Rowe, 2005) (**Figure 2.14**).

- Soft Tissue

The pre-achilles fat pad is visible in the triangular radiolucent region posterior to the tibia. It is bounded by the Achilles tendon posteriorly, anteriorly by the deep flexor muscles of the calf, and the superior border of the calcaneus. The Achilles can be recognised by a thin four to six millimetre soft tissue band. Due to thick fibrous septae the heel pad is mottled in appearance. It is important to note the thickness of the skin overlying the calcaneus posteriorly and on the plantar surface (Yochum and Rowe, 2005) (**Figure 2.14**).

2.4.1.4 AP foot projection

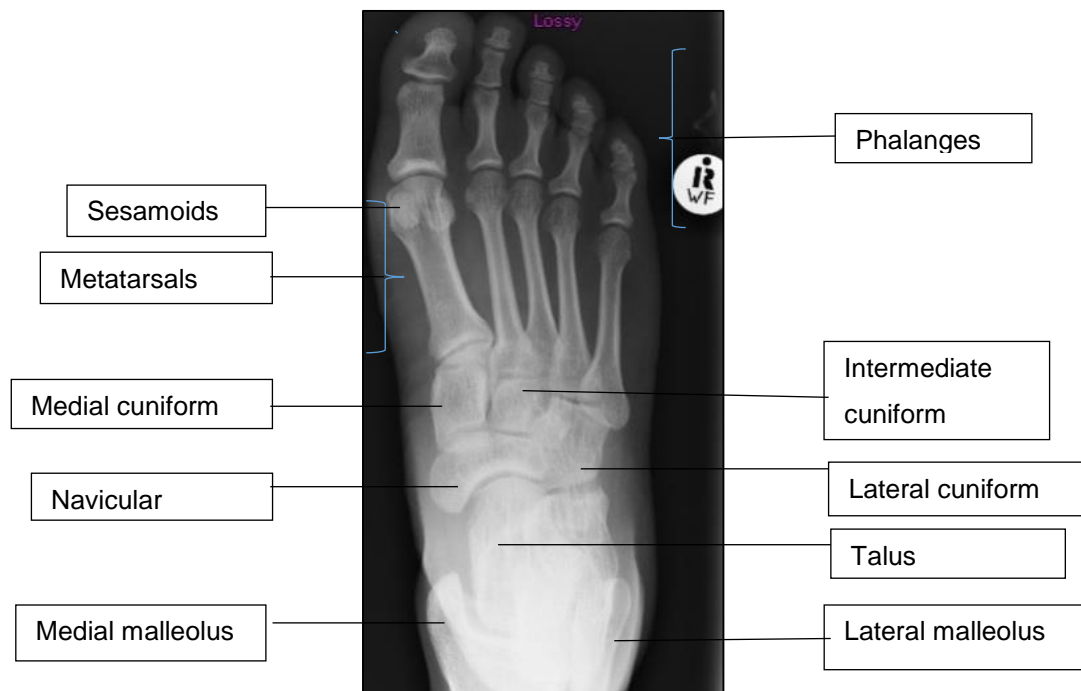


Figure 2.15: AP projection of the foot

- Alignment

In **Figure 2.15** it is important to note that each metatarsal-phalangeal joint is visible and in straight longitudinal alignment. Spacing between each metatarsal phalangeal joint should be equidistant to one another. There are three important angles to take note of in the AP foot projection (Yochum and Rowe, 2005).

1. Hallux abductus angle: This is the angle between the first metatarsals and the proximal phalanx. The angle may range from 0 to 15 degrees (Yochum and Rowe, 2005).
2. Intermetatarsal angle: This is the angle between the first and second metatarsal shafts. The angle should be 14 degrees (Yochum and Rowe, 2005).
3. Metatarsal angle: tangential lines drawn along the articular surfaces of the first and second metatarsal heads. The angle should be 140 degrees (Yochum and Rowe, 2005).

- Bone:

All bones should be identified (**Figure 2.15**). The first metatarsal bone is the shortest and the second metatarsal bone the longest. The metatarsal heads display slightly radiolucent and have thin cortices. Two sesamoid bones on the plantar aspect of the great toe will be superimposed. The expanded distal ends of the distal phalanges are known as the ungula or terminal tufts (Yochum and Rowe, 2005).

- Cartilage

It is important to identify all joints (**Figure 2.15**). It is difficult to view the articulations between the first and third tarsometatarsal junctions, cuneiforms and cuboid. The “Lisfrancs joint” refers to the tarsometatarsal joint. The “Chopart’s joint” refers to the joint between the tarso-navicular and calcaneocuboid articulations. Lisfrancs joint space should be approximately one millimetre, greater than this indicates Lisfranc’s injury. Congenital fusion of the fifth distal interphalangeal joint may be present (Yochum and Rowe, 2005).

- Soft tissue

The skin line is in close proximity to the underlying digits and over the medial and lateral midfoot (Yochum and Rowe, 2005) (**Figure 2.15**).

2.4.1.5 Lateral foot projection



Figure 2.16: Lateral projection of the foot

The lateral foot projection is an integral part of the foot series and should not be omitted (Yochum and Rowe, 2005) (**Figure 2.16**).

- Alignment

The longitudinal arch of the foot is important to note. Assess the maximum depth and its apex which is located at the level of the navicular. The first metatarsal angulation plane typically continues proximally and intersects the medial cuneiform, navicular and head of the talus. Relative to the plane of the forefoot and midfoot the calcaneus is angled cephalad. The position of the tibia on the talus should be assessed (Yochum and Rowe, 2005) (**Figure 2.16**).

- Bone

The cuboid, navicular, calcaneus and talus are visible (**Figure 2.16**). Only the base of the fifth metatarsal is well displayed. The talus divisions can be recognised by the dome (forms the talocrural joint), neck (narrow segment anterior to the joint) and head (has a convex surface to articulate with the navicular). The posterior plantar aspect of the calcaneus is typically thick and dense due to a normal compressive stress reaction. The trabecular pattern should be assessed (Yochum and Rowe, 2005) (**Figure 2.16**).

- Cartilage

The surfaces between the concave surface of the tibial plafond and the reciprocal surface of the convex talus should be congruent. In the midsection

where the subtalar joint may be observed, the sinus tarsi is located. The convex talonavicular joint is uniform (Yochum and Rowe, 2005) (**Figure 2.16**).

- Soft tissue

The pre-achilles fat pad is visible in the triangular radiolucent region posterior to the tibia. It is bounded by the Achilles tendon posteriorly, anteriorly by the deep flexor muscles of the calf, and the superior border of the calcaneus. The Achilles can be recognised by a thin four to six millimetre soft tissue band. Due to thick fibrous septae the heel pad is mottled in appearance. Note the thickness of the skin overlying the calcaneus posteriorly and on the plantar surface (Yochum and Rowe, 2005) (**Figure 2.16**).

Radiographs have their limitations; due to the lack of sensitivity it is difficult to detect hairline fractures, minor trauma and early stages of disease (Yochum and Rowe, 2005). The dangers associated with ionisation have been shown over recent years, i.e. the increasing risk of developing malignancies with the increased numbers of radiographic exposures (Andrieu *et al.*, 2006; Butt *et al.*, 2007; Pijpe *et al.*, 2012). The development of the justification principal was established to ensure that the benefits of radiographs exceed the risks (Faulkner, 2004), and guidelines to help primary health care practitioners recognise the indicators for the use of radiographs (Yochum and Rowe, 2005).

2.5 CLINICAL APPROACH TO RADIOGRAPHIC REFERRAL

To build a foundation for a safe and effective clinical practice it is paramount to have an appropriate level of anatomical knowledge (Smith *et al.*, 2016). Interns should be able to interpret relevant standard diagnostic images for the lower limb including a range of imaging modalities (Smith *et al.*, 2016).

There are many factors that contribute to the need for obtaining radiographs. The history and physical examination are crucial when dealing with a patient to rule out serious injury and red flags (Chauhan *et al.*, 2014; Bussi eres *et al.*, 2007). Conditions vary in presentation as some may be easy to diagnose while others may be more complicated, so the use of radiographs will often confirm the diagnosis

(Delzell *et al.*, 2017). A reliable history is paramount to determining an accurate diagnosis and, if impossible, it is advisable to refer for radiographs to confirm a diagnosis. Confirmation of a diagnosis is the most documented reason for radiograph referral (Bussi res *et al.*, 2007). Interns feel initial clinical anxiety and lack of confidence (Sharif and Masoumi, 2005), which leads to the need to confirm the diagnosis with the use of radiographs (Chauhan *et al.*, 2014; Bussi res *et al.*, 2007; Delzell *et al.*, 2017).

At the DUT CDC, each chiropractic consultation begins with a brief case history performed by a qualified chiropractic clinician prior to the student beginning their assessment. Subsequent to the clinician's history the intern will perform their own thorough case history and physical examination of the patient. The intern will then present their clinical findings to the clinician twice – once post a completed history and once post a completed physical examination. In the case of a patient referral, both the clinician and the intern need to agree that the referral is deemed necessary as a result of the clinical findings. These report backs enable the discussion of the case and the management plan (Durban University of Technology 2015; Korporaal 2017). If the request for radiographic examination referral is determined during the initial consultation, the intern and clinician should have a strong suspicion for any serious underlying conditions e.g. presence of red flags (Pederson, 2005; Michael *et al.*, 2009).

2.6 OVERVIEW OF THE MANAGEMENT OF PAIN

Foot and ankle conditions affect a large number of people in the general population. Due to the foot's weight-bearing function, there is a considerable impact on gait and posture, and, therefore, on different aspects of health-related quality of life (Hoskins *et al.*, 2006). Chiropractic management incorporates passive and active care, addressing the acute inflammatory/pain phase and the chronic/rehabilitation/injury prevention phase (Hoskins *et al.*, 2006). Chiropractic is a multimodal approach involving various manual therapy procedures, emphasising on high velocity techniques, massage, stretching and rehabilitation exercises which include proprioceptive exercises, motor pattern correction and sports specific training (Hoskins *et al.*, 2006).

Initial support therapy is important to aid in the enhancement of the healing process and avoid chronic ligamentous laxity and surgery (Chauhan *et al.*, 2014). According to Hiller *et al.* (2012), posttraumatic ankle osteoarthritis may result as a long-term consequence to ankle fractures, sprain, osteochondrosis and cartilage damage. Approximately 25% of people have poor to fair self-reported outcomes at two, five and fourteen years post fracture with residual problems including pain, decrease range of motion and impaired function (Hiller *et al.*, 2012). Foot pain has also been identified as an independent risk factor for impaired balance, functional activities, locomotive disability, and an increased risk of falling (Thomas *et al.*, 2011).

A full case history and physical and regional examination are tools which a chiropractor will use to reach a diagnosis. In the presence of red flags or otherwise indicated, specific examinations are requested such as radiographs and/or blood work (Pederson, 2005). In the case of failure of conservative management (4 to 6 weeks), chiropractic referral for special imaging, laboratory testing or medial evaluation is indicated (Souza, 2009).

Modalities such as strapping, ice, heat, electrotherapies, acupuncture, gait retraining, nutrition, footwear/ergonomic/training advice, and exercise/cross training programs may also be used (Hoskins *et al.*, 2006). Various soft tissue techniques including; ischaemic compression of myofascial trigger points, massage, active and passive release, acupuncture and dry needling may help facilitate the healing process. Electrotherapies such as ultrasound, interferential current (IFC), transcutaneous electrical nerve stimulation (TENS) and laser may also be used to supplement chiropractic adjustments and improve the healing process (Chiropractic Clinic Manual, 2013). Initial supportive therapy includes non-steroidal anti-inflammatories, rest, ice, compression, elevation and early mobilization (Chauhan *et al.*, 2014). Exercise maintains range of motion, assists in the lymphatic drainage and improves proprioception (Chauhan *et al.*, 2014). Stretching is important to recover full function and enhance the healing process (Chauhan *et al.*, 2014).

Chiropractic interns at the DUT CDC are exposed to many modalities to ensure optimal, evidence-based health care for all patients that present to the CDC. Manual therapy is the primary modality utilized. This involves the manipulation or

mobilization of the foot and ankle. Other modalities such as: dry needling, soft tissue therapy (ischaemic compression, massage, stretching), and electrotherapy (TENS, ultrasound, IFC) compliment chiropractic adjustments (Chiropractic Clinic Manual, 2013).

A trigger point area refers to a hyperirritable point in the muscle that may result in mechanical disruption. The use of dry needling involves advances of a needle into a trigger point with the aim to provoke a localized twitch response (Travell and Simons, 1999; Lavelle, Lavelle and Smith, 2007). Satellite cells may be stimulated resulting in the migration of these cells to the damaged area. These satellite cells help with the process of muscle regeneration as they repair and replace damaged myofibrils (Dommerholt, del Moral and Gröbli, 2006).

Myofascial release therapy is performed by applying a low load, long duration stretch to the myofascial complex to achieve and restore optimal length, decrease pain and improve function of the muscle complex (Ajimsha, Chithra and Thulasyammal, 2012). Active release therapy is performed by applying deep digital tension over a tender area while the individual actively moves the tissue from a shortened to a lengthened position. The aim of active release therapy is to break down adhesions formed in myofascial tissues (Trivedi *et al.*, 2014).

Ultrasound therapy is used to treat acute and chronic disorders of the musculoskeletal system. High-frequency acoustic energy which transmits vibration energy at a molecular level (Gam *et al.*, 1998; Esenyel, Caglar and Aldemir, 2000; Lavelle *et al.*, 2007) aids in the reduction in muscle pain and spasm, decrease in joint stiffness, increase in extensibility of tendons and joint capsules, and increase in blood flow to a target area to resolve a chronic inflammatory process (Pillay, 2003).

TENS and IFC are used in the treatment and management of acute and chronic pain (Graff-Radford *et al.*, 1989; Lavelle *et al.*, 2007). Electrodes are placed on the skin along areas of referred pain or over trigger point sites (Graff-Radford *et al.*, 1989; Lavelle *et al.*, 2007). Electrical stimulation is applied at varying frequencies, intensities, and pulse duration to achieve the best pain control (Sluka and Walsh, 2003; Vidyarthi *et al.*, 2014).

Laser therapy aims to mediate the inflammatory process, enhance tissue repair and promote analgesia in cases of acute or chronic pain. It does this by the penetration of wavelengths to the region of myofascial trigger points (Uemoto *et al.*, 2013).

The DUT Chiropractic Clinic manual (2013) states that radiographs will be considered if the clinician on duty and the student feel that the results will significantly contribute to the diagnosis and management of the patient. The decision to refer for radiographs will be based on the clinical findings obtained in the case history, physical examination, and regional examination. Thus, the use of radiographs is to confirm or reject the clinical diagnosis so the exposure to ionising radiation is minimized at the DUT CDC as routine radiographs for general screening purposes are not ethically indicated.

2.7 CONCLUSION

Foot and ankle problems are highly prevalent in the general community with the ankle being the most frequently injured major joint of the body. An accurate diagnosis is often difficult despite a careful, detailed clinical history and physical examination due to the complexity of the ankle joint. It is essential to identify the cause of the ankle pain in order for an adequate and speedy recovery. Radiographs are universally considered the first line of imaging investigation method; as a result, 85% of ankle radiographs show insignificant findings. Nowadays according to evidenced based guidelines, radiographs should only be requested in the presence of red flags or in patients that have not responded to conservative treatment in four to six weeks.

The aim of this study was to therefore determine whether a relationship exists between the clinical and radiological diagnoses of foot and ankle pain and whether foot and ankle radiographs affect the diagnosis and management of patients who presented to the DUT CDC with foot and ankle pain.

CHAPTER 3: MATERIALS AND METHODS

3.1 STUDY DESIGN

This research was designed as a retrospective, quantitative, descriptive, empirical clinical cohort study. Foot and ankle radiographs were obtained from the PACS software at the DUT Radiology Clinic (Appendix A) with their corresponding clinical records of those patients who presented with foot and/or ankle pain at the Chiropractic Day Clinic (CDC) at DUT (Appendix B). Approval to conduct the study and ethical clearance was obtained from the Faculty of Health Sciences Research Committee at DUT (Appendix C).

3.2 PATIENT CONFIDENTIALITY

Prior to initial consults at the DUT CDC, all patients sign a consent form (Appendix D), allowing their clinical and/or radiological information to be used in future research. The consent form clearly states that their identities will remain confidential. The consent form (Appendix D) is not specific to this study but is a requirement for patients to sign prior to treatment at the DUT CDC. This entitles the researcher access to clinical information for research purposes if ethical clearance is granted (Appendix C). An alpha numerical coding system (Appendix E) ensured this confidentiality throughout the research process. All electronic data was kept protected by a password and clinical files were locked up. Only the researcher, supervisor and co-supervisor were granted permission to access these files during the research process.

3.3 SAMPLING METHOD AND SAMPLE SIZE

Purposive sampling was used during the collection of all the information (Appendix F). This means that the sample was selected specifically according to the inclusion and exclusion criteria. The sample consisted of the clinical records of all patients that presented to the DUT CDC with foot and/or ankle pain and were referred to the Radiography Department for foot and/or ankle radiographs on the PACS system

which was introduced in January 2013. Therefore the sample size consisted of radiographs between January 2013 and April 2018. The final sample size consisted of $n = 26$ foot and/or ankle radiographs and their corresponding clinical records, which is all the patients that met the inclusion criteria of the study.

3.4 INCLUSION AND EXCLUSION CRITERIA

3.4.1 Inclusion criteria

- The patient must have received treatment at the DUT CDC for foot or ankle pain and have complete clinical records available with regards to patient history, physical examination, foot and ankle regional, SOAPE note, referral letter for radiograph and a radiologist's report.
- A radiograph of either the patient's foot or ankle must have been taken at some point during the treatment.
- At least two different radiographic views of the exposed area must have been taken.

3.4.2 Exclusion criteria

- Radiographs that were not requested by the chiropractic clinicians.
- Incomplete clinical records (lacking a patient history, physical examination, foot and ankle regional and/or SOAPE-note).

3.5 RESEARCH PROCEDURE

- The Head of the Chiropractic Department and the CDC Clinic directors granted permission to access the clinical records that were required for this research (Appendix B).
- The Head of the Radiography Department granted permission to access foot and ankle radiographs and their respective radiologist reports required for this research (Appendix A).
- The foot and ankle radiographs were obtained from the Radiology Department PACS system. The final sample size of $n = 26$ radiographs (Singh, 2017) was then determined by matching the corresponding clinic files with the

radiographs and evaluating how many met the inclusion and exclusion criteria. All those that met the criteria had their radiographs downloaded onto a disc and coded with their specific numerical code (see Appendix E).

- Each patient's name, date of birth and file number was then recorded on a data sheet (Appendix E) with a specific numerical code allocated to each individual for confidentiality purposes.
- In a pre-booked clinic room each radiograph was analysed and evaluated on a laptop by means of the ABCS System where the alignment, bony anatomy, cartilage and soft tissue were analysed and a diagnosis made. The radiographs were then searched for incidental findings and recorded. To avoid bias it was necessary to do this in isolation from the patient file.
- The reason for the referral for radiographs was noted and the request form was analysed for red flags.
- The radiologist's report was investigated and the diagnosis recorded. In the event of the referral letter or the radiologist report not being present in the patient file, the report was obtained from the Radiography Department.
- The clinical records were viewed for the main complaint of the foot or ankle pain and any red flags that may have been present were noted.
- The intern's diagnosis prior to and post radiographic examination were recorded and a change in the diagnosis was noted, if required.
- The plan of management was recorded before and after the foot or ankle radiograph was performed and any changes were noted.

Table 3.1 shows the steps of how the data was recorded, and the source of the data.

Table 3.1: Recorded data and source

Recorded data	Source
Code, age and gender	Appendix A; Case history form
Date of initial consultation	Case history form; SOAPE note
Clinical diagnosis at initial consultation	SOAPE note
Treatment at initial consultation (prior to radiographs)	SOAPE note
Reason for radiographic referral	SOAPE note and/or radiology request form
Number of treatments before radiographic referral	SOAPE note
Date of radiographs	Radiology report and/or identification marker on Radiograph
Researcher's radiographic diagnosis	Radiological findings of the researcher
Radiologist's diagnosis	Radiology report
Radiographic incidental findings	Radiology report and/or radiological findings of the researcher
Clinical diagnosis after radiographs	SOAPE note
Change/no change in treatment after radiographs	SOAPE note

Source: Adapted from Myburg (2015)

3.6 ETHICAL CONSIDERATIONS

- A consent form (Appendix D) needed to have been signed agreeing to the fact that their clinical and radiological information may be utilized for research purposes. The consent form was signed prior to the initial treatment thus is not specific to this study.
- Utilization of a numerical coding system (Appendix E) ensured confidentiality of the patients' personal information. This is in keeping with confidentiality, autonomy and justice to ensure ethical principles were upheld.
- The clinical records and foot or ankle radiographs were kept locked away and only the researcher and supervisor will be allowed to access it.

The following ethical principles were implemented:

- Confidentiality and autonomy – a letter of informed consent (Appendix D) was signed in order for clinical information to be accessed. Although the consent form is not specific to this study, consent is given at the initial treatment which allows clinical information to be accessed for research purposes.
- Non-maleficence: Patient consent was given (Appendix D) at the initial treatment of each patient that receives care at the DUT CDC. Therefore only patients that had signed consent could take place in the study.
- Justice: All aspects of the study relating to the participant were kept confidential to preserve autonomy and justice. Information related to the participant, their identity and their names were not disclosed (Appendix E).
- Accuracy of the data and their interpretation: No omission or fraud with the collection and analysis of data will occur.

3.7 STATISTICAL ANALYSIS

SPSS version 25.0 and McNemar's chi squared test for binary paired proportions were supposed to be utilized in the analysis of the data. The categories were too many and too different in the statistical association between the clinical and radiological diagnosis in a paired comparison. It was decided to not evaluate the association between the clinical diagnosis and radiological diagnosis using the *t*-test as they were not the same (Singh, 2018). In a similar study by Myburg (2015), statistical analysis for the same correlations were unable to be tested (Esterhuizen, 2015). Therefore, a descriptive assessment of the radiological diagnoses for each clinical diagnosis was performed by cross-tabulating the relevant variables. Objectives were purely descriptive. The outcomes were reported using frequency counts, means, standard deviations and percentages since all outcomes were categorical variables (Singh, 2018; Esterhuizen, 2015).

CHAPTER 4: RESULTS – STATEMENT OF FINDINGS, INTERPRETATION AND DISCUSSION OF THE DATA

4.1 INTRODUCTION

This chapter presents the results and discusses the findings obtained from the study. The data collected was analysed with SPSS version 25.0. The results present the descriptive statistics in the form of graphs, cross tabulations and other figures for the quantitative data that was collected.

In total, 26 records and their corresponding foot or ankle radiographs were analysed in this study.

The research instrument consisted of 26 items, with a level of measurement at a nominal or an ordinal level. The data capture sheet was divided into four sections as follows:

1. Biographical data
2. Initial Clinical Consultation
3. Radiologist Report
4. After Radiographs were performed

Key:

- n = Sample size.
- n_2 = Number of radiographic referrals during the initial consultation.
- n_3 = Number of radiographic referrals during the second consultation.
- n_4 = Number of radiographic referrals during the third consultation.
- n_5 = Number of radiographic referrals during the fourth consultation.
- n_6 = Number of radiographic referrals during the fifth consultation.
- n_7 = Number of radiographic referrals during the tenth consultation.
- n_8 = The total number of radiographic referrals.

4.2 DISTRIBUTION OF AGE AND GENDER

A total of 26 records and their corresponding foot or ankle radiographs were analysed during this study. The mean age of the participants was 38.12 years. The average age for female participants was 33.42 years of age and 42.07 years of age for male participants. Therefore on average the male participants were 8.65 older than the female participants. The range of the participants was from 19 to 75 years.

Figure 4.1 shows the gender distribution of participants. There were 14 male (53.8%) and 12 female (46.2%) participants.

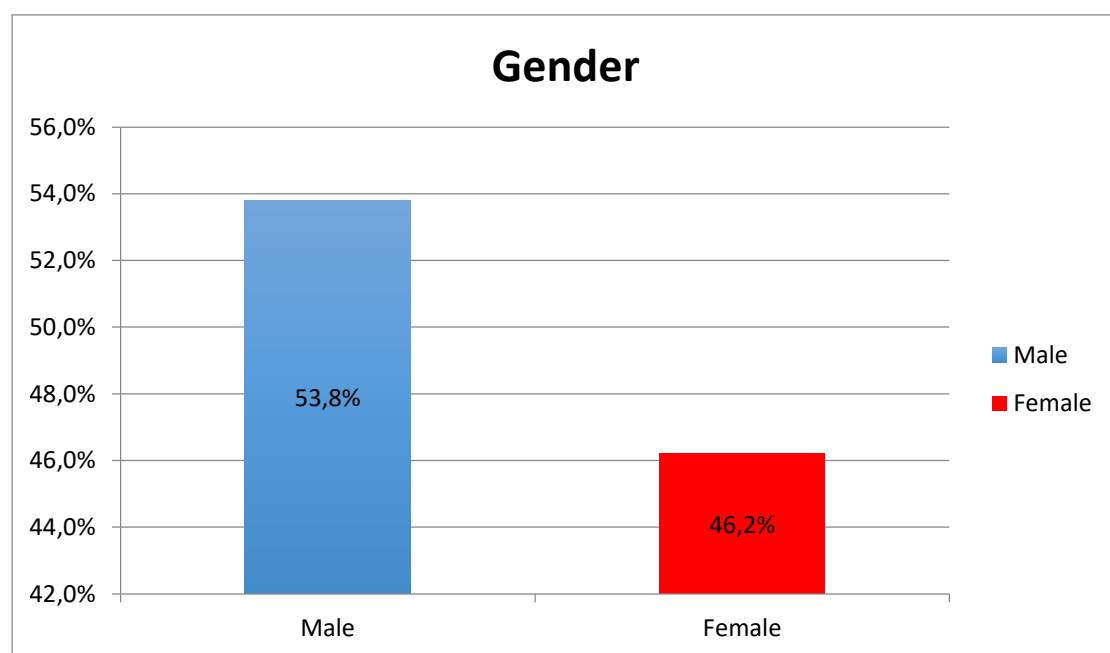


Figure 4.1: Gender distribution of participants

4.3 THE RELATIONSHIP BETWEEN THE CLINICAL AND THE RADIOLOGICAL DIAGNOSIS OF PARTICIPANTS

A cross tabulation was carried out between the pre-radiological primary clinical diagnosis and the primary (**Table 4.1**) and secondary (**Table 4.2**) radiological diagnosis. This proved too many categories and therefore too many cells had zero values which prevented a chi squared statistical test, or any other statistical test to correlate the variables, from being performed. Instead the relationship between the pre-radiological primary clinical diagnosis and either the primary or secondary

radiological diagnosis is shown in **Tables 4.1** and **4.2** (Singh, 2018; Esterhuizen, 2015).

After a thorough case history, physical and regional examination had been conducted by the attending intern, the pre-radiological primary clinical diagnosis was made. The primary radiological diagnosis refers to radiographic findings and the diagnosis made by the radiologist. The secondary radiological diagnosis refers to the diagnosis made by the researcher.

Table 4.1 indicates the pre-radiographic clinical diagnoses and the primary radiological diagnoses. **Table 4.2** indicates the pre-radiographic clinical diagnosis and the secondary radiological diagnoses. The columns of **Tables 4.1** and **4.2** represents the total number of records to which that particular pre-radiographic primary clinical diagnosis applies. The rows of **Tables 4.1** and **4.2** represent the total number of radiologic diagnoses.

Table 4.1: The pre-radiographic primary clinical diagnosis and the primary radiological diagnosis

		Primary Radiological Diagnosis						
		No significant findings	Heel spur	Avulsion fracture	Degeneration	Pes planus	Incidental findings	Total
Pre-Radiographic Primary Clinical Diagnosis	Foot or ankle fixation	5	0	0	1	0	1	7
	Inversion ankle sprain	3	0	1	0	0	0	4
	Plantar fasciitis	1	2	0	0	0	0	3
	Chronic ankle instability	2	0	0	0	0	0	2
	Pes Planus	0	0	0	1	1	1	3
	Cuboid syndrome	2	0	0	0	0	0	2
	Eversion ankle sprain	1	0	0	0	0	0	1
	Sesamoid fracture	1	0	0	0	0	0	1
	Turf toe	0	0	0	1	0	0	1
	Mortons neuroma	1	0	0	0	0	0	1
	Club foot	0	0	0	0	0	1	1
	Heel spur	0	1	0	0	0	0	1
	Total	16	3	1	3	1	3	27

Table 4.2: The pre-radiographic primary clinical diagnosis and the secondary radiological diagnosis

		Secondary Radiological Diagnosis						
		No significant findings	Heel spur	Avulsion fracture	Degeneration	Pes planus	Incidental findings	Total
Pre-Radiographic Primary Clinical Diagnosis	Foot or ankle fixation	5	0	0	1	0	1	7
	Inversion ankle sprain	3	0	1	0	0	0	4
	Plantar fasciitis	1	2	0	0	0	0	3
	Chronic ankle instability	2	0	0	0	0	0	2
	Pes Planus	0	0	0	1	1	1	3
	Cuboid syndrome	2	0	0	0	0	0	2
	Eversion ankle sprain	1	0	0	0	0	0	1
	Sesamoid fracture	1	0	0	0	0	0	1
	Turf toe	1	0	0	0	0	0	1
	Mortons neuroma	1	0	0	0	0	0	1
	Club foot	0	0	0	0	0	1	1
	Heel spur	0	1	0	0	0	0	1
	Total	17	3	1	2	1	3	27

Foot or ankle dysfunction were the most frequent pre-radiographic clinical diagnosis at 26.9% ($n = \frac{7}{26}$), followed by inversion ankle sprain at 15.4% ($n = \frac{4}{26}$). Plantar fasciitis was the third most common pre-radiographic diagnosis at 11.5% ($n = \frac{3}{26}$). Chronic ankle instability, cuboid syndrome and pes planus were present in 7.7% ($n = \frac{2}{26}$) of cases in the study. The least frequent diagnoses were eversion ankle sprain, sesamoid fracture, turf toe, Morton's neuroma, club foot and heel spur, which represented 3.8% ($n = \frac{1}{26}$) of cases. These figures are represented in **Table 4.1** and **4.2**.

Table 4.1 and **Table 4.2** reveal the most common primary and secondary radiological diagnosis. There were no significant findings in 61.5% ($n = \frac{16}{26}$) and 65.4% ($n = \frac{17}{26}$) of cases respectively. In both **Table 4.1** and **Table 4.2** it is revealed that heel spurs and incidental findings were present in 11.5% ($n = \frac{3}{26}$) of cases during the primary and secondary radiological diagnosis. Degeneration was diagnosed in 7.7% ($n = \frac{3}{26}$) of the primary radiological diagnosis (**Table 4.1**) with only 3.8% ($n = \frac{2}{26}$) in the secondary radiological diagnosis (**Table 4.2**). Avulsion fracture and pes planus were diagnosed in 3.8% ($n = \frac{1}{26}$) of cases during the primary and secondary radiological diagnosis (**Table 4.1** and **Table 4.2**).

4.4 THE CONSULTATION WHEN FOOT AND/OR ANKLE RADIOGRAPHS WERE REQUESTED AND THE REASONS THEREFORE

Table 4.3 shows the consultation and reason(s) for radiographic referral. The reason(s) for referral were based on clinical findings obtained from the case history, physical and regional examination. Therefore, the total count expressed in **Table 4.3** and **Table 4.4** may be greater than the amount of records as there may have been several reasons for radiographic referral.

Table 4.3The reasons for radiographic referral and at which consultation

Consultation number	Frequency	Percentage	Reason for radiographic referral	Count (n)
1	15	57.69%	❖ Trauma, check for fracture	8
			❖ Pain on palpation	7
			❖ Chronic, non-traumatic pain	5
			❖ Swelling	4
			❖ Pain weight bearing	3
			❖ Decrease range of motion	2
			❖ No response to conservative (elsewhere) treatment	1
			❖ Check for Haglund's deformity	1
			❖ Club foot correction surgery	1
2	4	15.38%	❖ Trauma, check for fracture	1
			❖ No response to conservative treatment	1
			❖ Severe, chronic progressive pain	1
			❖ Burning pain	1
			❖ Periosteal reaction to ultrasound	1
3	4	15.38%	❖ No response to conservation treatment	3
			❖ Check for heel spur	1
			❖ Recent history of cellulitis	1
4	1	3.84%	❖ Severe, chronic progressive pain	1
			❖ No response to conservative treatment	1
			❖ Trauma, check for fracture	1
5	1	3.84%	❖ No response to conservative treatment	1
10	1	3.84%	❖ Pain on palpation	1
			❖ No response to conservative treatment	1
Total	30	100%		48

The most frequent reasons for radiographic examination referral during the initial consultation ($n_2 = 32$) were trauma, check for fracture at 25.0% ($n_2 = \frac{8}{32}$), pain on palpation at 21.9% ($n_2 = \frac{7}{32}$) and chronic, non-progressive, non-traumatic at 15.6% ($n_2 = \frac{5}{32}$). Other reasons for radiographic examination referrals included swelling at 12.5% ($n_2 = \frac{4}{32}$), pain weight-bearing at 9.4% ($n_2 = \frac{3}{32}$) and decreased range of motion at 6.3% ($n_2 = \frac{2}{32}$). The least frequent reasons for radiographic examination referrals were club foot correction, check for Haglund's deformity and no response to conservative treatment all at 3.1% ($n_2 = \frac{1}{32}$) (**Table 4.3**).

The frequency of reasons for radiographic examination referral on the second consultation ($n_3 = 5$) were all equal. The frequency for severe, chronic, progressive pain; no response to conservative treatment; trauma, check for fracture; periosteal reaction to ultrasound and burning pain was 20% ($n_3 = \frac{1}{5}$) (**Table 4.3**).

The most frequent reasons for radiographic examination referral during the third consultation ($n_4 = 5$) was no response to conservative treatment at 60% ($n_4 = \frac{3}{5}$). The least frequent reasons for radiographic examination referral were recent history of cellulitis, and check for heel spur both at 20% ($n_4 = \frac{1}{5}$) (**Table 4.3**).

The frequency for the reasons for radiographic examination referral on the fourth consultation ($n_5 = 3$) were all equal. The frequency for severe, chronic, progressive pain, no response to conservative treatment and trauma, check for fracture was 33.3% ($n_5 = \frac{1}{3}$) (**Table 4.3**).

The frequency for the reasons for radiographic examination referral on the fifth consultation ($n_6 = 1$) consisted of no response to conservative treatment at 100% ($n_6 = \frac{1}{1}$) (**Table 4.3**).

The frequency for the reasons of radiographic examination referrals on the tenth consultation ($n_7 = 2$) was pain on palpation and no response to conservative treatment at 50% ($n_7 = \frac{1}{2}$) (**Table 4.3**).

Table 4.4 shows the most common reasons for radiographic referral. The number of radiographic referrals is greater than the sample size as there may have been several reasons for radiographic referral.

Table 4.4: The most common reasons for radiographic referral

Ranking	Reason for radiographic referral	Count (n)	Percentage
1	❖ Traumatic, check for fracture	10	20.8%
2	❖ Pain on palpation ❖ No response to conservative treatment	8	16.7%
4	❖ Chronic, non-traumatic, pain	5	10.4%
5	❖ Swelling	4	8.3%
6	❖ Pain weight bearing	3	6.3%
7	❖ Decrease range of motion ❖ Severe chronic progressive pain	2	4.2%
9	❖ Club foot correction ❖ Check Haglund's deformity ❖ Check heel spur ❖ Periosteal reaction to ultrasound ❖ Burning ❖ Recent history of cellulitis	1	2.1%

The majority of foot or ankle radiographs ($n = \frac{15}{26}$) were requested at the initial consultation. The frequency of radiographic examination requests decreased as the number of follow up consultations increased. Overall, the most common reasons for radiographic examination referrals ($n_8 = 48$) were trauma, check for fracture at 20.8% ($n_8 = \frac{10}{48}$), no response to conservative treatment and pain on palpation at 16.7% ($n_8 = \frac{8}{48}$), and chronic, non-progressive and non-traumatic pain at 10.4% ($n_8 = \frac{5}{48}$). Other reasons for radiographic examination referrals included swelling at 8.3% ($n_8 = \frac{4}{48}$), pain weight-bearing at 6.3% ($n_8 = \frac{3}{48}$), severe chronic progressive pain and decreased range of motion at 4.2% ($n_8 = \frac{2}{48}$). The least frequent reasons for radiographic examination referrals were check for Haglund's deformity, club foot correction, burning pain, check for heel spur and periosteal reaction to ultrasound, all at 2.1% ($n_8 = \frac{1}{48}$) (**Table 4.4**).

4.5 SUSPECTED CLINICAL DIAGNOSES AND MANAGEMENT

4.5.1 Prior to referral for foot or ankle radiographs

All management options provided by the attending intern for each of the pre-radiographic clinical diagnosis are expressed in **Table 4.5**.

The rows combined totals will be greater than the total number of records in the columns. This is because participants may have undergone multiple treatment sessions with multiple treatment modalities prior to radiographic referral.

Table 4.5: The suspected clinical diagnosis and management prior to radiographic evaluation

		Pre-radiographic management											
		EMT	Joint mobilization	Dry needling	Cross frictions	Ischaemic compression	TENS	Stretching	Ultrasound	Cryotherapy	Strapping	No treatment	Total participants
Pre-radiographic primary clinical diagnosis	Foot or ankle dysfunction	5	1	2	0	2	2	0	2	2	0	0	7
	Inversion ankle sprain	1	1	1	0	0	1	0	4	0	0	0	4
	Plantar fasciitis	3	0	1	0	2	0	0	1	0	1	0	2
	Chronic ankle instability	1	2	1	0	0	0	0	0	0	0	0	2
	Pes Planus	2	0	0	0	0	0	0	2	0	1	0	3
	Cuboid syndrome	0	1	0	0	1	0	0	1	0	0	0	2
	Eversion ankle sprain	0	0	0	0	0	0	0	0	0	0	1	1
	Sesamoid fracture	0	0	0	0	0	0	0	0	0	0	1	1
	Turf toe	0	0	0	0	1	0	0	1	0	0	0	1
	Mortons neuroma	0	0	0	1	0	0	0	1	0	0	0	1
	Club foot	0	1	0	0	0	0	0	1	0	0	0	1
	Heel spur	0	1	0	0	0	0	0	1	0	0	0	1
	Total	12	7	5	1	6	3	0	14	2	2	2	26

Figure 4.2 shows the frequencies of the management modalities used by the interns.

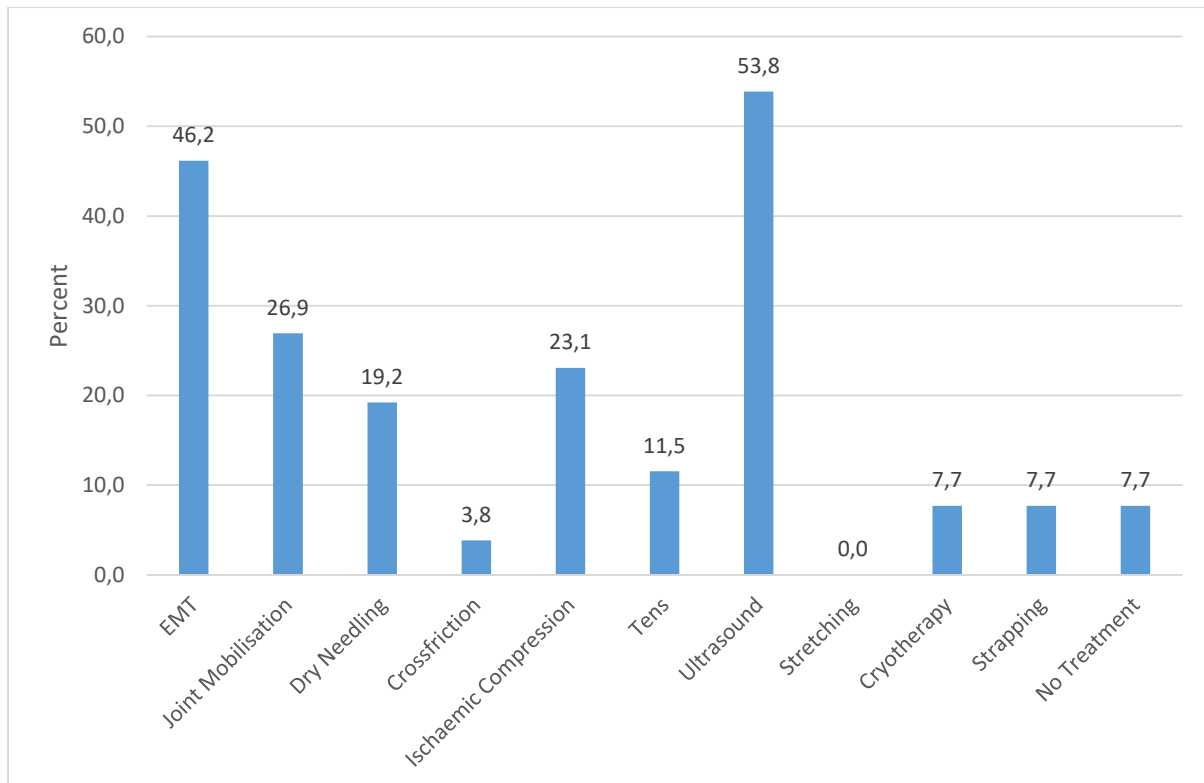


Figure 4.2: The management prior to radiographic referral

Soft tissue therapies involved modalities such as massage, ischaemic compression and cross friction of the foot and ankle musculature. Electro-modalities to aid in the management of participants with foot and/or ankle pain include transcutaneous electrical nerve stimulation (TENS) and ultrasound (US). Stretching of the foot and ankle musculature include proprioceptive neuromuscular facilitation (PNF) as well as static stretches. Extremity manipulative therapy (EMT) and foot and ankle mobilisation constitute as manual therapy. Dry needling was another form of soft tissue therapy that may have aided in the management of participants. Other management modalities include cryotherapy and strapping.

4.5.2 Changes in the clinical diagnoses and management after radiographic evaluation

Of the total $n = 26$ clinical records that were analysed in this study, a total of two records (8%) had a change in the diagnosis. A total of 18 records (69%) had no change in diagnosis and six of the records (23%) had confirmed clinical diagnoses and did not present for follow up consultation (**Figure 4.3**). It may have been deemed unnecessary for these six (23%) participants to present for follow up consultation if radiographic findings were insignificant and lacked impact on the initial clinical diagnosis.

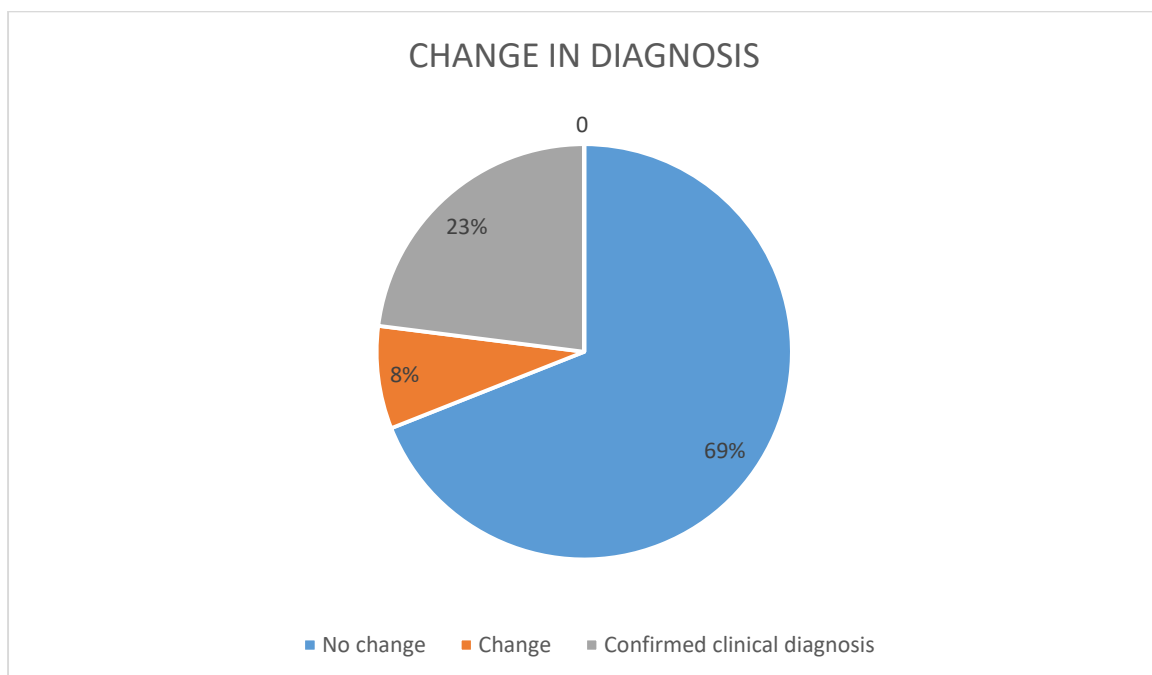


Figure 4.3: The impact radiographs had on the clinical diagnosis

Table 4.8 shows the impact the radiological diagnosis had on the clinical diagnosis. Also shown are the radiological findings of each clinical diagnosis as well as the post radiographic clinical diagnosis.

Table 4.6: Clinical diagnosis and the corresponding radiographic findings

Pre-radiographic primary clinical diagnoses	Primary radiologic diagnoses	Post-radiographic primary clinical diagnoses	Count
Foot or ankle dysfunction	No significant findings	Foot or ankle dysfunction	5
		Confirmed clinical diagnosis	1
	Degeneration	Foot or ankle dysfunction	1
Inversion ankle sprain	No significant findings	Inversion ankle sprain	3
	Medial malleolar avulsion fracture	Medial malleolar avulsion fracture	1
Plantar fasciitis	No significant findings	Heel spur	1
		Confirmed clinical diagnosis	2
Chronic ankle instability	No significant findings	Chronic ankle instability	2
Pes planus	No significant findings	Pes planus	1
	Pes Planus	Pes Planus	1
Cuboid syndrome	No significant findings	Cuboid syndrome	2
Eversion ankle sprain	No significant findings	Confirmed clinical diagnosis	1
Sesamoid fracture	No significant findings	Confirmed clinical diagnosis	1
Turf toe	Degenerative change	Confirmed clinical diagnosis	1
Mortons neuroma	No significant findings	Mortons neuroma	1
Club foot	No significant findings	Club foot	1
Heel spur	Heel spur	Heel spur	1
Total			26

Figure 4.4 shows the impact that radiographic examination had on the management, indicating that 10 (38%) participants had a change in the management. There were 6 (23%) participants that did not have a follow up consultation post radiographic examination, thus 10 (38%) participants did not have a change in the management. Therefore, of the 20 participants who presented for follow up consultations post radiographic examination, 10 (50%) had a change in management of their foot and/or ankle pain.

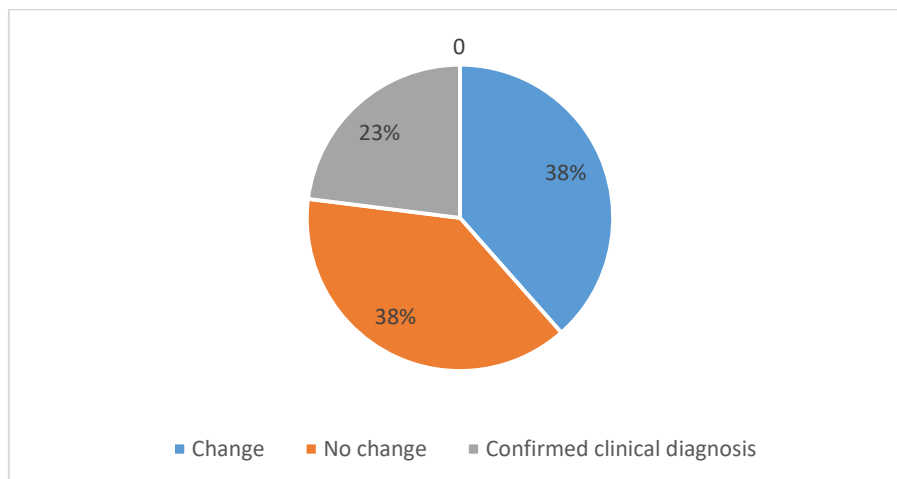


Figure 4.4: The impact the radiologic referral had on management

Figure 4.5 indicates the most commonly used management modalities following referral for radiographic examination. EMT was the most popular management modality post radiographic examination, while US was the second most popular management modality.

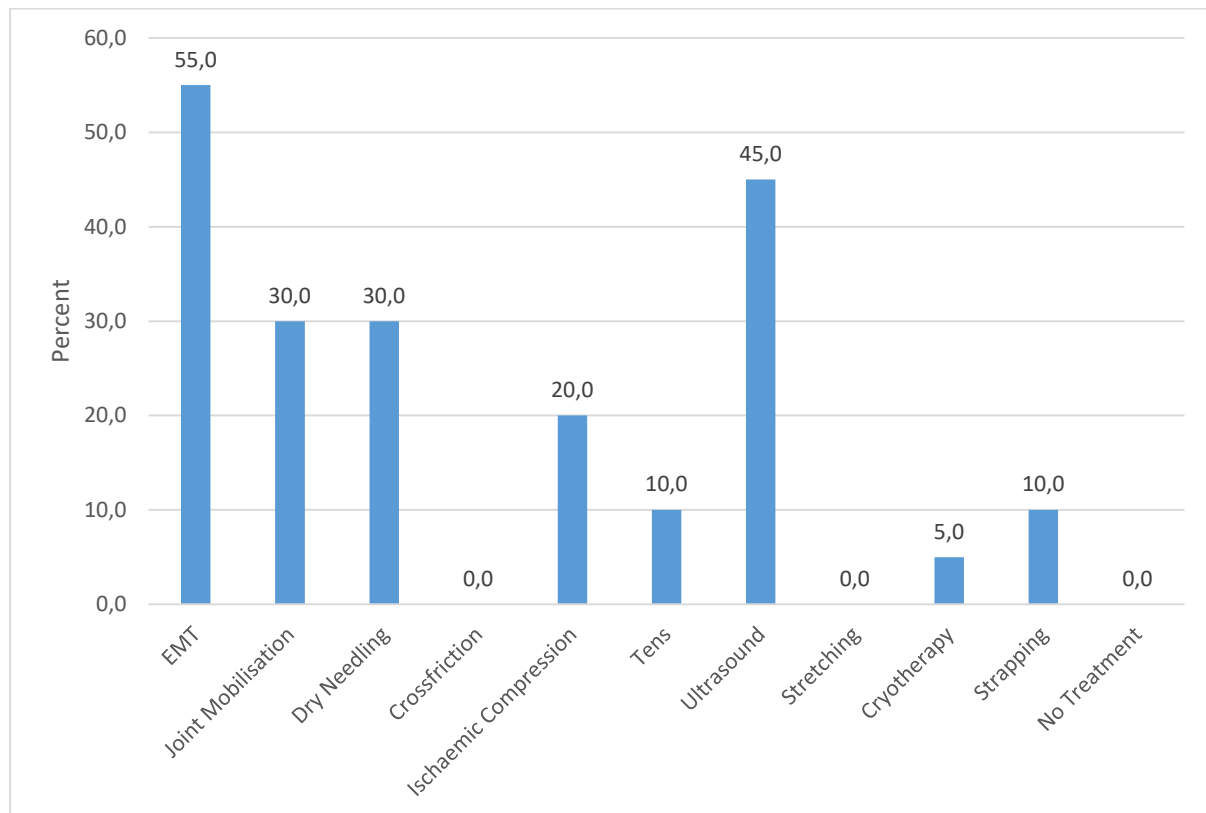


Figure 4.5: The management post radiographic referral

Figure 4.6 indicates which management modality was added or removed after the radiologic examination. EMT, dry needling and ischaemic compression were the most frequently added modality for the management of the patient post radiographic examination.

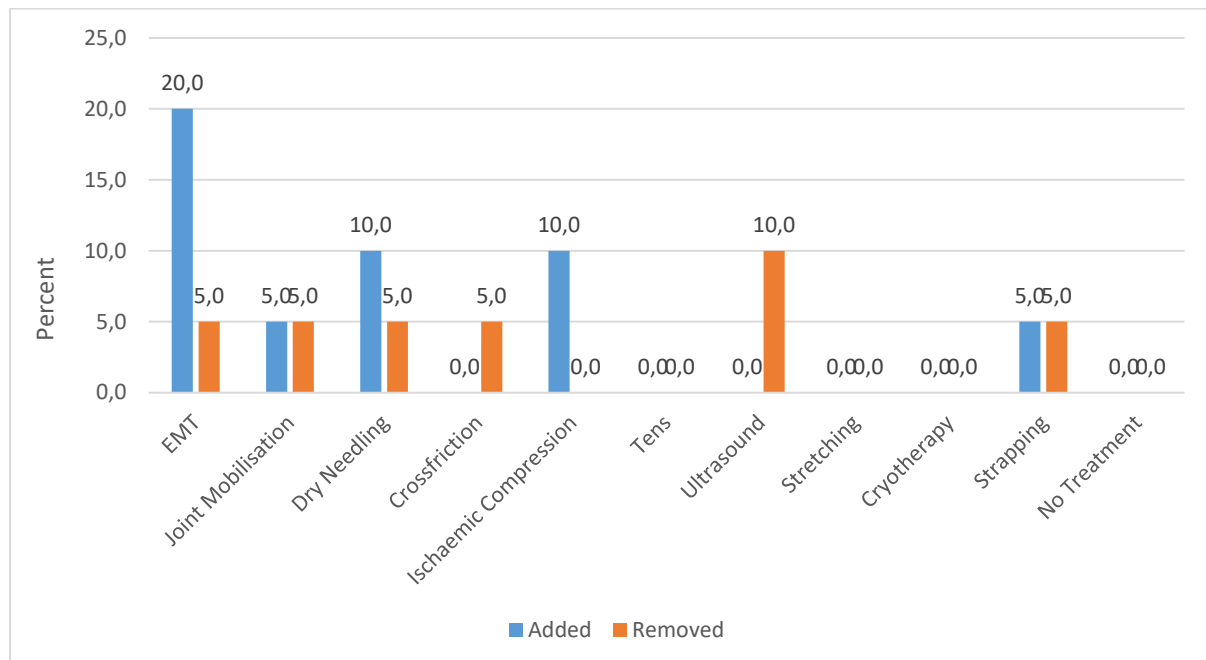


Figure 4.6: The change in management post radiographic referral

4.6 INCIDENTAL FINDINGS ON RADIOGRAPHS

Of the total 3 (11.5%) participants presented with incidental findings as shown in **Figure 4.7**.

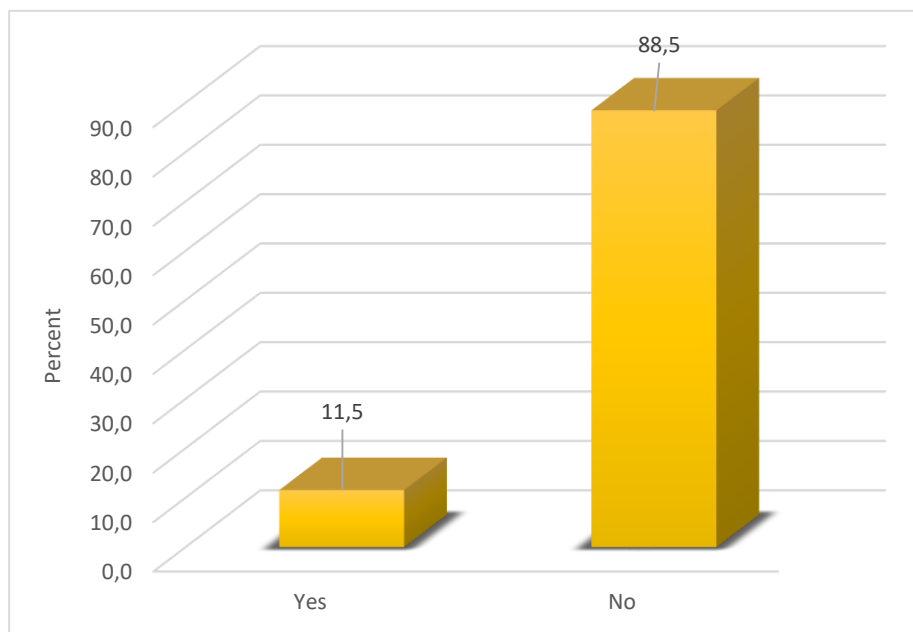


Figure 4.7: The number of incidental findings on radiographs

Table 4.9 reflects the incidental findings that present in the radiographic examination and the clinical diagnoses pre and post radiographic examination. There were a total of three (11.5%) incidental findings observed in the $n = 26$ foot and ankle radiographs. Each incidental finding accounted for 3.8% of the total number of clinical records in this study. No patient had more than one incidental finding and no incidental finding presented more than once. The three incidental findings included early bunion formation, calcaneal heel spur and arteriole calcification.

Table 4.7: Incidental findings related to the pre-radiographic clinical diagnosis and post-radiographic clinical diagnosis

Incidental findings	Count (%)	Pre-radiographic clinical diagnosis (with percentage)	Post-radiographic clinical diagnosis (with percentage)
Calcaneal heel spur	1 (3.8%)	Club foot (3.8%)	Club foot (5%)
Arteriole calcification	1(3.8%)	Foot or ankle dysfunction (26.9%)	Foot or ankle dysfunction (30%)
Bunion formation	1(3.8%)	Pes Planus (7.7%)	Pes planus (10%)
Total	3 (11.5%)		

Table 4.10 correlates a change in management in the clinical records of those participants with foot and/or ankle pain following the observation of the incidental finding on radiographic examination. **Table 4.10** shows a change in management in 66.7% (2) of the clinical records in which incidental findings were observed.

Table 4.8: Incidental findings and the effect on the post-radiographic management

				Count	Count %
Incidental finding (Count)	Calcaneal heel spur	Change management in	Yes	1	100%
			No	0	0%
	Arteriole calcification	Change management in	Yes	0	0%
			No	1	100%
	Bunion formation	Change management in	Yes	1	100%
			No	0	0%

CHAPTER 5: DISCUSSION OF RESULTS

5.1 INTRODUCTION

In this chapter the results, as presented previously, will be discussed and compared to existing literature. An overview of the age and gender distribution as well as the relationship between the pre-radiographic clinical diagnosis and the radiological diagnoses will be discussed. A record of the consultation of which the patient was referred for radiographic examination and the reasons therefor will be interpreted. The clinical diagnosis and the management prior to and post radiographic examination referral will be compared as well as the incidental findings that presented on the radiographs, and their impact on the diagnosis and management.

5.1.1 Age and gender

The mean age of the participants was 38.12 years. The mean age for female participants was 33.42 years of age and 42.07 years of age for male participants. Therefore on average the male participants were 8.65 older than the female participants. The range of the participants was from 19 to 75 years. The mean age of the participants that presented with foot and ankle pain is in keeping with the average of patients that presented to the CDC in the year 2000 (37.03 years of age) and 2011 (37.8 years of age) (McDonald, 2012).

Ankle injuries are typically more prevalent in females rather than males (Thomas *et al.*, 2011). The findings of this study did not concur as 14 (53.8%) participants were males thus 12 (46.2%) participants were female. The reasons for this are unclear, however, results may reflect the demographic characteristics of the DUT CDC as determined by McDonald (2012). He found that the amount of female and male patients that presented to the DUT CDC was 51.2% and 48.8% respectively in 2011.

5.2 THE RELATIONSHIP BETWEEN THE PRE-RADIOGRAPHIC AND RADIOLOGICAL DIAGNOSES OF PATIENTS WITH FOOT AND/OR ANKLE PAIN

There were a number of categories involved in this study with many variables, therefore no statistical tests were able to be performed to compare the diagnoses or test associations. Attempts to correlate the pre-radiographic clinical diagnoses and radiological diagnoses were unsuccessful due to the large number of different diagnoses of foot and/or ankle pain (Singh, 2018). Failure to establish any relationship between the two diagnoses may be due to incorrect initial clinical diagnosis, incorrect or missed radiological diagnosis, failure to incorporate radiographic findings in the final diagnosis, and uncertainty of the intern as to whether to stay with the initial pre-radiographic clinical diagnosis or to change it to the radiologic diagnosis.

Although the clinician on duty and interns at the DUT CDC should maintain a high level of suspicion for red flags (Pederson, 2005; Michael *et al.*, 2009) in patients with foot and/or ankle pain, the results of the study may indicate an over-reliance of the interns on radiographic examination to reach a diagnosis as there are many factors that contribute to the need for obtaining radiographs (Chauhan *et al.*, 2014; Bussi res *et al.*, 2007). Presentations of conditions may vary resulting in a diagnosis being difficult to obtain (Delzell *et al.*, 2017). There may be a level of inexperience and/or lack of confidence of the student to formulate an accurate clinical diagnosis (Sharif and Masoumi, 2005). The use of radiographs will often confirm a diagnosis (Delzell *et al.*, 2017).

Foot or ankle dysfunction is a clinical diagnosis which is characterised by a collection of signs and symptoms which identify dysfunction in spinal, pelvic and peripheral joints (Bergman and Peterson, 2011). Foot or ankle dysfunction was the most common pre-radiographic clinical diagnosis in the study at 26.9% ($n = \frac{7}{26}$), as shown in **Table 4.1** in Chapter 4 previously. This clinical diagnosis may have been obtained by a fault in one or more of the five qualities of normal joint function (joint play, active and passive range of motion, end feel and paraphysiologic movement) (Bergman and Peterson, 2011).

Subsequent to foot and ankle dysfunction, inversion ankle sprains were the next most common clinical diagnosis at 15.4% ($n = \frac{4}{26}$). Ankle sprains are the most common musculo-skeletal injury (Bindiya *et al.*, 2014). A possible reason for inversion ankle sprains being the second most common clinical diagnosis to foot or ankle dysfunction may be due to missed diagnosis as joint dysfunction often results from inversion ankle sprains (Denegar and Miller, 2002; Hertel, 2002; Bonnel *et al.*, 2010).

Trauma is an indication for radiographic examination referral, such as in an inversion ankle sprain (Bussi res *et al.*, 2007), as it increases the likelihood of a fracture as well as presenting in a similar manner to a fracture (Daniels, Welk and Enix, 2016). The Ottawa ankle rules may aid in the initial screening to determine a diagnosis between ankle fracture and sprain, therefore limiting the need for imaging studies (Daniels, Welk and Enix, 2016). **Table 4.1** and **Table 4.2** in Chapter 4 revealed that 75% of participants that presented with inversion ankle sprains had no significant radiological findings. This therefore questions the use of the Ottawa ankle rules at the DUT CDC as use of these rules is said to decrease radiographic referrals for ankle sprains by up to 33% (Yazdani *et al.*, 2005).

Plantar fasciitis was present in 11.5% ($n = \frac{3}{26}$) of participants of which 66.7% of which presented with a heel spur. Plantar fasciitis is a common cause of heel pain affecting people in both sedentary and athletic populations (James, Goff and Crawford, 2011). Although radiographs are not routinely requested they may aid in the diagnosis and identify bony lesions of the foot and ankle (James, Goff and Crawford, 2011; Yochum and Rowe, 2005). Interns at the DUT CDC are more conservative with management of participants due to their inexperience and potential lack of confidence (Sharif and Masoumi, 2005), but heel spurs were identified early due to their prompt radiographic referral.

Chronic ankle instability was present in 7.7% ($n = \frac{2}{26}$) of cases (**Figure 4.1** and **Figure 4.2**). This may develop in up to 40% of participants subjected to previous ankle trauma (Bindiya *et al.*, 2014). Many conditions may mimic CAI such as fractures of the foot and ankle, peroneal tendonitis, osteoarthritis of the ankle joint,

ankle impingement syndrome, Achilles tendonitis, lateral malleolar bursitis, tarsal coalition, posterior tibialis tendon dysfunction, sinus tarsi syndrome and osteochondritis dissecans (de Bie *et al.*, 2003; Chan, Ding and Mroczek, 2011). The results revealed that there were no significant findings with participants diagnosed with CAI. Although the radiographic outcomes may not support the need for radiographic examination, the safety of participants at the DUT CDC is tremendously important with such complex conditions (Bonnel *et al.*, 2010).

Cuboid syndrome was present in 7.7% ($n = \frac{2}{26}$) of cases in the study. Both cases presented with no significant findings, therefore there was a confirmation of the clinical diagnoses with the use of radiographs. Cuboid syndrome is defined as a combination of symptoms, including pain on weight-bearing and during palpation (Durell, 2011; Patterson, 2006). This may replicate the symptoms of stress fractures which are often missed diagnoses that result in delayed treatment (Welck *et al.*, 2015; Sormaala *et al.*, 2006).

Pes planus was present in 7.7% ($n = \frac{2}{26}$) of cases in this study. On radiological examination, degeneration, an incidental finding and a confirmation of pes planus, was present. This is interesting as acquired flat feet is often a result of degeneration as it causes a dysfunction of the tibialis posterior (dynamic arch support) (Moore, Dalley and Agur, 2010). This shows that there was a positive impact of the use of radiographs to confirm the clinical diagnosis (Bussi res *et al.*, 2007).

The diagnoses of eversion ankle sprain and sesamoid fracture were the least common clinical diagnosis ($n = \frac{1}{26}$). Both of these cases had no significant findings. Both were traumatic cases and thus it was necessary to send for radiographs (Chauhan *et al.*, 2014; Bussi res *et al.*, 2007). Neither case presented for a follow up consultation post radiographic examination as the clinical diagnosis was confirmed. The intern may have not regarded it as necessary to continue with management or the patient may not have felt the need to continue with management after a serious injury with red flags having been ruled out (Chauhan *et al.*, 2014; Bussi res *et al.*, 2007).

Heel spur was also one of the least common clinical diagnosis ($n = \frac{1}{26}$). Heel spurs may not confirm the diagnosis of plantar fasciitis as they can occur without plantar fasciitis (James, Goff and Crawford, 2011). There was a positive outcome arising from the use of radiographic examination referral by the intern and clinician to confirm the clinical diagnosis, as radiography can confirm bony lesions including subcalcaneal heel spurs (James, Goff and Crawford, 2011).

5.3 THE CONSULTATION WHEN FOOT AND ANKLE RADIOGRAPHS WERE REQUESTED AND REASONS THEREFOR

Chiropractic is the most popular drug-free, primary contact health care profession in the world and is growing at an exponential rate (Western Province Chiropractic Association, 2015). Chiropractors mainly focus on the diagnosis and management of neuro-musculoskeletal conditions in a conservative manner without the utilization of medicine or surgery (World Federation of Chiropractic, 2012). A considerable amount of time is devoted to the foot by primary healthcare physicians and the ankle is the most frequently injured major joint in the body (Moore, Dalley and Agur, 2010), therefore it is one of the most common presenting acute injuries to emergency departments (Yazdani, 2006).

There are many causes of foot and ankle symptoms that will result in an individual seeking care from a physician (Delzell *et al.*, 2017). Disorders may manifest as both local and systemic disease processes (Montgomery and Davies, 2016). Some conditions may be easy to diagnose by physical examination, others may have non-specific examination findings, therefore optimal management decisions may be difficult (Delzell *et al.*, 2017). Clinical examination together with radiographs can frequently confirm the correct diagnosis or even provide a definitive diagnosis (Delzell *et al.*, 2017). It is interesting to see that 15 (57.69%) radiographs were requested after the initial consultation. Although 6 (40%) cases did not have a follow up consultation after radiographic examination, the remaining 9 (60%) participants had an increase in EMT by 44.4%. This finding therefore suggests that the interns were more confident in using EMT as a management modality post radiographic examination and after EMT contraindications had been ruled out. The total count (n_2

= 48) of reasons for radiographic referral is greater than the amount of records as mentioned before regarding **Table 4.3** and **Table 4.4**. This is due to the fact that more than one reason for radiographic referral may have recorded on the radiographic referral letter. A total of 66.67% ($n_8 = \frac{32}{48}$) reasons were recorded for radiographic examination during the initial consultation (**Table 4.3**). The reasons shown in **Table 4.3** include: trauma, check for fracture ($n_8 = \frac{8}{48}$), pain on palpation ($n_8 = \frac{7}{48}$), chronic, non-traumatic pain ($n_8 = \frac{5}{48}$), swelling ($n_8 = \frac{4}{48}$), pain weight-bearing ($n_8 = \frac{3}{48}$), decrease range of motion ($n_8 = \frac{2}{48}$), no response to conservative treatment ($n_8 = \frac{1}{48}$), check for Hugland deformity ($n_8 = \frac{1}{48}$) and club foot correction surgery ($n_8 = \frac{1}{48}$). Radiographs should only be requested at the initial consultation if the intern and clinician have a strong suspicion of any serious underlying conditions e.g. presence of red flags (Pederson, 2005; Michael *et al.*, 2009). This may have been true during the initial consultation when the participants were referred for radiographs.

As the number of consultations increased, the percentage of radiographic examination referrals decreased ($p = -1.069$) (**Table 4.4**). It is shown in **Table 4.4** that the consultation number is not a good predictor of frequency ($p = 0.182$). **Table 4.3** shows that the radiographic examination referral on the second and third consultation was 15.38% ($n = \frac{4}{26}$). The reasons for referral on the second consultation include: trauma, check for fracture ($n_3 = \frac{1}{5}$), no response to conservative treatment ($n_3 = \frac{1}{5}$), severe, chronic progressive pain ($n_3 = \frac{1}{5}$), burning pain ($n_3 = \frac{1}{5}$) and periosteal reaction to ultrasound ($n_3 = \frac{1}{5}$). Conservative chiropractic management should allow four to six weeks of treatment before referral for special imaging such as radiographs (Souza, 2009). This is not in keeping with the results in **Table 4.3**, as no response to conservative treatment was a reason for radiographic referral. This may allude to the inexperience and lack of confidence in the interns at the DUT CDC (Sharif and Masoumi, 2005). Although that may be the case regarding the interns at the DUT CDC, their caution resulted in the early discovery of a heel spur which is a positive finding, although this did not impact the management of the patient. Burning pain and periosteal reaction to ultrasound are not within the guidelines of

radiographic referral. Although burning pain is not a reason for radiographic examination referral, there was a significant finding of a heel spur which led to referral to an orthopaedic surgeon.

5.4 SUSPECTED CLINICAL DIAGNOSES AND MANAGEMENT PRIOR TO REFERRAL FOR FOOT OR ANKLE RADIOGRAPHS

The most common clinical diagnosis was foot or ankle dysfunction ($n = \frac{7}{26}$). This may be due to this functional diagnosis being characterised as a collection of symptoms that are assumed to cause dysfunction in peripheral joints (Bergman and Peterson, 2011). The lack of experience of the interns may lead to this non-specific functional diagnosis and the amount of radiographic examination referral for this diagnosis may demonstrate the lack of confidence in the interns at the DUT CDC (Sharif and Masoumi, 2005).

Ultrasound was the most commonly used management modality as 53.8% ($n = \frac{14}{26}$) of cases were exposed to ultrasound. This may be a popular modality for the foot and ankle as it aids in the reduction in muscle pain and spasm, decrease in joint stiffness, increase in extensibility of tendons and joint capsules, and increase blood flow to a target area to resolve a chronic inflammatory process (Pillay, 2003). Chiropractic emphasises high velocity techniques such as manipulation in the management of patients. It is interesting that EMT was only used in 46.2% of cases. This may be due to the lack of confidence or the safety of the patients prior to radiographic examination referral (Sharif and Masoumi, 2005).

5.5 CHANGES IN THE CLINICAL DIAGNOSIS AND MANAGEMENT AFTER FOOT OR ANKLE RADIOGRAPHS

Of the total 26 clinical records that were analysed in this study, a total of two records (7.7%) had a change in the diagnosis. A total of 18 records (69.2%) had no change in diagnosis and six of the records (23.1%) the participants did not have a follow up appointment after the radiographic examination (**Figure 4.3**). Of the six (23.1%) records, all of the radiographic findings were insignificant thus the clinical diagnosis prior to the radiographic examination was confirmed. Foot and ankle joint dysfunction

was the most common clinical diagnosis at 26% (n=7) prior to, and 30% (n=8) post radiographic examination (**Table 4.8**).

Figure 4.4 shows that of the 26 cases, 10 (38%) of these cases had a change in management, and 6 (23%) of these cases had a confirmed clinical diagnosis which implies that it may have not been deemed necessary to have a radiograph for continued management. Therefore, of the files that had a follow up consultation, 10 (50%) of the cases had a change in the management. **Figure 4.5** shows that EMT was the most popular management modality (55%). This is interesting as this may indicate that the interns at the DUT CDC are a lot more confident using EMT as a management modality post radiographic examination. **Figure 4.6** shows the change in management post radiographic examination. It indicates which management modality was added or removed. EMT was added in 20% of cases but removed in 5%. This indicates that the radiographic examination had a positive influence on the use of EMT, although it may also indicate that these cases were unnecessary for radiographic examination referral. Cross friction and ischaemic compression were added in 10% of cases. The reason for this may be a coincidence or may be due to the intern reassessing the patient post radiographic examination and deciding the patient would benefit from other management modalities.

5.6 INCIDENTAL RADIOGRAPHIC FINDINGS

Occasional incidental findings may require alterations in the treatment protocols (Beck *et. al.*, 2004). As shown in **Table 4.9** there were a total of three (11.5%) incidental findings observed in the 26 foot and ankle radiographs. This is in keeping with Yap *et al.*, 2015 where they found incidental findings to be present in 8.7% of radiographs. Each incidental finding accounted for 3.8% of the total number of clinical records in this study. No patient had more than one incidental finding and no incidental finding presented more than once. The three incidental findings included early bunion formation, calcaneal heel spur and arteriole calcification.

Early bunion formation occurred as an incidental finding in the pre-radiographic clinical diagnosis of Pes planus. The radiographic examination referral was requested on the third treatment due to no response to conservative treatment. The

bunion was present on the medial aspect of the first metatarsal phalangeal joint, which is in keeping with Moore *et al.* (2010) and (Charrette, 2009). There was a mild hallux valgus malalignment present which may have caused a biomechanical variation which may have resulted in constant friction against the inside of shoes, causing the formation of a bunion (Charete, 2009). As seen in **Table 4.10** the change in management occurred in this instance. Both EMT and ultrasound were removed from the management, but strapping remained.

Calcaneal heel spur occurred as an incidental finding in the pre-radiographic clinical diagnosis of club foot. The reason for the referral requested was due to club foot and pain on palpation over the dorsal aspect of the foot. As can be seen from **Table 4.10**, the management of the patient had changed. EMT and ischaemic compression were added into the management while ultrasound remained. The intern may have not been comfortable with the use of EMT as the patient had a previous history of surgery to the ankle.

Arteriole calcification occurred as an incidental finding in the pre-radiographic diagnosis of foot or ankle fixation. The radiographic examination request was made on the third consultation due to dorsal foot pain that had no response to conservative treatment. The incidental finding had no effect on the management of the patient, as shown in **Table 4.10**.

Table 4.10 correlates a change in management in the clinical records of those participants with foot and/or ankle pain following the observation of an incidental finding on radiographic examination. **Table 4.10** shows a change in management in 66.7% of the clinical records in which incidental findings were observed.

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

In this chapter the conclusion of the study will be discussed as well as the recommendations proposed for future similar studies.

6.1 CONCLUSION

The majority of participants (57.69%) were referred for foot or ankle radiographs after their initial consultation. Progressively, as the consultation number increased, the amount of radiograph referrals decreased. Although the majority of reasons (79.2%) were considered relevant indicators for radiographic examination, there was little impact on the diagnosis (7.7%) and management (38%) of these participants.

The majority of foot and ankle pre-radiographic clinical diagnoses (26.9%) were non-specific mechanical causes of foot or ankle pain with the most common being foot or ankle joint dysfunction. Although foot and ankle radiographs were not influential in changing the clinical diagnosis in 92.3% of cases, it did however change the clinical diagnosis in 7.7%. The majority (92.3%) of diagnoses did not have a change thus foot and ankle radiographs have little impact on the non-specific mechanical diagnoses of participants that present with foot and/or ankle pain to the DUT CDC.

The impact of foot or ankle radiographs lead to a change in the management of participants (38%) that presented to the DUT CDC with foot and/or ankle pain. The most commonly used management option prior to radiographic examination referral was electro-modalities (65%), consisting of ultrasound and TENS. EMT was present as a management option in 46.2% of participants prior to radiographic examination. Interestingly, electro-modalities decreased by 10.4% and EMT increased by 8.8% post radiographic examination. Although radiographic examination didn't change the diagnosis in 92.3% of cases, EMT increased by 8.8% and electro-modalities decreased by 10.4%. Thus, these management modalities are equal as the most common management protocol post radiographic examination. The fact that EMT has become equal to the most common management option may suggest that interns at the DUT CDC may feel safe to implement EMT in patients with foot and/or ankle pain after red flags had been ruled as a result of radiographic examination.

All incidental findings occurred at the same frequency of 11.5% of cases. Incidental findings such as calcaneal heel spur and bunion formation led to a change in management while the finding of arteriole calcification had no impact on the management. Therefore, radiographic incidental findings of the foot and ankle change the management in 66.7% (2) of cases.

Only 7.7% of cases did not have treatment prior to radiographic examination which confirms that interns and clinicians at the DUT CDC are ethical in the management of patients as they do not withhold management options unnecessarily. It is therefore vital that an adequate case history and physical examination is performed on each patient in order for the interns at the DUT CDC to be confident in their management options.

The sample population in this study showed that foot and ankle radiographs have little impact on the diagnosis of patients with non-specific mechanical foot and/or ankle pain (7.7%) at the DUT CDC. Although there was little impact on foot and/or ankle pain in this study (7.7%), foot or ankle radiographs are necessary for specific conditions such as fracture, arteriole calcification, systemic disease or pes planus (Bussi res *et al.*, 2007). Radiographic examination had a change in management of 38% of the total number of cases that presented with foot and/or ankle pain to the DUT CDC. It was shown that EMT was more commonly implemented after radiological results deemed it safe to do so. Therefore, interns of the DUT CDC are over reliant on radiographs to confirm their clinical diagnosis and practice a safe management protocol.

6.2 LIMITATIONS OF THE STUDY

The study was limited to all the foot and ankle radiographs and corresponding patient files that satisfies the inclusion and exclusion criteria within the DUT Radiography Department PACS system which was established in 2013. The study may therefore be limited due to the number of radiographs available. The small sample size resulted in a restricted amount of data to portray worldly comparisons and conclusions.

The participants were required to be referred for foot and ankle radiographs during their treatment at the DUT CDC, so patients that presented to the DUT CDC with foot and ankle radiographs at their first consult were excluded from the study as such radiographs would already have influenced the diagnosis and management of the patient. The study design was retrospective, the time frame in which data was collected was short thus there was limited data that fell into the inclusion criteria. Examiners often evaluated and interpreted findings differently thus details in the history and physical examination may have been left out of the documentation.

6.3 RECOMMENDATIONS

- The clinicians should encourage the interns to consider and explore all the possible clinical diagnoses based on the patient history, physical examination and radiographs rather than over-relying on the common, mechanical, clinical diagnoses such as foot or ankle joint dysfunction.
- The study should be replicated with an increased sample size.
- Adherence to research-based guidelines and clinic manual guidelines for plain film radiographic referral at the CDC needs to be monitored more effectively since adherence to these guidelines have been shown to reduce unnecessary ionising radiation exposure (Bussi res *et al.*, 2007).
- Exposure of the interns to different fields of expertise would most likely improve their diagnostic skills and help develop their means of management in patients with foot and/or ankle pain.
- A similar study should be performed at the Chiropractic Day Clinic at the University of Johannesburg to determine whether these findings are unique to the DUT CDC or if they are comparable to those of another chiropractic teaching clinic.
- This study should also be conducted at a private chiropractic practice to compare the results of a chiropractic teaching clinic to those of a private chiropractic practice.

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APPENDICES

Appendix A: Approval to access the PACS system



05 February 2018

Mr A L Revell (IREC Reference: REC 132/7)
c/o Department of Chiropractic and Somatology
Faculty of Health Sciences
Durban University of Technology

Dear Mr Revell

PERMISSION TO CONDUCT RESEARCH in the RADIOGRAPHY CLINIC

Your email correspondence in respect of the above refers.

I am pleased to inform you that permission is granted to you to conduct your research study titled "The impact of foot and ankle radiographs in the diagnosis and management of patients with ankle pain", following IREC approval.

Kindly contact Mrs Kismath in the Radiography Clinic to make arrangements for data collection.

I wish you the best in your studies.

Yours sincerely

Mrs Roshnee Sunder (HOD)

CC: Mrs P Kismath (Radiography Clinic Coordinator)

Appendix B: Permission to record data from the CDC

MEMORANDUM

To : Prof Ross
Chair : RHDC

Prof Adam
Chair : IREC

From : Dr Charmaine Korporaal Clinic Director :
Chiropractic Clinic

Date : 17.08.2017

Re : Request for permission to access the radiograph store at the Chiropractic Day Clinic for
research purposes (determination of the sample size)

Permission is hereby granted to :

Mr Andrew Lex Revell (Student Number: 21208980)

Research title : "The impact of foot and ankle radiographs in the diagnosis and management of patients with ankle pain".

Mr Revell, is requested to submit a copy of his IREC approved proposal along with the letter of approval as well as proof of his MTech : Chiropractic registration to the Clinic Administrators (Mrs Twiggs) before he starts with his research in order that any special procedures with regards to his research can be implemented prior to the commencement of him beginning his data collection.

Thank you for your time.

Kind regards



Dr Charmaine Korporaal

Clinic Director : Chiropractic Clinic

Cc: Mrs L Twiggs: Chiropractic Day Clinic

Drs K Padayachee and A Pastellides: Research supervisors

Appendix C: Ethics Approval



Institutional Research Ethics Committee
Research and Postgraduate Support Directorate
2nd Floor, Berwyn Court
Gate 1, Steve Biko Campus
Durban University of Technology

P O Box 1334, Durban, South Africa, 4001

Tel: 031 373 2375

Email: laviehad@dut.ac.za

http://www.dut.ac.za/research/institutional_research_ethics

www.dut.ac.za

6 December 2017

IREC Reference Number: **REC 132/17**

Mr A L Revell
4 Avalon Road
Claremont
Cape Town
7700

Dear Mr Revell

The impact of foot and ankle radiographs in the diagnosis and management of patients with ankle pain

I am pleased to inform you that Full Approval has been granted to your proposal REC 132/17.

The Proposal has been allocated the following Ethical Clearance number **IREC 116/17**. Please use this number in all communication with this office.

Approval has been granted for a period of two years, before the expiry of which you are required to apply for safety monitoring and annual recertification. Please use the Safety Monitoring and Annual Recertification Report form which can be found in the Standard Operating Procedures [SOP's] of the IREC. This form must be submitted to the IREC at least 3 months before the ethics approval for the study expires.

Any adverse events [serious or minor] which occur in connection with this study and/or which may alter its ethical consideration must be reported to the IREC according to the IREC SOP's.

Please note that any deviations from the approved proposal require the approval of the IREC as outlined in the IREC SOP's.

Yours Sincerely



Professor J K Adam
Chairperson: IREC



Appendix D: The DUT CDC indemnity form highlighting permission for utilization of clinical information for research purposes

Medical Aid schemes pay in varying degrees for coverage of Chiropractic Services. This coverage is therefore medical aid dependant and we request that you check with your medical aid in this respect. The DUT Chiropractic Day Clinic is contracted out of medical aid, which means that we run on a strictly cash only basis, whereby you are requested to pay cash in advance of services rendered. You will be sent a monthly statement which you must submit to your medical aid for them to refund you directly. This statement will be sent out at the end of each month.

Charges are not applicable to research patients

Medico-Legal Reports:

As the Chiropractic Day Clinic is a teaching facility we are not in a position to generate any reports required for medico-legal purposes, claims that relate to injury on duty (IOD) or workman's compensation

Report of findings:

It is imperative that the student treating you explains fully your diagnosed condition, both as an educational requirement for the student but also, and more importantly, such that you are able to make an informed decision about the type of treatment that you wish to receive.

Treatment options:

It is imperative that the student explains all treatment options that are available for you based on the diagnosed condition(s) that was/were given to you in respect of the above.

Risks/Benefits:

The student must explain to your satisfaction/understanding all risks and benefits in relation to treatment of your reported diagnosis/condition(s).

As a Patient at this, the Chiropractic Day Clinic, I understand that I am attending an educational facility and I give my permission to allow observation, and if necessary the video recording of supervised examination and treatment by Doctors of Chiropractic and Students. In addition I, as the patient note, that information generated through my attendance of the clinic, may be used for research purposes (either through my direct participation in the research or alternatively through data collected in my patient file).

By signing this form I agree that

- I understand and take full financial responsibility for consultations.
- I understand that I cannot request records for medico legal reasons.
- I understand that should I be on medical aid, that my diagnosis and treatment information will be shared for the purposes of medical aid reimbursing me according to that which I am contractually bound in terms of my medical cover (and that only a written request or instruction from myself will be accepted in terms of discontinuing this practice by my health care provider – the Chiropractic Day Clinic).
- Should I need to be referred that my medical information (pertinent to my condition) will be shared with the doctor / specialist to whom I have been referred.
- I understand that with my attendance at the Chiropractic Day Clinic, that my medical information will be discussed between the student responsible for my care and the supervising clinician who is responsible for overall oversight of my care.

Date:	Patient Signature:
Parent/legal guardian signature: (in the case of patient's who are under the age of 12 years and those requiring assistance between the ages of 12-18 years)	
Relationship of guardian to the minor:	
Date:	Student Signature:
Date:	Clinician Signature:

By signing this section of the form I agree that (to be completed after you have been assessed and prior to your treatment / referral):

- The student has discussed with me to my satisfaction, and I fully understand, my / my minor child's diagnosed condition(s) that I have.
- The student has discussed with me to my satisfaction, and I fully understand all treatment and/or non treatment options and their relative successes and/or failures as applicable to the diagnosed condition(s).
- I am making an informed decision with regard to, and will submit to / consent to my minor child being submitted to, the treatment protocol as explained.

Based on the above I therefore give consent for the treatment of my named complaint by signing the form hereunder:

Date:	Patient Signature:
Parent/legal guardian signature: (in the case of patient's who are under the age of 12 years and those requiring assistance between the ages of 12-18 years)	
Relationship of guardian to the minor:	
Date:	Student Signature:
Date:	Clinician Signature:

Appendix E: File capture sheet

[illegible]

Appendix F: Data capture sheet

Patient Information from patient file												
Code												
Age												
Gender	Male				Female							

Patient's Initial Clinical Consultation from patient file												
Date												
Clinical Diagnosis												
Treatment	SMT	Dry Needling	Stretching	Electro-Modalities	Soft Tissue Therapy	Refer	Other (specify)					
Reason for Radiographic Referral												
Number of treatments before referral for radiographs												

Radiologist Report/ Radiograph												
Date radiograph Performed												
Researchers Diagnosis												
Radiologist Diagnosis												
Incidental Findings	Yes											
	No											

After Radiographs were performed												
Change in the Clinical Diagnosis	Yes											
	No											
Change in Treatment And was a modality added or removed	Yes	SMT		Dry Needling		Stretching		Electro-Modalities		Soft Tissue Therapy		Refer or Other modality (specify)
	No	added	Removed	added	Removed	added	Removed	added	Removed	added	Removed	

(Adapted from M^cPhail 2011)