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Research article

Tibial derotation osteotomies are effective in improving pain and function and avoiding hip arthroscopy in patients with hip pain—a short-term follow-up

Vitali Goriainov[1,2*], Mohamed Farook[1], Ivor Vanhegan[1,3], Tom Pollard[1] and Antonio Andrade[1]

[1]Department of Trauma and Orthopaedics, Royal Berkshire Hospital, Reading RG1 5AN, UK, [2]Department of Trauma and Orthopaedics, Queen Alexandra Hospital, Portsmouth PO6 3LY, UK and [3]Department of Trauma and Orthopaedics, Salisbury District Hospital, Salisbury SP2 8BJ, UK.

*Correspondence to: V. Goriainov. E-mail: vitaligoriainov@hotmail.com

ABSTRACT

The primary objective was to determine short-term clinical outcomes following distal tibial derotation osteotomy (DTDO) performed to manage hip pain in the presence of tibial maltorsion and to review how co-existing pathomorphology affected the management. All patients undergoing DTDO for hip pain with tibial rotational deformities recognized as the predominant aetiology were included. Normal tibial torsion range was assumed as 0–40°, measured by trans-malleolar line relative to femoral posterior condyles. All patients had a positive hip impingement test Flexion Adduction Internal Rotation test (FADIR). The patients older than 50 years or presenting with degenerative joint changes and neuromuscular conditions were excluded. Associated ipsilateral MRI-defined intra-articular pathomorphology (cam/pincer), non-cam/pincer-related labral tears and abnormal combined femoral/acetabular version (McKibbin index) were noted. Pre-operative and post-operative functional outcomes were analysed. Thirty-two patients underwent DTDO. Mean tibial torsion was 48.8° (41–63°), average age was 27 years (18–44), and average follow-up was 30 months (16–45). Nine patients (28%) had a co-existing cam/pincer, and eight patients (25%) had an excessive McKibbin index (51–76°). Overall, 63% of all patients (including 54% of patients with co-existing pathology) experienced significant hip functional improvement following DTDO alone. Pre-operative vs 12 months post-operative scores were calculated as follows: International Hip Outcome Tool-12—41 vs 67 ($P < 0.01$); Hip Outcome Score Activities of Daily Living Scale—47 vs 70 ($P < 0.05$); and Hip Outcome Score Sport Scale—36 vs 64 ($P < 0.05$). Patients with hip pain frequently present with a combination of tibial and/or femoral rotational deformity and cam/pincer lesions. It is important to consider tibial maltorsion as an aetiology of hip pain. Tibial derotation with DTDO results in significant clinical and functional recovery within 12 months in symptomatic hip impingement patients even in the presence of co-existing pathomorphology.

INTRODUCTION

Accurately identifying the actual source of a painful hip can be complicated by a multitude of, and often combinations of, potential contributors, including an intra- and extra-articular hip, pelvic, abdominal and lower back pathology. The rotational profile of the tibia significantly contributes to the kinematics of the hip joint and, therefore, its symptomatology. The clinical presentation is further complicated by an interplay of the component alignment combinations (acetabulum, femur and tibia) contributing towards the joint movement kinematics, soft tissue balance and gait effectiveness as well as aesthetics [1, 2].

The more prevalent tibial malrotation—external tibial torsion—is likely to be considered as a principal aetiology in the patients presenting clinically with an out-toeing gait, clumsiness and inferior physical performance. However, the lower limb rotational profile in patients presenting with the hip symptoms is frequently not routinely assessed. Furthermore, even when the rotational profile assessment is undertaken in these patients, the correctly identified tibial rotational abnormalities may often be thought unrelated to the causation of hip pain. We propose that, while in the position of rest and during slow walking, the habitual out-toeing may be well tolerated, and as the cadence accelerates, the foot progression assumes an increasingly neutral forward-pointing angle (Fig. 1). This progressive change takes place as a result of an incremental hip internal rotation. In the scenarios of a normal femoral version or, even more dramatically, in the presence of a femoral retroversion, a point is reached when this adaptive change of the hip posture to optimize foot progression may lead to a functional retroversion and impingement of the femoral head/neck junction on the anterior acetabular rim, with the ensuing injury to the chondrolabral complex. Failure to recognize and appropriately address the associated rotational

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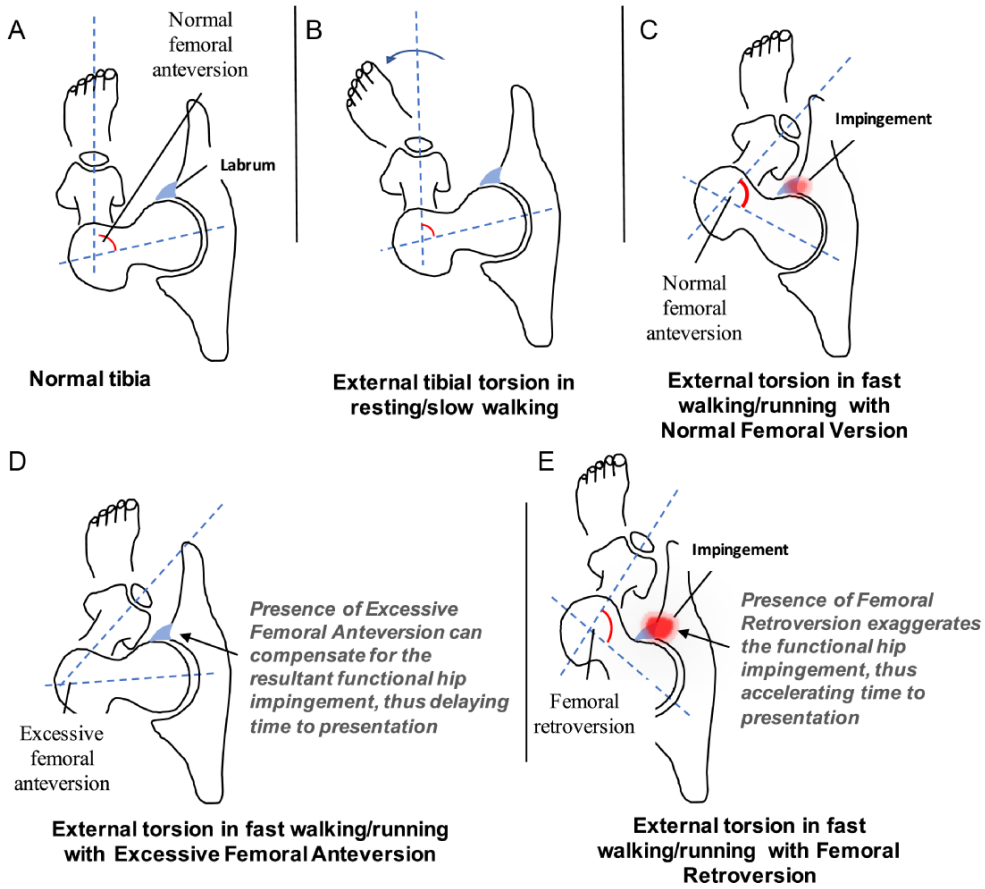

Fig. 1. Schematic depicting the sky view of the hip joint orientation in relation to the knee joint and foot position. (**A**) Normal femoral anteversion of 10–25° with normal lower limb alignment resulting in neutral foot position. (**B**) External tibial torsion with out-toeing foot progression. (**C**) Theoretical adaptation of the hip joint with ensuing functional retroversion in order to accommodate forward-pointing foot position. Note the resultant anterior FAI. (**D**) Excessive femoral anteversion can potentially offset the anterior FAI resulting from external tibial torsion-induced functional retroversion. (**E**) In contrast, femoral retroversion exacerbates the functional retroversion secondary to external tibial torsion.

deformities in the patients presenting with hip pain results in the ongoing impingement and joint damage. In turn, this leads to the persistent symptoms, suboptimal operative results from other hip preservation surgical interventions and ongoing requirement for further surgery [3].

The aetiology of rotational tibial deformities is commonly idiopathic, although it can be metabolic or neurological in origin [4]. Though the natural course of a tibial rotation development and the resultant anatomical range were described, there is no established consensus on the pathological threshold level.

A supramalleolar or distal tibial derotation osteotomy (DTDO) is advocated for the treatment of symptomatic patients that failed non-operative management and whose deformities involve a uniplanar tibial maltorsion [5]. Although the tibial torsional abnormalities have previously been implicated in the knee pain and patellofemoral instability, and DTDO is a recognized treatment modality [6, 7], we failed to identify any previous reports of the use of distal tibial derotation for the management of hip symptoms.

The aim was to determine the clinical outcomes as measured by the hip-specific patient-reported outcome measures (PROM) following DTDO used for the treatment of hip pain in the presence of the tibial maltorsion and to review the management of co-existing pathomorphology. The union rate, complication profile and time-specific profile of the functional recovery following DTDO were evaluated. A sub-analysis of co-existing hip joint and alignment abnormalities and their impact on post-operative outcomes was performed.

Null hypothesis

Tibial maltorsion correction with a derotation osteotomy will not lead to significant functional improvements in the patients presenting with hip pain.

MATERIALS AND METHODS

Ethics and consent

This study was a service evaluation and was exempt from an ethical approval requirement in our institution. Each patient underwent an informed pre-operative consent process in accordance with the local ethical guidelines and clinical standards.

Patient involvement

Throughout the consent process, detailed discussions on the clinical plans and anticipated outcomes were held with the

patients to ensure that an informed patient–clinician partnership was established to facilitate clinical progress. An active patient involvement ensured a high rate of follow-up compliance (94%) to assess the burden of the intervention.

Demographics

A retrospective review of the prospectively collected data in a patient cohort that underwent DTDO between 2018 and 2020 in a joint preservation setting was undertaken. The inclusion criteria comprised every patient presenting with hip pain on exercising, with the tibial rotational deformities recognized as the predominant aetiology. All patients demonstrated a positive hip impingement test (FADIR). All of these patients had failed the non-operative management including analgesia, physiotherapy, hip joint injections and/or previous surgical interventions. The patients older than 50 years or presenting with the degenerative joint changes and neuromuscular conditions were automatically excluded. The patients older than 50 years were considered more likely to progress to non-union, have a higher likelihood of potential subclinical hip arthritic changes and possess less plasticity to adjust to altered limb rotational profile.

Co-existing pathology and rotational profile assessment

All patients were routinely clinically evaluated by the senior authors (A.A. or T.P.). The examination included a gait observation (foot progression angle), rotational profile of the hip (internal/external rotation with hip in extension and at 90° of flexion), hip impingement/labral irritability (FADIR test), femoral (trochanteric prominence angle) and tibial (thigh/foot angle with the patient prone and in sitting position) rotational profile and leg length assessment. All patients with the clinically suspected abnormalities and the hip pain/positive hip impingement findings underwent a lower limb computed tomography rotational profile assessment (CT-RPA) and hip MRI. Prevalence of a radiographically evident femoroacetabular impingement (FAI) due to cam/pincer lesions, labral tears and combined hip version was recorded. The indications for DTDO were the symptomatic patients with a clinically and radiologically characterized tibial maltorsion.

A combined hip version was measured using the McKibbin index (MI)—a sum of femoral and acetabular version. A normal MI was defined as 20–50° (proximal femoral anteversion—10–25° and central acetabular version—10–25°) [1, 8].

CT-RPA included the three blocks with an equal field of view: the first block—the pelvis and hip joints, the second—the knee joints and the third—the ankles, with the patients' limbs strapped together during the scan. The cuts were axial (2.5 mm cut thickness, 2.5 mm intervals).

The rotational profile was assessed by the senior musculoskeletal radiologists according to the previously described methods (Fig. 2) [1, 9–11].

The surgical management prior to the index DTDO and additional surgical interventions [including hip arthroscopy and proximal femoral derotation osteotomy (PFDO)] were reviewed.

Functional assessment

The pre-operative and interval post-operative (3-, 6-, 12- and 18-month) functional assessments were performed in the clinic using the patient-reported joint-specific outcomes in all patients undergoing DTDO. The functional outcomes included International Hip Outcome Tool (iHOT12—percentage of 0–68 points), Hip Outcome Score Activities of Daily Living Scale (HOS ADLS—percentage of 0–68 points) and Hip Outcome Score Sport Scale (HOS SS—percentage of 0–36 points). The HOS scores included additional graphical scores (percentage on a scale).

The patients were assessed on the intention-to-treat basis, with DTDO intended to be the definitive surgical intervention. However, all patients continued to participate in PROM data collection, even if the additional operative interventions had been undertaken or planned. Therefore, the PROM data analysis included all patients enrolled into the study cohort. A further PROM data analysis was performed on the patients requiring only DTDO as the definitive intervention.

Operative technique and post-operative management

A hip examination under anaesthetic and clinical limb rotational assessment was performed in all cases. A DTDO was performed with the patient in the supine position on a standard operating table. A fibular osteotomy was performed in a proximal-anterior to distal-posterior oblique direction through a small lateral incision above the level of the syndesmosis. A longitudinal skin incision was then made medially over the distal metaphyseal region of the tibia. The osteotomy was performed 3–4 cm proximal to the tibial plafond and perpendicular to the longitudinal tibial axis to ensure a uniplanar correction. Reference 2 mm K-wires were inserted in parallel proximal and distal to the proposed osteotomy site to aid the assessment of a subsequent rotational correction. The osteotomy was performed by predrilling the osteotomy site, performing the osteotomy with an oscillating saw under fluoroscopic control and completing the osteotomy with an osteotome. Desired rotational correction was achieved at a 90/90 position of knee and ankle and the degree of correction estimated by the reference K-wire alignment. Subsequently, the osteotomy was stabilized with a low-profile six-hole 2.7 mm Evos mini-plate (Smith & Nephew, Watford, UK) [12]. The fibula osteotomy was not routinely stabilized.

The patients were immobilized in a plaster backslab and remained non-weight-bearing for 2 weeks and then placed into a walking boot to partially weight-bear for a further 4 weeks. Following a radiographic assessment at 6 weeks post-operatively, the patients were allowed to fully weight-bear and gradually wean out of the boot. A radiographic assessment of osteotomy union was performed using the Radiographic Union Score in Tibia (RUST score) [13]. Throughout, the patients were undergoing a hip- and ankle-specific physiotherapy including the range-of-movement restoration, muscle strengthening/conditioning and stamina-building followed by the exercises to return to the specific sports.

Data analysis

The data were analysed using the Statistical Package for the Social Sciences version 25. The data were summarized using mean and

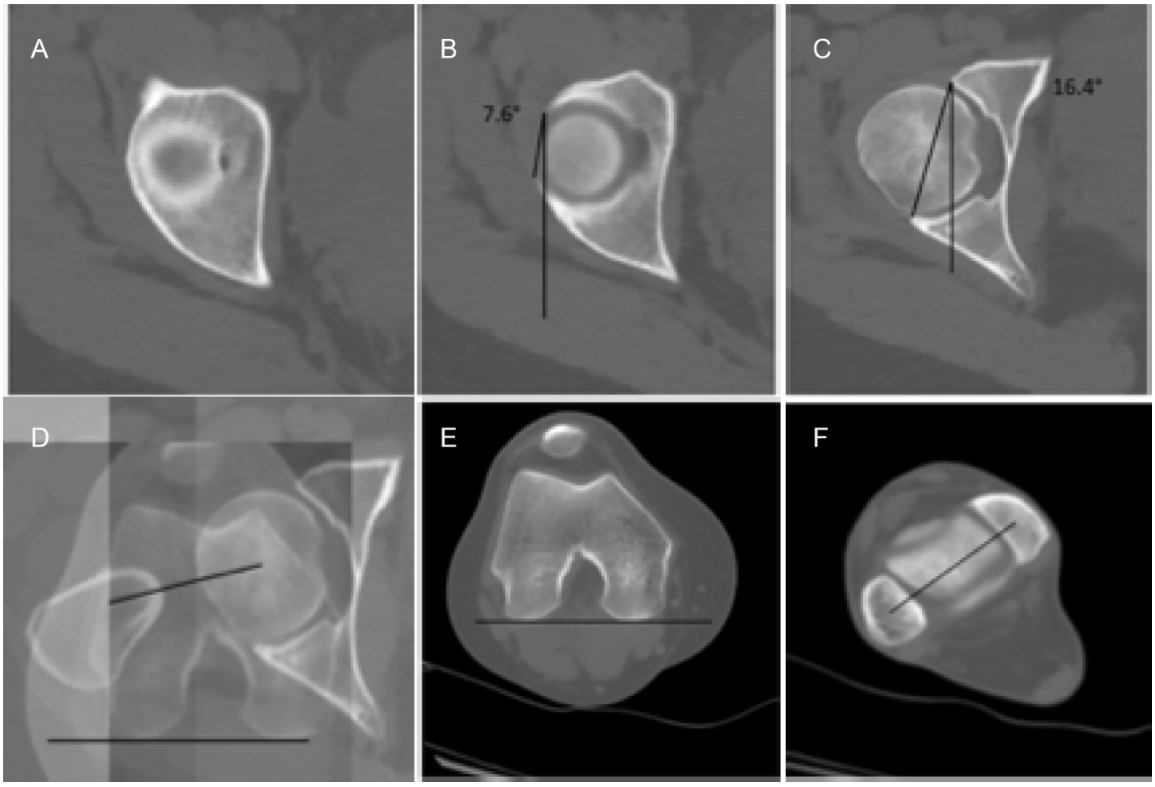

Fig. 2. (**A**) First, the dome of the acetabulum was identified. (**B**) At 5 mm distal to the dome, the cranial acetabular version was measured [9]. (**C**) The centre of the femoral head was identified, and the central acetabular version was measured as the angle between the anterior and posterior rims of the acetabulum and a sagittal line at the level of the centre of the femoral head [1]. (**D**) Measurement of femoral anteversion as the angle between a line drawn from the centre of the femoral head and the centre of the femoral neck base, with the posterior condylar axis at its maximum prominence [10]. (**E**) First reference line at the most prominent part of the posterior femoral condyle. (**F**) Second reference line between the centre of the medial and lateral malleoli, just distal to tibial plafond. Tibial torsion was measured as the angle between the two reference lines [11]. Tibial torsion outside 0–40° range was assumed as maltorsion.

95% CI of mean. The comparisons between quantitative variables were performed using the non-parametric Mann–Whitney tests ($P < 0.05$ were considered statistically significant) to mitigate the effects of a relatively small patient cohort.

RESULTS

Demographics

Thirty-two patients undergoing DTDO for hip pain were included (28 females). The average age was 27 years (18–44). The average follow-up was 36 months (24–45). All patients completed the follow-up.

Of the 32 patients, the patients either completed the follow-up with significant symptomatic improvement or required additional operative interventions to address the persistent symptoms. All patients achieved a union at an average of 3 months (2–6), and to date, the post-operative complications included four unplanned plate removals.

Management of co-existing pathology and rotational profile abnormalities (Fig. 3)

Within the patient cohort, the tibial malrotations exclusively comprised an excessive external torsion (mean—49° and range—41–63). Nine patients (28%) had a co-existing cam/pincer at the time of DTDO, and eight patients (25%) had an excessive MI (51–76°). No hip retroversion (MI < 20°) was observed in this cohort.

Five out of nine patients with known cam/pincer lesions at the time of DTDO required an additional hip arthroscopy within 1 year post-DTDO and subsequently consistently improved, all with a normal MI. The remaining four patients (all with normal MI) experienced a significant symptom improvement post-DTDO alone.

Four further patients had hip arthroscopy for cam/pincer lesions prior to DTDO: one completely symptomatically improved post-DTDO; one remained symptomatic and required PFDO for an excessive MI = 55°; and two required further hip arthroscopy due to the persistent symptoms corresponding with an intra-articular pathology.

Of the 19 remaining patients, 5 had isolated labral tears. Out of these five patients, all patients experienced a significant symptomatic improvement post-DTDO alone. Further eight patients had excessive MI. Of these eight patients, four experienced a significant symptomatic improvement, and four required PFDO. Further six patients experienced a significant symptomatic improvement.

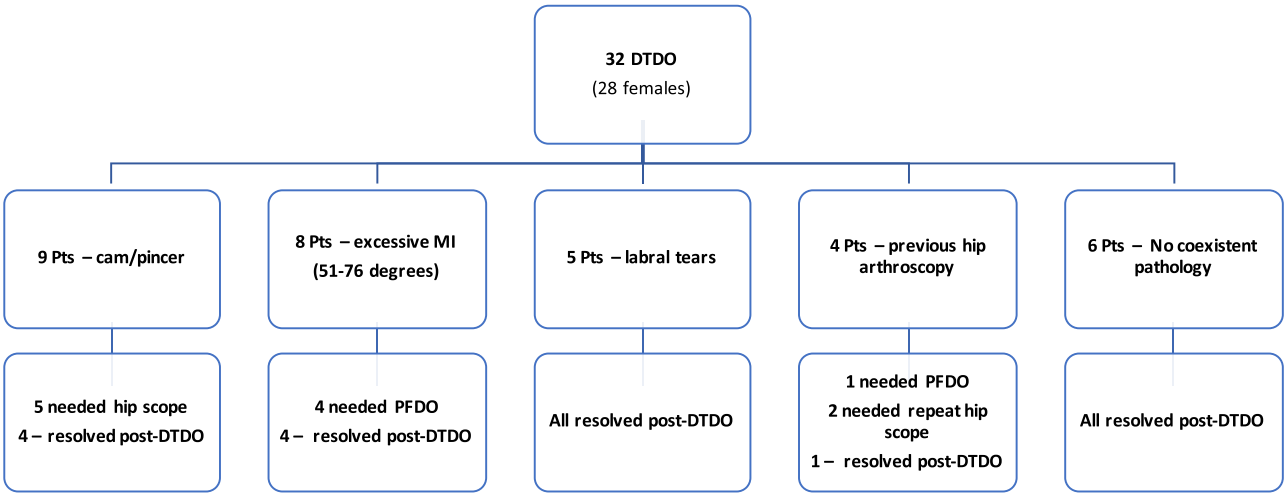

Fig. 3. Flowchart summarizing the management of lower limb pathology co-existent with external tibial torsion.

Table I. ***The functional scores post-DTDO with symptomatic co-existent pathology included***

Time-point / *Functional score*	*Pre-operative*	*6 months*	*12 months*	*18 months*
iHOT12	41 (27–49)	48 (31–84)	68 (51–96)*	83 (56–97)*
HOS ADLS	47 (28–64)	57 (35–81)	70 (55–91)*	82 (59–96)*
HOS ADLS graphical	41 (33–61)	55 (39–80)	68 (53–91)*	77 (55–95)*
HOS SS	36 (26–53)	37 (25–50)	64 (39–83)*	75 (45–92)*
HOS SS graphical	37 (27–55)	35 (27–57)	62 (37–82)*	76 (49–91)*

The data were presented as a mean and 95% CI of mean. Post-operative outcomes with statistical significance when compared to corresponding pre-operative values were marked with * ($P < 0.05$). iHOT12, HOS ADLS (and graphical) and HOS SS (and graphical) presented as percentages with 68/68, 68/68 and 36/36 being 100%, respectively.

Overall, 20 of the 32 patients (63%) experienced a significant improvement in the hip pain and did not require further surgical interventions post-DTDO alone. Fourteen of 26 patients (54%) with known co-existing cam/pincer lesions, excessive MI and/or labral tears significantly improved and did not require further surgical interventions post-DTDO alone. The persistent hip symptoms post-DTDO necessitated hip arthroscopy in seven patients and PFDO in five patients. All patients with the labral tears as an isolated co-existing pathology resolved post-DTDO alone.

Functional assessment

Within the entire patient cohort, including patients requiring and having undergone additional operative interventions, a statistically significant difference of all functional outcomes was achieved at 12 months post-DTDO when compared to the pre-operative scores (Table I, Fig. 4):

(i) iHOT12—68 (51–96) vs 41 (27–49) ($P < 0.01$);
(ii) HOS ADLS—70 (55–91) vs 47 (28–64) ($P < 0.05$);
(iii) HOS ADLS graphical—68 (53–91) vs 41 (33–61) ($P < 0.05$);
(iv) HOS SS—64 (39–83) vs 36 (26–53) ($P < 0.05$);
(v) HOS SS graphical—62 (37–82) vs 37 (27–55) ($P < 0.05$).

Predictably, when the patients that underwent additional procedures were excluded (seven patients required additional hip arthroscopy, and five patients required additional PFDO), the functional improvement in the remaining patients that only required DTDO was more statistically significant (Table II, Fig. 5):

(i) iHOT12—81 (66–96) vs 38 (30–46) ($P < 0.001$);
(ii) HOS ADLS—76 (61–90) vs 54 (28–61) ($P < 0.001$);
(iii) HOS ADLS graphical—79 (68–89) vs 46 (34–56) ($P < 0.01$);
(iv) HOS SS—79 (61–83) vs 40 (26–53) ($P < 0.01$);
(v) HOS SS graphical—77 (60–82) vs 44 (27–55) ($P < 0.01$).

DISCUSSION

The most important finding of this study was the demonstration of DTDO effectiveness in achieving a functional improvement in the patients presenting with hip symptoms. Thus, the original null hypothesis was incorrect. The prevalence of a co-existing pathology in this patient cohort was relatively high (21/32 patients had cam/pincer lesions and/or excessive MI, 5/32 patients—isolated labral tears). However, all patients without co-existing pathology (6/32) and with isolated labral tears experienced a significant symptomatic improvement following DTDO alone as did 14/26 (54%) patients with the co-existing cam/pincer lesions and/or excessive MI. Twelve patients (45%)

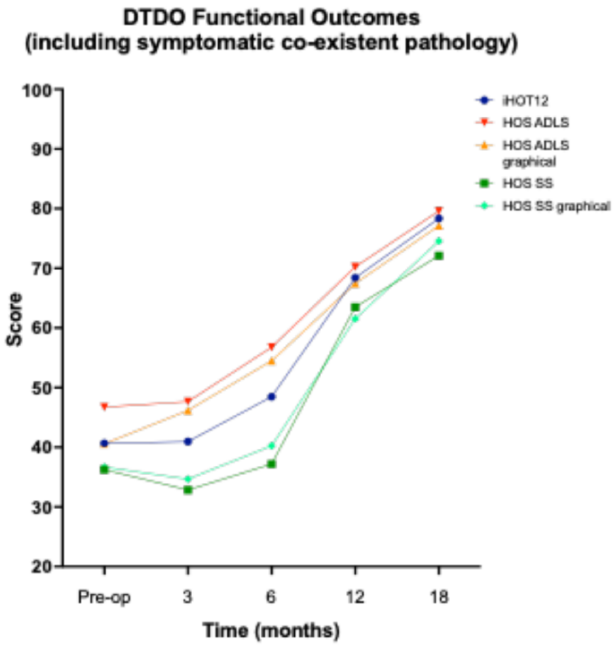

Fig. 4. Functional outcomes post-DTDO with co-existent symptomatic pathology included at time-points pre-operative, 3, 6, 12 and 18 months. Higher functional scores represented better pain/function. The scores were calculated as follows: iHOT12—percentage of 0–68 points; KOS ADLS—percentage of 0–70 points; KOS ADLS graphical—percentage on a scale; KOS SS—percentage of 0–55 points; KOS SS graphical—percentage on a scale; AKP—0–100 points. The data were presented as means.

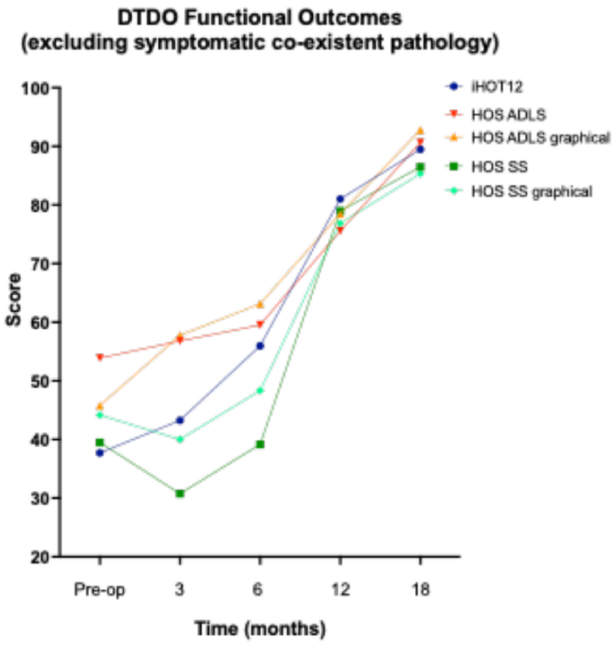

Fig. 5. Functional outcomes post-DTDO with co-existent symptomatic pathology excluded at time-points pre-operative, 3, 6, 12 and 18 months. Higher functional scores represented better pain/function. The scores were calculated as follows: iHOT12—percentage of 0–68 points; KOS ADLS—percentage of 0–70 points; KOS ADLS graphical—percentage on a scale; KOS SS—percentage of 0–55 points; KOS SS graphical—percentage on a scale; AKP—0–100 points. The data were presented as means.

required a hip arthroscopy or PFDO for the persistent hip symptoms post-DTDO. DTDO was associated with a minimal requirement for the metalwork removal (13%).

In our joint preservation clinic, a relatively high prevalence of an excessive tibial torsion instigated interest in its contribution to the hip pain and function and the clinical value of its correction—the aspects that had not received an adequate recognition in the appropriate literature. A recognition of the complexity and significant prevalence of co-existing pathology in this patient cohort required a bespoke approach in individual cases. Our treatment protocol is outlined in Supplement 1 but is flexible, determined by a combination of the presenting pathology, required functional level to fulfil professional or other commitments, timeframe of treatment in relation to patient's schedule and our clinical preferences.

All patients demonstrated a positive hip impingement clinically. Although initially the mechanical impingement with a tibial maltorsion is likely to occur while exercising (see Fig. 1), it will consequently result in the labral irritability/labral tears and, in turn, groin pain. Clinically, the anterior impingement tests (i.e. FADIR) are likely to yield an exacerbation of pain, as it did in our cohort.

The femoral and tibial version/torsion change during the skeletal development. A femoral anteversion at birth and 8 years of age are on average 40° and 15°, respectively [14]. A tibial torsion normally changes from a minimal internal torsion at birth to 15–20° of an external torsion [4, 15]. However, a wide range of mean values was reported by the previous studies, partly due to the disparate measurement methods and reference points used [16].

Table II. ***The functional scores post-DTDO alone with symptomatic co-existent pathology excluded***

Time-point / *Functional score*	*Pre-operative*	*6 months*	*12 months*	*18 months*
iHOT12	38 (30–46)	56 (39–73)*	81 (66–96)*	89 (82–97)*
HOS ADLS	54 (28–61)	60 (39–80)	76 (61–90)*	90 (80–96)*
HOS ADLS graphical	46 (34–56)	64 (53–73)	79 (68–89)*	93 (80–95)*
HOS SS	40 (26–53)	39 (28–50)	79 (61–83)*	87 (78–92)*
HOS SS graphical	44 (27–55)	48 (30–57)	77 (60–82)*	85 (77–91)*

The data were presented as a mean and 95% CI of mean. Post-operative outcomes with statistical significance when compared to corresponding pre-operative values were marked with * ($P < 0.05$). iHOT12, HOS ADLS (and graphical) and HOS SS (and graphical) presented as percentages with 68/68, 68/68 and 36/36 being 100%, respectively.

In this study, the accepted normal range of tibial torsion was 0–40° [17] as the majority of reported 'normal' values fall within this range. More recent CT-based studies reported the mean values of a tibial torsion of 19–50.8° [18] and 25.5–27.7° [19], with the disparity being due to the different measurement methods and population cohorts. The reported normal range of MI was 20–50° [1, 8]. Of the eight patients with the co-existing excessive tibial malrotation and excessive MI, to date, four patients required a correction of excessive MI (proximal femoral derotation or periacetabular osteotomy) following DTDO. We feel that it is advisable for the clinicians to personally review the investigations and not exclusively rely on the values reported by the radiologists. Perhaps more importantly, the treatment decisions in the symptomatic patients should be based on a correlation of the radiological investigation and clinical findings, including a hip range of movement.

The combined abnormal tibial torsion and cam/pincer lesions were identified in 41% and the combined abnormal tibial torsion and abnormal MI in 25% of patients in our cohort. Previously, Lerch *et al.* examined the prevalence of the femoral and tibial rotational abnormalities in relation to one another and other parameters, including acetabular version and coverage and the presence of cam lesions [2]. They postulated that high prevalence of excessive tibial torsion was associated with cam lesions (34%), acetabular retroversion (25%) and femoral maltorsion (10%).

Our findings suggested that the hip function recovery was effective post-tibial maltorsion correction; however, a relatively long post-operative rehabilitation was required (hip-specific scores achieved a statistically significant level of improvement between 6 and 12 months post-DTDO). The improvement continued and was sustained throughout the remaining follow-up. Due to a scarcity of data on the management of patients with the hip pain and tibial maltorsion, we were unable to compare our outcomes to those previously reported.

Our clinical observation indicated that setting patient expectations at the right level, particularly regarding the initial level of pain and disability, the length of recovery and the potential need for further operative interventions, significantly improved the patient engagement with the treatment process and enhanced their post-operative experience.

This study contributed towards the informed approach of managing patients presenting with the hip pain and lower limb rotational malalignment, enabled awareness of the potential presenting complexity and recognized the tibial maltorsion contribution to the hip function.

Limitations

The limitations of the study included a retrospective nature and a relatively short follow-up period. However, with the statistically significant functional recovery identified as ∼12 months, it was felt that the follow-up presented was appropriate (mean—30 months). The accepted 'normal' ranges of the version/torsion could be disputed, as there is a wide disparity in the reported data. However, we aimed to utilize the most inclusive ranges. The cohort was of a relatively small size, and no power analysis was performed. The sample reflected the number of patients eligible for DTDO and treated at our tertiary joint preservation unit. The clinical management was pragmatic, with further interventions undertaken as required clinically. This introduced potentially significant confounding factors into the results although has not altered the observational value of the outcomes. To mitigate this confounder, the patients awaiting or having undergone additional operative interventions were included in the functional PROM follow-up. Although some patients presented with a combination of hip and knee symptoms, the hip pain exclusively was reviewed as the hip symptoms were predominant. Therefore, further data aimed to specifically assess knee functional recovery in more details (currently being collected in a new patient cohort) will be beneficial. Our patient cohort displayed a heterogeneity of co-existing pathology, reflecting the complexity of the diagnostic and treatment steps required. We hope that our experience with the treatment of these complex patients will assist other clinicians in their future decision-making.

CONCLUSIONS

The patients with hip pain frequently present with a combination of tibial and/or femoral rotational deformity and cam/pincer lesions. It is important to consider the tibial maltorsion as an aetiology of hip pain. The tibial derotation with DTDO results in a significant clinical and functional recovery within 12 months in the symptomatic hip impingement patients even in the presence of co-existing pathomorphology.

SUPPLEMENTARY DATA

Supplementary data are available at *Journal of Hip Preservation Surgery* online.

DATA AVAIILABILITY

In order to promote collaboration, the deidentified data from this study will be openly available upon reasonable request.

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CONFLICT OF INTEREST STATEMENT

None declared.

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AUTHOR CONTRIBUTIONS

The manuscript was written through contributions of all authors. All authors have given approval to the final version of the manuscript. There was no additional funding or support required.

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