Aspects of Femoral Trochlear Dysplasia

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A Science-Based Review

By

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FOREWORD

"When one is very young and knows a little, mountains are mountains, water is water and trees are trees. When one has studied and become learned, mountains are no longer mountains, water is no longer water, and trees are no longer trees. When one has become wise, mountains are mountains again, water is water and trees are trees".

(Old Zen Buddhist saying)

PREFACE

Back in 1991, after having graduated from the University of Copenhagen, I was introduced to orthopaedic surgery during my residency at The University Hospital of Glostrup. I soon became acquainted with patients who had patellofemoral problems of one kind or another and how the approach to treatment varied from surgeon to surgeon and physiotherapist to physiotherapist. Common to all, however, seemed to be that they knew quite well how these patients should be treated surgically. When I asked why the treatment was the way it was, they had to admit that there was little evidence in the area. The senior orthopaedic surgeons explained to me that many of these patients had large psychological superstructures on their disorders. Another common feature was that all patients were treated with the same surgical method, which was lateral release and, eventually, medial imbrication. Often, the treatment did not work, and the patients then had to be operated on with the next method, which was the Elmslie-Trillat procedure, and if that did not work, you probably could not do anything. Some were treated with total knee replacement, which sometimes made the situation worse. Another paradigm was that these patients outgrew the problems as soon as they were out of their teens. I worked in the evenings at a sports clinic, a place where patients who were members of a sports club could enter free of charge without a referral. The sports clinic only offered investigation and recommendations but could not provide any treatments except for a prescription of medicine. The common reason patients sought help was patellofemoral disorders, and I found out from the archives that many patients had been diagnosed with patellofemoral pain, and I wanted to investigate whether these patients had outgrown the condition. The patients had not received treatment but had been handed over a leaflet on how to strengthen their inner thigh muscles by self-training. We managed to have 250 patients examined five to six years later, and it turned out that 50% had recovered, which was in line with the fact that it was a condition they had outgrown. Conversely, there was a large group that was still afflicted and a smaller group where it had been more or less debilitating for them. In the years that followed, I continued to take an interest in patients with patellofemoral problems. At my first ESSKA congress in Budapest in 1996, I attended a session where David Dejour presented the trochleoplasty operation. I found it interesting and discussed the presentation with my older, experienced sports medicine colleagues, whom I looked up to a lot.

They said that it was a completely crazy operation and that they could not imagine that it would find a foothold as it was far too pervasive and irrelevant. I wondered why they could be so negative, but I somehow accepted their assessment. In the following years, I joined the board of SAKS (Danish Society for Arthroscopic Surgery and Sports Traumatology), and I participated in organising a patellofemoral meeting in 2004. Prof. Andreas Imhoff was invited to our committee, and he recommended that we also invite Phillip Schöttle to present trochleoplasty operations and medial patellofemoral ligament (MPFL) reconstructions. Phillip came and presented and was very convincing. Subsequently, I invited Phillip to Denmark in 2005, where he trained me in both performing MFPL reconstruction with inlay techniques and open trochleoplasty surgery. In the following few years, I performed open trochleoplasty operations, the first in Denmark. It was a patient who made me come up with the idea that it was an operation that might be performed arthroscopically, if possible. It was a young woman who came for a check-up after an open trochleoplasty operation, and I was expecting a very satisfied patient, but I got the shock of my life when it turned out she had been in excruciating pain in the hours after her operation. The anaesthesiologist had promised her epidural anaesthesia, but she had been given only spinal anaesthesia, and no anaesthesiologist had time to help her, and I had left the hospital. Even though she had received a good surgical result, because of the traumatic experience, she did not want to have the other knee operated on, despite the fact that the other knee was affected to the same degree as the knee which had been operated on. At the time, I was teaching arthroscopic surgery to young orthopaedic surgeons on an annual cadaver course. Due to this, I had the opportunity to test portals and solutions for trochlear cartilage thin flap release with the Bereiter technique. This was the starting point for the development of arthroscopic trochleoplasty. At the same time, I began to take an interest in and try to understand the condition of trochlear dysplasia and later worked scientifically in the area. Currently, this author is participating in a very interesting study to investigate the familial association of trochlear dysplasia (TD) in a national cohort in the Faroe Islands. We examine the prevalence, which is known to be very high, and how genetic risk factors may contribute to the high prevalence. The Faroe Islands are a small group of islands in the North Atlantic Sea with 52,000 inhabitants, with unique opportunities for genetic research due to its natural geographical isolation, demographic history and multi-generation registry going back to the 17th century. By using this genealogical registry, it will be possible to draw a digital family tree to analyse the inheritance patterns.

In parallel with the creation of this book, I have worked in the Patella Instability Committee under ESSKA and participated in several patellofemoral meetings, where I have experienced how much divergence there is in the way TD is perceived and assessed.

Today, when I look back, after having spent more than 25 years as a knee surgeon treating patients with all kinds of surgeries, especially patellofemoral surgeries, and concomitantly reading a substantial amount of scientific literature published on different patellofemoral topics, participating in numerous patellofemoral meetings and cooperating with other patellofemoral nerds globally, I found myself obliged to write this book about TD. You can read the book as it is, or you can use it as a compendium.

First of all, if you can only remember one thing from this book, please remember the most crucial thing is that the trochlear groove configuration changes from proximal to distal, with the trochlear groove being flatter in the proximal part and becoming deeper distally and this is especially pronounced when TD is present.

> “The reasonable man adapts himself to the world: the unreasonable one persists in trying to adapt the world to himself. Therefore, all progress depends on the unreasonable man.” (George Bernard Shaw 1903)

> Lorsqu’on recherche dam les auteurs anciens ou modernes l´origine des doctrines assez généralement admises aujourd’hui sur les luxations de la rotule, on est surpris de trouver entre euz un tel désaccord, et une telle disette de faits auec une telle abondance d’opinions.

> [When one searches among ancient or modern authors for the origin of the doctrines fairly generally accepted today on dislocations of the patella, one is surprised to find such disagreement among them and such a dearth of facts with such an abundance of opinions.]
>
> *(Malgaigne 1836)*

ABBREVIATIONS

AI	Artificial intelligence
AKP	Anterior knee pain
AUC	Area under the curve
CEA	Central edge angle
EP	Entry point-transition point
EQ	Emotional quotient
ICRS	International Cartilage Repair Society grading system
IPP	Inferomedial patellar protuberance
LM	Ligamentum mucosum
LTI	Lateral trochlea inclination
MFC	Medial Femoral Condyle
MPFL	Medial patellofemoral ligament
MUA	Manipulation under anaesthesia
PD	Patella dislocation
PDC	Pathologic Double Contour
PFCL	Posterior Femoral Condyle Line
PI	Patella instability
ReDPAT	Reverse Dynamic Patella Apprehension test
ROC	Radius of Curvature
SSM	Statistical shape model
TD	Trochlear dysplasia AND Trochlear Depth
TFA	Trochlea flexion angle
TG	Trochlear groove
TT	Tibial Tubercle
TTO	Tibial tubercle osteotomy

These abbreviations are used but were not defined:

ACL	Anterior Cruciate Ligament
ADT	Arthroscopic deepening trochleoplasty
BCE	Before Common Era
CE	Common Era
CM	Centimetre
ESSKA	European Society for Sports Traumatology, Knee Surgery and Arthroscopy.
IKDC	International Knee Documentation Committee

ISAKOS	International Society of Arthroscopy, Knee Surgery and Orthopaedic Sports Medicine
LPD	Lateral patella dislocation
MFPL	Medial patellofemoral ligament
MINORS	Methodological index for non-randomized studies
MOST	The Multicenter Osteoarthritis Study
MRI	Magnetic Resonance Imaging
OA	Osteoarthritis
PEEK	Polyetheretherketone
PF	Patellofemoral
PFJ	Patellofemoral joint
PFOA	Patellofemoral osteoarthritis
PFP	Patellofemoral pain
PROM	Patient-Reported Outcome Measures
ROM	Range Of Movement
SAKS	Danish Society for Arthrocopic Surgery and Sports Traumatology *(Dansk Selskab for Artroskopisk Kirurgi og Sportstraumatologi)*
STS	Supratrochlear spur
TP	Transition point
UL	Ultrasound
VAS	Visual analogue scale
VMO	Vastus medialis obliquus

CHAPTER 1

INTRODUCTION

Femoral trochlear dysplasia (TD) is relatively common in knees, and despite being known for years with a good amount of scientific literature on the topic, there is a lack of a compilation of all that information. This book is, surprisingly, the first review of the literature, and you can read it, or you can use it as a compendium to immerse yourself in special sub-topics. Despite the importance of TD, there is still a huge lack of knowledge among those who deal with knee problems. Even now, TD is repeatedly overlooked, not only by clinicians but also radiologists. There is an increasing amount of evidence that patellar dislocation is related to certain anatomic risk factors like TD, patella alta, torsional abnormalities and valgus deformity and that TD is the most significant and common cause. This pathology affects young children, adolescents and young adults. The psychological impacts for those troubled are huge and, often, those afflicted never encounter a normal way of life. Parents are concerned and possibly feel responsible for the knee difficulties of their children. Early intervention seems to be of crucial importance. Knowledge of TD is one of the keys to success in treating these patients. TD has other impacts on other knee problems, such as patellofemoral pain and isolated patellofemoral osteoarthritis.

The trochlea is an anatomical structure that is held to resemble a pulley. From the late 17th century: Latin, ‘pulley.’ Contracted from *Ancient Greek τροχῐλείᾱ* (trokhileíā, “pulley, block-and-tackle equipment”), from *τροχῐ́λος* (“sheave in block-and-tackle equipment”) + *-είᾱ* (nominal suffix)

CHAPTER 2

WHAT IS TROCHLEAR DYSPLASIA?

TD is an abnormal morphology of the knee´s trochlear groove, and there is an invisible transition between normal and what is pathologic. The facies patellaris of the femur features a groove called trochlea. The knee's trochlear groove is the guide channel into which the patella engages and glides during flexion and extension of the knee. TD is characterised by a loss of the normal concave anatomy, the depth of the trochlear groove being reduced, and the groove configuration being abnormal in some cases. The degree of dysplasia varies from a shallow to a flatter and convex trochlea. A reduced lateral trochlea slope is a result of this odd configuration.

TD is a continuum ranging from normal to severely abnormal trochlear configuration.

CHAPTER 3

THE HISTORY OF THE PATELLOFEMORAL JOINT

Skeletal findings prove that the knee joint has existed for about 320 million years. The Eryops, the ancestor of reptiles, birds and mammals, seems to be the first creature in the animal kingdom with a bicondylar knee joint. The patellofemoral joint, as an integral part of the knee joint, however, only began to develop some 65 million years ago (Tecklenburg et al. 2006, 235–240). The patella, as the largest sesamoid bone, serves as a biomechanical lever arm and, therefore, improves the effective extension capacity of the quadriceps muscle by increasing the moment arm of the patellar tendon. It also centralises the divergent forces of the quadriceps muscle and transmits the tension around the femur to the patellar tendon.

CHAPTER 4

THE EVOLUTION OF THE KNEE TROCHLEA

According to the French anthropologists Christine Tardieu and Dupont (2001, 373–383; 2010, 174–186), larger apes have a flat and symmetrical trochlea (see Figures 1 & 2). For apes, this works because they are keeping their knee flexed during locomotion, and thereby there is always a load on the patella to keep the patella stabilised into the trochlea. Since humans began walking upright, evolution has resulted in 8–10 degrees of valgus configuration. This brings the knee joints closer together and assists the upper body to be positioned above the centre of gravity for walking. The consequence is a lateral-acting q-factor on the patella that attempts to dislocate the patella laterally (see Figure 3). To compensate for that, humans have developed a deepening trochlear sulcus with a lateral trochlea slope that helps to stabilise the patella. From an evolutionary aspect, the trochlear sulcus started to develop three million years ago. During hominin evolution, the formation of the femoral obliquity angle-initiated selection for the protuberance of the lateral lip of the trochlea to prevent lateral dislocation of the patella (Christine Tardieu et al. 2006, 491–500). The femoral groove in humans, the only exclusively biped primate, is asymmetrical, with a lateral margin that is more elevated than the medial one. This asymmetrical patellar groove is a specificity of the modern human being. This feature might be caused by bipedalism (Jouve et al. 2006, 1–5; Garron et al. 2003, 407–412; Shefelbine, Tardieu, & Carter 2002, 765–770).

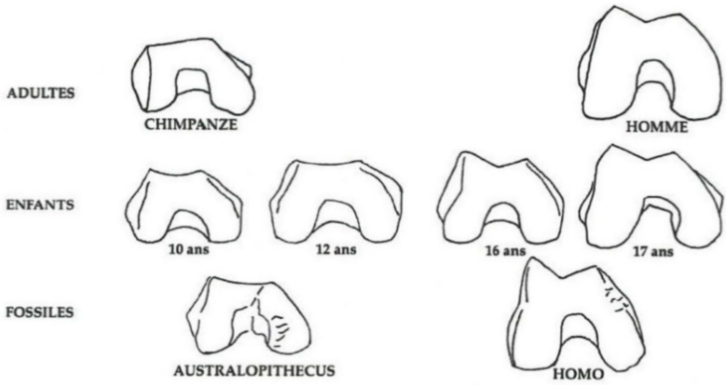

FIG. 9. – *(Echelle : 4 cm) En haut : Vues inférieures de l'épiphyse droite d'un chimpanzé et d'un homme adultes. Au milieu : Développement de l'épiphyse osseuse durant l'enfance et l'adolescence chez l'homme. De gauche à droite : épiphyses droites d'enfants de 10, 12, 16 et 17 ans. En bas : Séquence évolutive des fossiles hominidés (tous adultes), parallèle à la séquence ontogénétique des enfants : A gauche, un spécimen d'Australopithecus (3 millions d'années), à droite, un spécimen d'Homo (1,8 million d'années).*

Figure 4-1. This is from a French article from Tardieu et Dupont (2001, 373–383) and demonstrates the differences in bony configuration between chimpanzees and humans and how the bony part of the trochlear groove deepens from ten to seventeen years old. Permission to replicate Figure obtained.

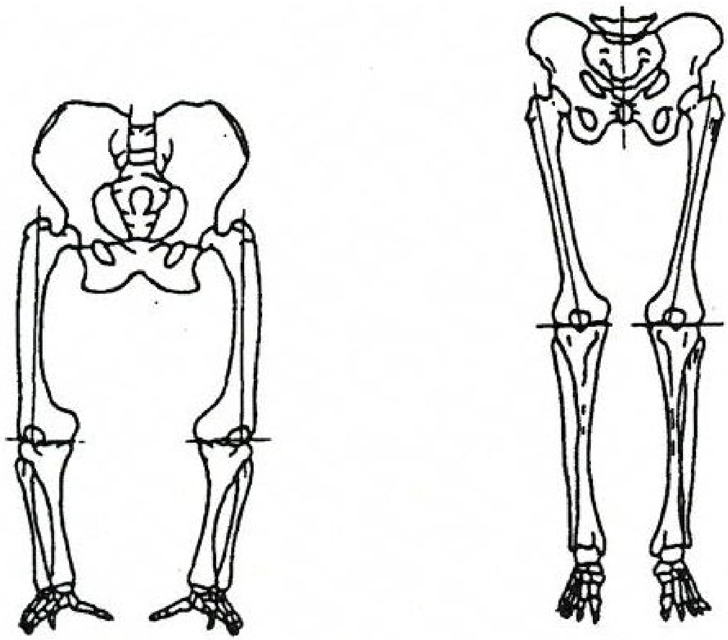

FIG. 4. – *Vue antérieure du bassin et du fémur d'un gorille (à gauche) et d'un homme (à droite).*

Figure 4-2. On the left is the skeleton of a gorilla, and on the right is the human skeleton with a valgus configuration. Tardieu et Dupont (2001, 373–383). Permission to replicate Figure obtained.

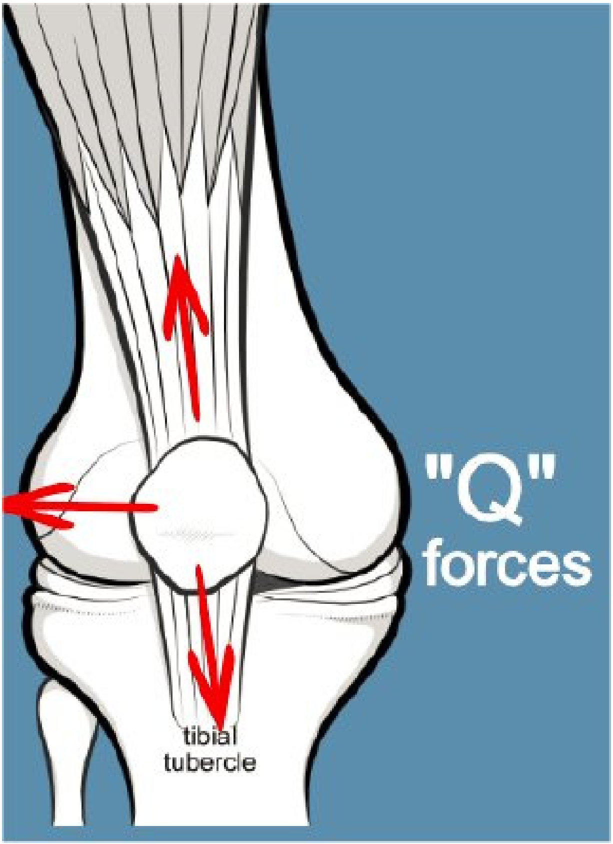

Figure 4-3. This illustrates how lateral 'q-forces' forces act on the patella due to the lateral placed tibial tubercle and the valgus configuration of the normal knee.

Humans have developed a lateral trochlear slope to compensate for the q-forces acting on the patella.

CHAPTER 5

THE HISTORY OF TROCHLEAR DYSPLASIA

Aelius Galenus or Claudius Galenus, who lived 129–200 CE, was perhaps the first to describe patella dislocation, and he also indicated a method of how to bandage a knee after such an incident. In 1802, i.e., before the start of the Rontgen epoch, Richerand described three instances of dislocation of the patella and pointed out that in all of them, the lateral condyle was lower and that affected the trochlea shape, and he saw this as the reason for the dislocations (Brattström 1964, 1–148). In the following chapter, which deals with image diagnostics, we will go further into the history of TD because image diagnostics itself is so closely related to the discovery and understanding of TD.

CHAPTER 6

THE HISTORICAL PERSPECTIVE OF IMAGE DIAGNOSTICS IN TROCHLEAR DYSPLASIA

Roentgen era X-rays

The discussion of the degree and type of femoral dysplasia (TD) was put on a more solid basis after it became possible to reproduce the patellofemoral joint on so-called radiographic axial pictures. The first to describe a method of obtaining such an axial picture was Settegast (1921, 76), but this was done with the knee in deep flexion, a position that is excellent for studies on the patella, but it did not allow an assessment of the proximal portion of the trochlea, where the TD is localised. According to Brattström´s (1964, 1–148) famous thesis, many authors at the beginning of the twentieth century were aware that dysplasia plays a big role in the origin of patella dislocation. Wiberg (1941, 319–410), in his paper about the patella shape, explains the following:

> Discussion centres mainly about two theories regarding the origin of congenital luxation of the patella. According to the first, maldevelopment of the lateral femoral condyle is the essential cause, while according to the second, it is an abnormal traction on the part of the vastus lateralis muscle. The first theory is favoured by several authors, among them Smith, Stokes, Hervier, Canton and Appel, who believe defective development of the femoral condyle to be congenital, while other workers disagree with this, arguing that malformation of a femoral condyle should be regarded not as a cause but rather as an effect of a dislocation of the patella.

Wiberg also presented an X-ray demonstrating a knee with TD. See Figure 4. In fact, the X-ray was the opposite knee of the one operated on. He regretted that they did not manage to take an X-ray of the operated knee before the surgery, where they observed no groove for the patella. Wiberg says:

> After six months, there was a recurrence, and the patient was operated upon again in May 1939. This time, a more radical measure was adopted. The lateral femoral condyle was elevated by chiselling into the bone from the

> lateral aspect and filling in the carved-out area with bone chips. The width of the patella was also reduced to enable it to fit more exactly into the new-formed groove between the condyles.

Wiberg also used the word 'dysplasia' with respect to both the kneecaps and the condyles, and he also mentioned that there was a gradual transition between the different types of configurations.

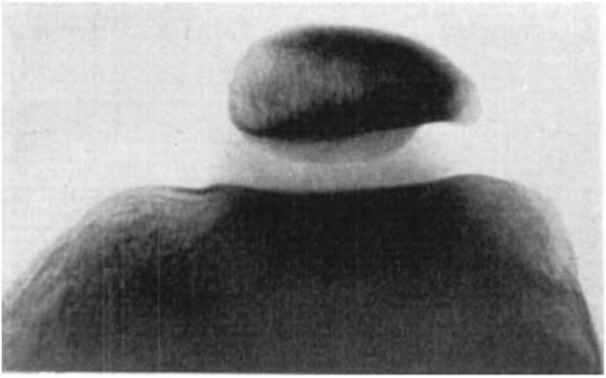

Fig. 13. **Case 9621. Axial view of the left knee.**

Figure 6-1. This is the first axial X-ray demonstrating trochlear dysplasia.

Knutsson (1941) was the first to use the concept of femoropatellar dysplasia, although the changes underlying the concept have been known and described for a long time. He also described an improved axial X-ray projection (Knutsson 1941, 371–376). Håkan Brattström (1964, 1–148) described not only the renowned sulcus angle from axial X-rays but also the 'lateral sulcus angle', the one that created the basis for the later LTI. He separated the sulcus angle into the lateral sulcus angle and the medial sulcus angle. However, by merging the two angles, he stated that the impact of knee rotation was reduced. Still, he believed that the lateral sulcus angle was the one that expressed the lateral osseous support for the patella.

In 1974, Merchant et al. (1974, 1391–1396) optimised the axial projection to 45°, and this was further optimised by Laurin et al. (1979, 16–26) in 1978, so that TD was now better revealed. In 1981, Bernageau et al. (1981, 39–42) published in French '*L`óbliquité de la joue externe de la trochlée femorale',* which described the radiological predecessor for what later became the lateral trochlear inclination angle measured on cross-sectional images by MRI scans. Salzmann et al. (2010, 335–340), many years later, compared MRI and plain axial X-rays taken when the patient supine with the knee flexed 30°. They found that measurements between X-ray and MRI were significantly different among all TD types. In Dejour type D TD, it was 135.6° on the X-ray, while it was above 180° on the MRI. The conclusion was that plain axial radiographs do not represent the natural bony trochlear morphology and may mislead further clinical management.

In the 1980s, strict lateral radiographs for the detection of a TD began to gain traction. Malghem and Maldague (1989, 507–510; 1986, 725–735; 1985, 5–13) in the late 1980s were the first to report on this. The first classifications of TD briefly mentioned here started to evolve. The first was the Masse Classification and later the Hepp classification (1982, 259–267) in 1982. In 1990, Henry Dejour (1990, 45–54) published a three-group classification on TD and introduced the so-called crossing sign. In 2006, this classification was refined by Tecklenburg et al. (2006, 235–240) to a four-group classification, and they introduced the double contour and trochlear bump. This classification has been widely used and is also known as the Dejour classification, named after the contributions of Henry Dejour and his son David Dejour. In 2012, Lippacher et al. (2012, 837–843) suggested that the classification should only contain two groups in order to become more reproducible and later papers have supported this (Blønd 2020, 317–321).

Brattström, in 1964, not only described the renowned sulcus angle from axial X-rays, but he also described the 'lateral sulcus angle', the one that created the basis for the later lateral trochlea inclination angle.

Computer Tomography Scanning—CT Scans

Martinez et al. (1983 249–253) pioneered the use of CT scans to evaluate the femoral trochlea configuration. Several studies have been published with respect to CT evaluation of the patellofemoral joint. One of the advantages is the dynamic CT scan and 3D reconstruction of the bone structure (see Figure 5). One of the cons of CT is the inability to evaluate cartilage and radiation. Nevertheless, Tavernier and Dejour in 2001 proposed that the TD is localised proximally in the trochlea and the evaluation should be on the most proximal axial CT scan where the femoral trochlea has full cartilaginous coverage (Tavernier & Dejour 2001, 387–405).

Figure 6-2. This is an example of a 3-D evaluation of two femora. The left femoral has increased femoral anteversion.

Ultrasound Scans—UL Scans

Ultrasound of the knee allows high-resolution imaging of superficial knee anatomy while simultaneously allowing dynamic evaluation of some of the tendons and ligaments. Nietosvaara and Aalto (Aalto 1993, 62–64) were perhaps the first in 1993 to evaluate the trochlear groove by UL, and they evaluated both the osseous and cartilaginous trochlea sulcus angle. Since then, several studies have been published. Ultrasound is especially useful in newborns and small children. Schlüter et al. (2022, 1–8) found that measurements of the sulcus angle had moderate to excellent reliability. However, Toms et al. (2009, 329–338) compared UL sound to MRI and CT and found that the reliability was inferior, especially with respect to cartilage measures. This author found UL sound to be a good screening tool. However, due to the variability of the sulcus angle from proximal to distal, precise measures are difficult.

Magnetic resonance imaging scans—MRI scans

Today, MRI scans of the knee are imperative to evaluate the patellofemoral joint before considering most patellofemoral surgeries, perhaps except for patellofemoral arthroplasty replacements. The MRI scan provides information about the trochlear groove configuration, the patella configuration and the relationship between them. MRIs also provide information about cartilage and soft tissue related to the patellofemoral joint. MRI is an effective method for the assessment of the patellofemoral joint, but classical parameters describing its anatomy need, in many respects, to be revised, both in terms of normal values and pathological cut-offs. New studies are published and, luckily, the interobserver agreement is being settled. The most common problem is the number of studies publishing results based on faulty measurements more distal in the trochlear groove, in the part of the trochlea where the dysplasia fades out. It is crucial to measure proximally in the trochlear groove, and it should be mandatory to measure that part of the knee before publishing data.

Shellock et al. (1988, 551–553) in 1988 were perhaps the first to evaluate the patellofemoral joint by MRI scan and evaluated the joint in different degrees of flexion. MRI axial views are excellent for evaluating the trochlear groove configuration. Figure 6 illustrates the difference between an axial X-ray obtained with the knee at 30 degrees of flexion and an MRI scan with an axial view of the most proximal part of the same knee.

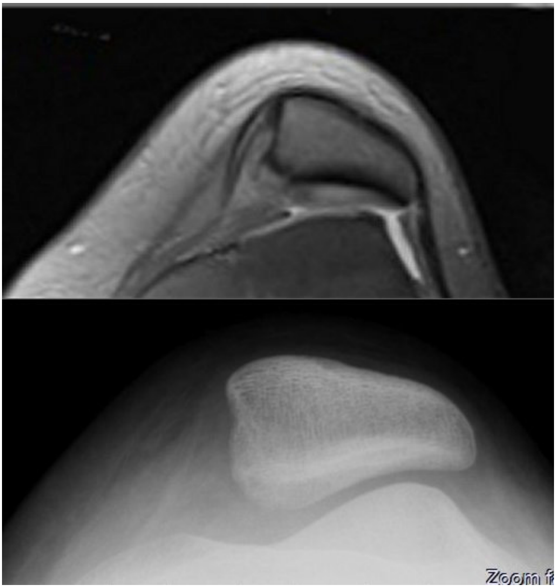

Figure 6-3. These are two pictures of the same knee. Above is an MRI scan with an axial view of the most proximal part of the trochlear groove, and it demonstrates a dysplastic trochlear configuration with a flat trochlea. Below is a standard axial X-ray, a so-called skyline view, Laurin view or Merchant view. Notice that due to the

slight flexion needed to obtain the X-ray, the trochlea configuration represents a more distal part of the trochlear groove.

In 2000, Carrillon and Dejour (2000, 582–585) came out with their highly cited paper about the LTI, the measurement that characterises the osseous stability provided by the trochlea slope. Recently, Joseph et al. (2020, 1–9) refined the LTI and pointed out that this is a two-image measurement. The LTI will be explained in a separate section.

Also, in 2000, Pfirrmann et al. (2000, 858–864) published their important MRI study on TD, and they also included a control group with 23 individuals without TD and any symptoms from the patellofemoral joint. They measured on axial MRI 3 cm above the joint line, and this study seems to be the first study that more systematically included several of the measurements that today characterise TD, like trochlear depth, trochlear facet asymmetry and ventral prominence. The metric ventral prominence is analogous to Henri Dejour's "trochlear bump," except that the bump is a measure on bone, and the prominence is a cartilaginous measure.

Biedert and Bachmann (2009, 1225–1230), in order to separate between TD characterised by elevated trochlear floor or hypoplasia of the medial or lateral condyle, introduced the anterior-posterior measurements to describe the height of the medial and lateral trochlear facets as well as the central groove. Biedert and colleagues (2011, 1327–1331) in 2011 introduced the lateral condyle index for assessing the length of the lateral articular trochlea. Salzmann et al. (2010, 335–340) found in a comparative MRI study and axial X-ray study that the sulcus angle varies significantly on the two types of measures. Pennock et al. in 2020 introduced 3D to objectify different trochlea measurements.

MRI scans are the key radiologic method to evaluate the patellofemoral joint in a non-invasive way.

Fusion MRI and UL

Fusion MRI and ultrasound have never really gained traction when it comes to assessing knees, and they are mostly used in relation to ultrasound-guided biopsies. Figure 6-4 is an example of a knee MRI and ultrasound fusion.

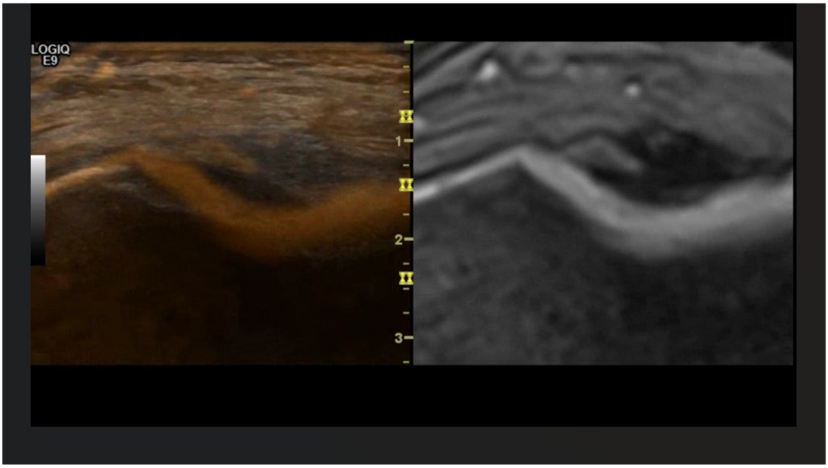

Figure 6-4: This is an example of a fusion of ultrasound (left) and an MRI axial view (right) in a trochlear groove following arthroscopic trochleoplasty.

Arthroscopic Evaluation

Nelitz et al. (2013, 2788–2794) did arthroscopic views from the lateral superior arthroscopic portal. On arthroscopy, signs of TD were identified and classified into two types. They included 46 patients treated surgically for patella instability, and all had preoperatively been evaluated by MRI and a strict lateral radiograph. They showed excellent intra- and interobserver agreements (81–92 %) with their two-type classification. However, the arthroscopic evaluation was not consistent with Dejour's classification. The arthroscopic classification is described in more detail in the 'Definition and Classification' chapter.

CHAPTER 7

HEREDITY, ORIGIN AND AETIOLOGY

It is unknown whether TD is causal or secondary to developmental forces. The two main theories about the aetiology of TD are that it may be hereditary due to genetic factors or a result of stress stimulation of the patella, either during foetal life because of knee position in utero or eventually reduced patella/trochlea stress forces during growth. However, both theories seem possible, and both causes can coexist. From early anatomic studies from the 18th and 19th centuries, it is well known that patellofemoral articulation develops early on in gestation, between nine and 16 weeks (Glard et al. 2005, 305–308). The point at which TD develops is unknown. However, the breech position has importance and will be explored further below. The breech position is, to some degree, inherited (Nordtveit et al. 2008, 872–876). The theory for the development of TD is that due to the extended position of the knee in the frank breech position, where both knees are extended, the patella has not engaged the trochlear groove since this normally first occurs at 15-30 degrees of flexion. As such, the patella lies proximal to the trochlea during foetal development. It is conceivable that without the consistent engagement of the patella in the trochlea, a shallower trochlear morphology may develop, like the pathological process noted in developmental dysplasia of the hip, where a subluxated or dislocated femoral head precipitates the development of a shallow and abnormal acetabulum. An incomplete frank breech presentation, where only one is extended, might explain why unilateral TD can develop. See Figure 7-1

TD seems to be developed due to genetic factors and/or due to leg position during foetal life; however, the breech position is a hereditary condition. The incomplete breech position might explain why TD is occasionally unilateral.