ISSN 2218-5836 (online)

World Journal of *Orthopedics*

World J Orthop 2024 July 18; 15(7): 608-682

Published by Baishideng Publishing Group Inc

W J O

World Journal of
Orthopedics

Contents

Monthly Volume 15 Number 7 July 18, 2024

ABOUT COVER

Peer Reviewer of *World Journal of Orthopedics*, Jie Wang, PhD, MD, Academic Research, Surgeon, Department of Orthopedic Surgery, Second Affiliated Hospital of Xi'an Jiaotong University, Xi'an 710004, Shaanxi Province, China. doctorwang8685@163.com

AIMS AND SCOPE

The primary aim of *World Journal of Orthopedics* (*WJO*, *World J Orthop*) is to provide scholars and readers from various fields of orthopedics with a platform to publish high-quality basic and clinical research articles and communicate their research findings online.

WJO mainly publishes articles reporting research results and findings obtained in the field of orthopedics and covering a wide range of topics including arthroscopy, bone trauma, bone tumors, hand and foot surgery, joint surgery, orthopedic trauma, osteoarthropathy, osteoporosis, pediatric orthopedics, spinal diseases, spine surgery, and sports medicine.

INDEXING/ABSTRACTING

WJO is now abstracted and indexed in PubMed, PubMed Central, Emerging Sources Citation Index (Web of Science), Scopus, Reference Citation Analysis, China Science and Technology Journal Database, and Superstar Journals Database. The 2024 Edition of Journal Citation Reports® cites the 2023 journal impact factor (JIF) for *WJO* as 2.0; JIF Quartile: Q2. The *WJO*'s CiteScore for 2023 is 3.1.

RESPONSIBLE EDITORS FOR THIS ISSUE

Production Editor: *Yu-Qing Zhao*; **Production Department Director:** *Xiang Li*; **Cover Editor:** *Jin-Lei Wang*.

NAME OF JOURNAL
World Journal of Orthopedics

ISSN
ISSN 2218-5836 (online)

LAUNCH DATE
November 18, 2010

FREQUENCY
Monthly

EDITORS-IN-CHIEF
Massimiliano Leigheb, Xiao-Jian Ye

EXECUTIVE ASSOCIATE EDITORS-IN-CHIEF
Xin Gu

EDITORIAL BOARD MEMBERS
http://www.wjgnet.com/2218-5836/editorialboard.htm

PUBLICATION DATE
July 18, 2024

PUBLISHING PARTNER
The Minimally Invasive Spine Surgery Research Center Of Shanghai Jiaotong University

INSTRUCTIONS TO AUTHORS
https://www.wjgnet.com/bpg/gerinfo/204

GUIDELINES FOR ETHICS DOCUMENTS
https://www.wjgnet.com/bpg/GerInfo/287

GUIDELINES FOR NON-NATIVE SPEAKERS OF ENGLISH
https://www.wjgnet.com/bpg/gerinfo/240

PUBLICATION ETHICS
https://www.wjgnet.com/bpg/GerInfo/288

PUBLICATION MISCONDUCT
https://www.wjgnet.com/bpg/gerinfo/208

POLICY OF CO-AUTHORS
https://www.wjgnet.com/bpg/GerInfo/310

ARTICLE PROCESSING CHARGE
https://www.wjgnet.com/bpg/gerinfo/242

STEPS FOR SUBMITTING MANUSCRIPTS
https://www.wjgnet.com/bpg/GerInfo/239

ONLINE SUBMISSION
https://www.f6publishing.com

PUBLISHING PARTNER's OFFICIAL WEBSITE
https://www.shtrhospital.com/zkjs/info_29.aspx?itemid=647

World Journal of Orthopedics

Submit a Manuscript: https://www.f6publishing.com

World J Orthop 2024 July 18; 15(7): 608-617

DOI: 10.5312/wjo.v15.i7.608

ISSN 2218-5836 (online)

ORIGINAL ARTICLE

Retrospective Cohort Study

Eight of ten patients return to daily activities, work, and sports after total knee arthroplasty

Maud Cornelia Wilhelmina Maria Peters, Yvette Pronk, Justus-Martijn Brinkman

Specialty type: Orthopedics

Provenance and peer review: Unsolicited article; Externally peer reviewed.

Peer-review model: Single blind

Peer-review report's classification

Scientific Quality: Grade D

Novelty: Grade C

Creativity or Innovation: Grade C

Scientific Significance: Grade C

P-Reviewer: Busso C, Italy

Received: March 21, 2024

Revised: May 13, 2024

Accepted: May 29, 2024

Published online: July 18, 2024

Processing time: 112 Days and 12.9 Hours

Maud Cornelia Wilhelmina Maria Peters, Yvette Pronk, Department of Research, Kliniek ViaSana, Mill 5451 AA, Netherlands

Justus-Martijn Brinkman, Department of Orthopedic Surgery, Kliniek ViaSana, Mill 5451 AA, Netherlands

Corresponding author: Maud Cornelia Wilhelmina Maria Peters, MSc, Researcher, Department of Research, Kliniek ViaSana, Hoogveldseweg 1, Mill 5451 AA, Netherlands. m.peters@viasana.nl

Abstract

BACKGROUND

Besides return to work (RTW) and return to sports (RTS), patients also prefer to return to daily activities (RTA) such as walking, sleeping, grocery shopping, and domestic work following total knee arthroplasty (TKA). However, evidence on the timelines and probability of patients' RTA is sparse.

AIM

To assess the percentage of patients able to RTA, RTW, and RTS after TKA, as well as the timeframe and influencing factors of this return.

METHODS

A retrospective cohort study with prospectively collected data was conducted at a medium-sized Dutch orthopedic hospital. Assessments of RTA, RTW, and RTS were performed at 3 mo and/or 6 mo following TKA. Investigated factors encompassed patient characteristics, surgical characteristics, and preoperative patient-reported outcomes.

RESULTS

TKA patients [n = 2063; 66 years old (interquartile range [IQR]: 7 years); 47% male; 28 kg/m^2 (IQR: 4 kg/m^2)] showed RTA ranging from 28% for kneeling to 94% for grocery shopping, with 20 d (IQR: 27 d) spent for putting on shoes to 74 d (IQR: 57 d) for kneeling. RTW rates varied from 62% for medium-impact work to 87% for low-impact work, taking 33 d (IQR: 29 d) to 78 d (IQR: 55 d). RTS ranged from 48% for medium-impact sports to 90% for low-impact sports, occurring within 43 d (IQR: 24 d) to 90 d (IQR: 60 d). One or more of the investigated factors influenced the return to each of the 14 activities examined, with R^2 values ranging from 0.013 to 0.127.

CONCLUSION
Approximately 80% of patients can RTA, RTW, and RTS within 6 mo after TKA. Return is not consistently influenced by predictive factors. Results help set realistic pre- and postoperative expectations.

Key Words: Knee; Arthroplasty; Replacement; Return to work; Return to daily activities; Return to sports

Core Tip: Everyday, patients with knee osteoarthritis and knee arthroplasty are seen in consultation rooms. In this large sample study (n = 2063 patients), approximately 80% of patients were able to return to daily activities, work, and sports within 6 mo after total knee arthroplasty. Return was not consistently influenced by identifiable predictive factors. This new knowledge creates realistic pre- and postoperative expectations.

Citation: Peters MCWM, Pronk Y, Brinkman JM. Eight of ten patients return to daily activities, work, and sports after total knee arthroplasty. *World J Orthop* 2024; 15(7): 608-617
URL: https://www.wjgnet.com/2218-5836/full/v15/i7/608.htm
DOI: https://dx.doi.org/10.5312/wjo.v15.i7.608

INTRODUCTION

In cases where conservative treatment is ineffective, total knee arthroplasty (TKA) is an established intervention for patients with end-stage osteoarthritis. TKA alleviates pain, restores function, and improves quality of life[1-3]. The prevalence of osteoarthritis is projected to increase 40% between 2015 and 2040. In combination with the rising prevalence of obesity and longer life expectancy, physical activity has become a crucial component of successful aging[4-6].

Physical activity following TKA encompasses return to daily activities (RTA), return to work (RTW), and return to sports (RTS). Wide ranges of RTW and RTS rates have been reported[7,8]. Nevertheless, there is limited evidence regarding RTA such as walking, sleeping, grocery shopping, and domestic work after TKA.

Moreover, recommendations regarding RTA, RTW, and RTS following TKA significantly vary among Dutch hospitals and clinics[8]. Consequently, these discrepancies contribute to a lack of consistent evidence and suboptimal implementation when evidence is available.

Therefore, evidence-based patient-specific recommendations are essential for setting realistic patient expectations[9]. Accordingly, this study assessed the percentage of patients able to RTA, RTW, and RTS after TKA. As a secondary goal, this study investigated the timeframe for this return and identified the influencing factors. It was hypothesized that the majority of patients will successfully RTA, RTW, and RTS within 6 mo after TKA.

MATERIALS AND METHODS

Patients and setting

A retrospective cohort study with prospectively collected data of primary TKA patients was conducted. The study involved patients who underwent TKA from August 2019 to November 2022 at a medium-sized Dutch orthopedic hospital (Kliniek ViaSana, Mill, The Netherlands). Patients were characterized by an American Society of Anesthesiologists (ASA) score of I-II and body mass index (BMI) ≤ 35 kg/m^2.

As part of routine clinical practice, patients started doing exercises guided by a physiotherapist within a few hours after surgery. Approximately 4 d post-surgery, patients started home-based physiotherapy. Furthermore, these patients were advised to gradually resume daily activities and swimming (no breaststroke) 4 wk post-surgery, engage in low-impact sports and work 6 wk post-surgery, and participate in swimming (all techniques), medium-impact sports, and work 3 mo post-surgery. Patients were also advised to avoid engagement in heavy-impact sports (*e.g.*, squash, contact sports, and running) and work (*e.g.*, construction, paving, and plumbing). Patients were encouraged not to rush these returns and to do so only when they felt ready.

Eligibility for inclusion required informed consent for the use of anonymized data for scientific analysis prior to undergoing primary TKA and completion of a questionnaire at 3 mo and/or 6 mo after TKA. The institutional review board determined that formal approval was not required.

Outcomes and measurements

Primary outcome focused on the percentage of respondents who had returned to daily activities, work, and sports following TKA. This was evaluated separately at 3 mo and 6 mo postoperatively. These timeframes were determined during an expert consensus meeting involving three experienced high-volume orthopedic knee surgeons. These timeframes were based on clinical practice when the majority of patients returned to the activities. A total of 14 different activities related to daily life, work, or sports were assessed *via* questionnaire at 3 mo. Daily life activities consisted of night rest, walking without aid, stair climbing, grocery shopping, domestic work, putting on shoes/socks, kneeling, driving a car, and outdoor cycling. Work-related activities included low-impact work (*e.g.*, office or education) and medium-impact work (*e.g.*, healthcare, painter, or hospitality industry). Sports activities assessed included low-impact sports (*e.g.*, walking or cycling), medium-impact sports [*e.g.*, full-swing golf, fitness, dancing, skiing, and tennis (no competitions)], and swimming. At the 6-mo follow-up, reassessment focused on kneeling, medium-impact work, medium-impact sports, and swimming. Participants indicated whether they had resumed each activity (yes, no, or not applicable). 'Not applicable' was defined as activities not aligning with the patient's pre-surgery lifestyle (*e.g.*, not employed in a low-impact job sector or lacking a driver's license). The first secondary outcome included the time to RTA, RTW, and RTS measured in days. Patients who reported being able to return to a certain activity were asked to provide the date of their return (dd/mm/yyyy).

The second secondary outcome involved identifying potential predictive factors for returning to each activity individually. These factors were determined through literature review, expert opinions, and their availability[10-16]. Factors were categorized into patient characteristics, surgical characteristics, and preoperative patient-reported outcomes (PROs). Investigated patient characteristics included age (years), sex (male = 0, female = 1), BMI (kg/m^2), ASA (I = 0 or II = 1), Charnley classification, diagnosis (osteoarthritis = 1, other = 0), history of previous knee surgery (yes = 1, no = 0), smoking status (yes = 1, no/quit = 0), and alcohol consumption (yes = 1, no/quit = 0)[10-12,17-20]. Surgical characteristics examined were anesthesia technique (general = 0, spinal = 1), operative duration (min from time of incision to a closed wound), and occurrence of complications (yes = 1, no = 0). Both patient and surgical characteristics were obtained from the electronic patient records. The studied preoperative PROs included pain at rest and pain during activity, function, and quality of life. Pain scores were measured using the Numeric Rating Scale (NRS) on a scale from 0 (no pain) to 10 (worst imaginable pain). Function was evaluated using the Knee Injury and Osteoarthritis Outcome Score - Physical Function Short Form scored from 0 (no difficulty) to 100 (extreme difficulty)[21]. Combined pain and function were measured with Oxford Knee Score (OKS) scored from 0 (most severe symptoms) to 48 (least severe symptoms)[22]. Furthermore, quality of life was assessed with the 5-level version of the EuroQol 5 dimensions (EQ-5D-5L) consisting of a Visual Analogue Scale (EQ VAS) and descriptive system (EQ-5D descriptive system). EQ VAS was scored from 0 (worst imaginable health state) to 100 (best imaginable health state)[23].

Preoperative PROs were primary collected digitally (OnlinePROMs, Interactive Studios-Hertogenbosch, The Netherlands). In case that a patient was not able to handle a computer, paper forms were sent. Postoperative RTA, RTW, and RTS were exclusively collected digitally. A maximum of two digital reminders were sent.

Statistical analysis

Data were analyzed using SPSS version 29.0 (IBM Corp, Armonk, NY, United States). Differences between patients who completed the questionnaires at 3 mo and/or 6 mo (respondents) and patients who did not respond to the questionnaires (non-respondents) were examined to evaluate the generalizability of results. *T*-tests were used for normally distributed data, Mann-Whitney *U* test for not normally distributed data, and χ^2 tests for categorical data. Descriptive statistics are reported as the mean with SD, median with interquartile range (IQR), or number with percentages.

Primary outcome was calculated by dividing the number of patients who had returned to a specific activity by the number of patients who completed the corresponding question minus the number of patients for whom the activity was not applicable or not applicable anymore. In cases where activities were queried at both 3 mo and 6 mo, within-6-mo scores were created by merging 3-mo and 6-mo responses. When patients indicated a return at 6 mo, this response overruled 3-mo responses. If a patient responded with ‘yes’ or ‘no’ at 3 mo and ‘no’ or ‘not applicable’ at 6 mo for a certain activity, their return to that activity was considered not applicable anymore. Percentages were calculated for each activity separately. Mean percentages of RTA, RTW, and RTS were calculated by dividing the sum of percentages for RTA, RTW, or RTS by the number of activities in each respective category.

The first secondary outcome, time to return to an activity, was calculated for each activity by subtracting the date of surgery from the date of return to that activity. If patients provided responses for time to return for activities queried at both 3 mo and 6 mo, the 3-mo responses were utilized unless the differences fell within a 14-d timeframe. When differences exceeded the 14-d timeframe, time to return was defined as missing value. This was the case for 2.1% of the outcomes for medium-impact sports, 2.8% of the outcomes for swimming and medium-impact work, and 5.1% of the outcomes for kneeling. For each activity, the distribution of answers for the time to return in days was assessed using histograms accompanied by Shapiro-Wilk tests. Descriptive statistics are reported based on the distribution of the data as follows: Mean and SD if data were normally distributed; median and IQR if data were not normally distributed; and mode with percentage if more than 50% of the responses were similar.

For the second secondary outcome, logistic regression models were applied to evaluate the factors influencing patients’ return to each activity separately (no = 0, yes = 1). Initially, the presence of missing values was investigated, revealing that these were below 15% (≤ 3.4%) for all factors and thus considered to be missing at random. Subsequently, each factor was tested individually in a univariate regression model. Then, characteristics with $P < 0.05$ were assessed using a multiple logistic regression model with backward selection. The same set of all on beforehand selected, potential predictive factors was utilized for each model to ensure comparability. The Nagelkerke R^2 was calculated for each model to assess model fit. R^2 values ranged from 0 to 1 and higher values represented more reliable models. Odds ratios (ORs) were calculated to determine the effect of the factors on return to each activity separately. Statistical significance was set at $P < 0.05$.

RESULTS

A total of 2430 patients underwent primary TKA surgery between August 2019 and November 2022. Among these individuals, 2327 (95.8%) responded to the follow-up questionnaires at either 3 mo and/or 6 mo postoperatively. At 3 mo postoperatively, 2063 (84.9%) patients responded. In total, 2114 (87.0%) patients responded at 6 mo postoperatively. The preoperative PRO response rate was 99.4%. Distinctions were observed between respondents and nonrespondents in smoking status, alcohol consumption, NRS pain score at rest, EQ-5D descriptive system score, and OKS (Table 1), but these differences were not clinically relevant.

RTA

A mean 8 of 10 patients RTA within 6 mo following their surgery. The proportion of patients who RTA varied across specific activities, ranging from 27.7% (551 of 1439) for kneeling to 94.4% (1867 of 1977) for grocery shopping. First, patients returned to putting on shoes/socks at 20 d (IQR: 27 d) followed by night rest at 26 d (IQR: 36 d). It took patients the longest to return to kneeling [74 d (IQR: 57 d); Table 2]. Return to each daily activity separately was predicted by one or more of the selected predictive factors in the multivariate models. R^2 scores ranged from 0.029 (night rest) to 0.127 (driving a car) (Table 3).

RTW

A mean 7 of 10 patients RTW within 6 mo after TKA. Specifically, 86.6% (691 of 798) of the patients returned to low-impact work at 33 d (IQR: 29 d; Table 2). Preoperative EQ-5D descriptive system score was a significant predictive factor for the return to low-impact work (odds ratio [OR]: 2.540; P = 0.021; R^2 = 0.026; Table 3). Medium-impact work was returned to by 62.1% (422 of 680) of the patients at 78 d (IQR: 55 d; Table 2). For 9.2% (192 of 2090) of patients, this activity was defined as not applicable anymore. Preoperative EQ VAS score was a significant predictor for return to medium-impact work (OR: 1.015; P = 0.007; R^2 = 0.069; Table 3).

RTS

A mean 7 of 10 patients RTS within 6 mo after TKA. Low-impact sports were returned to by 89.5% (1588 of 1775) of the patients at 43 d (IQR: 24.0 d; Table 2). Age (OR: 1.038; P = 0.001) and preoperative EQ VAS score (OR: 1.009; P = 0.032) significantly predicted the return to low-impact sports (R^2 = 0.022; Table 3).

A total of 48.4% (381 of 788) of the patients returned to medium-impact sports at 89.5 d (IQR: 60 d; Table 2). For 12.0% (251 of 2089) of patients, this specific activity was defined as not applicable anymore. Return to medium-impact sports was significantly predicted by operative duration (OR: 0.985; P = 0.044) and preoperative OKS (OR: 1.026; P = 0.018; R^2 = 0.028; Table 3).

Swimming was returned to by 68.6% (468 of 682) of patients at 80 d (IQR: 61; Table 2). For 9.5% of patients (198 of 2089), this specific activity was defined as not applicable anymore. RTS was significantly predicted by preoperative EQ-5D descriptive system score (OR: 0.398; P = 0.041) and OKS (OR: 1.039; P = 0.016; R^2 = 0.013; Table 3).

DISCUSSION

This study's primary aim was to assess the percentage of patients who were able to RTA, RTW, and RTS after TKA. Secondarily, the time to RTA, RTW, and RTS, and factors influencing the return were identified. Eight of ten patients managed to RTA, RTW, and RTS within 6 mo after TKA. Specifically, less than half of the patients managed to return to kneeling and medium-impact sports. Putting on shoes and socks was the first activity that patients returned to, while returning to medium-impact sports generally took the longest. Although various factors were identified influencing the return to all studied activities, the reliability of each predictive model was low.

Interestingly, a significant proportion of patients, approximately 80%, returned to their daily routines within the first 6 wk (40 d) post-surgery. The exception was kneeling. Only 28% of patients managed to return to kneeling within 6 mo. A previous study highlighted the challenges associated with kneeling post-surgery. Two-thirds of the patients reported difficulties with kneeling even 5 years after TKA[24]. However, there was an observable discrepancy between patients' self-reported inability to kneel and their actual capacity to do so when observed by healthcare professionals. Half of the studied patients reported the inability to kneel, whereas 80% of the patients were able to do so easily[25]. This suggests that supervised practice of kneeling might enhance patients' likelihood of successfully resuming this activity. Consequently, both pre- and postoperative patient education should include information on kneeling to improve its return rates.

Regarding RTW, 70% of the patients returned to their professional activities with higher resumption rates observed in low-impact jobs (87% within 33 d) compared to medium-impact ones (62% within 78 d). Existing systematic reviews on RTW report the following wide range of return rates: 10% to 98% with an average time to RTW of 8 wk to 16 wk[7,26]. These variations seem to be related to the physical demands of different job types. Comparable to the present study, Scott *et al*[27] categorized the physical nature of work into sedentary, light, moderate, and heavy manual work. They found that approximately 50% of participants returned to moderate manual work and about 66% returned to light manual work within a mean of 13.5 wk. These return rates were below the percentages observed in the current study. Interestingly, studies focusing exclusively on patients employed prior to surgery reported significantly higher RTW rates (scores above 92%)[13,28-30]. This indicates that preoperative employment status is an influential factor and should be included in future studies.

Table 1 Patient characteristics, surgical characteristics, and preoperative patient-reported outcomes, *n* (%)

Characteristics	Respondents, *n* = 2063	Nonrespondents, *n* = 367	*P* value
Patient characteristics			
Age in year, median (IQR)	65.80 (7.19)	65.13 (8.39)	0.222
BMI in kg/m^2, median (IQR)	27.77 (3.44)	27.84 (3.31)	0.516
Sex, male	973 (47.2)	190 (51.8)	0.112
ASA, I	799 (38.7)	143 (39.0)	0.954
Smoking status, yes	156 (7.6)	42 (11.4)	0.017[a]
Alcohol consumption, yes	1499 (72.7)	244 (66.5)	0.020[a]
Previous knee surgery, yes	986 (47.8)	173 (47.1)	0.821
Charnley classification			0.113
A Unilateral knee arthritis	972 (47.1)	160 (43.6)	
B1 Unilateral knee TKA	482 (23.4)	78 (21.3)	
B2 Bilateral TKA	412 (20.0)	94 (25.6)	
C more joints affected	197 (9.5)	34 (9.3)	
Surgical characteristics			
Diagnosis, osteoarthritis	2021 (98.0)	355 (96.7)	0.175
Anesthesia technique, spinal	2043 (99.0)	362 (98.6)	0.763
Operative duration in min, median (IQR)	40.77 (9.51)	41.04 (9.83)	0.551
Complication, yes	62 (3.0)	18 (4.9)	0.078
Preoperative PROs			
NRS pain score at rest, median (IQR)	4.92 (2.38)	5.23 (2.43)	0.021[a]
NRS pain score during activity, median (IQR)	7.18 (1.88)	7.18 (2.00)	0.558
KOOS-PS score, median (IQR)	47.23 (12.74)	48.98 (14.19)	0.084
EQVAS score, median (IQR)	72.91 (18.65)	72.96 (19.03)	0.906
EQ-5D descriptive system score, median (IQR)	0.590 (0.250)	0.551 (0.273)	0.013[a]
OKS, median (IQR)	24.92 (7.16)	23.83 (7.64)	0.042[a]

[a]$P < 0.05$.

ASA: American Society of Anesthesiologists score; BMI: Body mass index; EQ-5D descriptive system: EuroQol five dimensions descriptive system; EQ VAS: EuroQol five dimensions Visual Analogue Scale; KOOS-PS: Knee Injury and Osteoarthritis Outcome Score - Physical Function Short Form; NRS: Numeric rating scale; OKS: Oxford knee score; PRO: Patient-reported outcomes; TKA: Total knee arthroplasty; IQR: Interquartile range.

RTS was achieved by 70% of the patients with variations depending on the impact level of sports. Swimming was returned to by 69% within 80 d, 90% returned to low-impact sports within 43 d, and 48% returned to medium-impact sports within 90 d. The low resumption rate for medium-impact sports could indicate either an ongoing recovery process at the 6-mo mark or a permanent shift in patients' sporting preferences. A prolonged study period might gain further insights into the return to medium-impact sports. As seen for RTW, previous studies combined in an umbrella review on RTS after TKA reported wide ranges from 34% to 100% at 13 wk[14]. This could be explained by different definitions of sports participation used in these studies. Furthermore, there are different definitions of activity levels. For instance, Konings *et al*[31] categorized dancing and tennis as high-impact sport activities with participation rates of 128% and 106% within 1 year after surgery, respectively. The present study categorized these activities as medium-impact sports. Categorization of low- and medium-impact sports is a potential explanation for the lower RTS rates observed in the present study. To facilitate study comparisons and develop evidence-based, patient-specific recommendations for setting realistic patient expectations, uniform definitions for RTW and RTS are crucial. Additionally, there is a need for consensus on categorizing activity levels for both RTW and RTS[9]. This study provides valuable information for formulating these recommendations. Regarding swimming, 69% returned in 80 d after TKA in the present study. Another study reported an RTS rate of 107% due to increased postoperative swimming participation[30]. One study accounting for pre- and postoperative sports participation reported that 81% of participants returned to swimming at 13.1 wk after

Table 2 Return to daily activities, work, and sports within 6 mo after total knee arthroplasty

Activity	3 mo		6 mo		Within 6 mo	
	Return to activity, *n* (%)[1]	Time to return in days, median (IQR)	Return to activity, *n* (%)[1]	Time to return in days, median (IQR)	Return to activity, *n* (%)[1]	Time to return in days, median (IQR)
Daily activities						
Night rest	1435 (72.6)	26.0 (36.0)	-	-	1435 (72.6)	26.0 (36.0)
Walking without aids	1859 (94.0)	32.0 (23.5)	-	-	1859 (94.0)	32.0 (23.5)
Stair climbing	1655 (83.7)	42.0 (26.0)	-	-	1655 (83.7)	42.0 (26.0)
Grocery shopping	1867 (94.4)	37.0 (23.0)	-	-	1867 (94.4)	37.0 (23.0)
Domestic work	1700 (86.0)	42.0 (25.0)	-	-	1700 (86.0)	42.0 (25.0)
Putting on shoes/socks	1940 (98.1)	20.0 (27.0)	-	-	1940 (98.1)	20.0 (27.0)
Kneeling	403 (20.4)	57.0 (25.0)	439 (30.0)	96.0 (50.3)	551 (27.7)	74.0 (56.5)
Driving a car	1725 (91.7)	42.0 (20.0)	-	-	1725 (91.7)	42.0 (20.0)
Outdoor cycling	1518 (80.8)	43.0 (24.0)	-	-	1518 (80.8)	43.0 (24.0)
Work						
Low-impact work	691 (86.6)	33.0 (29.0)	-	-	691 (86.6)	33.0 (29.0)
Medium-impact work	238 (34.9)	57.0 (24.0)	342 (72.3)	97.0 (54.0)	422 (62.1)	78.0 (55.0)
Sports						
Low-impact sports	1588 (89.5)	43.0 (24.0)	-	-	1588 (89.5)	43.0 (24.0)
Medium-impact sports	185 (21.7)	57.0 (26.0)	327 (63.0)	98.0 (52.0)	381 (48.4)	89.5 (60.0)
Swimming	231 (34.9)	51.0 (28.5)	385 (81.6)	90.8 (36.0)	468 (68.6)	80.0 (61.0)

[1]Percentages represent the portion of patients who answered "yes" on the questionnaire out of the total number of patients who answered "yes" or "no" to that specific question.
IQR: Interquartile range.

surgery[32]. This shows that preoperative sports participation should be included in future studies.

Several predictive factors for RTA, RTW, and RTS were identified in this study. Moreover, this study confirmed the impact of demographic factors and preoperative aspects on the return to activities[10-12]. For the factors BMI, ASA, preoperative function, and preoperative quality of life, the observed associations showed identical alignment. However, contradictory evidence was found regarding the influence of age, sex, and preoperative pain scores on the return of activities. Despite these findings, the predictive value of these factors was relatively low ($R^2 < 0.127$) diminishing their clinical relevance. Interestingly, preoperative participation in sports or work emerged as the most significant predictive factor of return[14,16], alongside the level of activity and urgency felt regarding the return[11,12,16]. These factors were not included in the present study due to its retrospective nature. This highlights an area for future prospective research.

It is important to mention the potential influence of recall bias on the study's results. It is a common challenge in retrospective studies where longer recall periods can lead to less accurate reporting[33]. Four out of the fourteen activities were questioned at both 3 mo and 6 mo after TKA. The analyses revealed acceptable discrepancies in the recall of return dates within a maximum 5% of patients per activity.

The current study has several strengths. First, to the best of the authors' knowledge, this study represents the first comprehensive investigation into RTA after TKA. By investigating a broad range of activities, it offers an almost total perspective of the recovery process. Additionally, the inclusion of a large sample size strengthens the reliability of the findings. The study's approach of examining the combination of RTA, RTW, and RTS puts the outcomes in perspective. This helps in setting realistic expectations for patients and healthcare providers. As a limitation of the present study, the generalizability of the results may be restricted. This study only included patients who were characterized by an ASA score of I to II and a BMI of ≤ 35 kg/m^2, representing 80% of the total TKA population. Moreover, the retrospective research design is a limitation. Consequently, it was not possible to include preoperative work experience, preoperative sports participation, and whether patients adhered to the advised rehabilitation protocol. Future research should address these limitations by extending the study timeframe, incorporating preoperative work status and/or sport participation,

Table 3 Factors predicting return to daily activities, work, and sports within 6 mo after total knee arthroplasty

Activity	*n*	R^2	Predictive factors	OR (95%CI)	*P* value
Daily activities					
Night rest	1901	0.029	Sex	0.734 (0.589-0.913)	0.006[b]
			ASA	1.217 (0.989-1.498)	0.064
			Previous surgery	0.829 (0.670-1.025)	0.083
			Operative duration	0.989 (0.978-1.000)	0.047[a]
			NRS pain at rest	0.912 (0.863-0.964)	0.001[b]
			NRS pain during activity	1.080 (1.003-1.163)	0.042[a]
			OKS	1.020 (1.002-1.038)	0.030[a]
Walking without aids	1901	0.033	Sex	0.681 (0.456-1.016)	0.06
			Anesthesia technique	4.456 (1.232-16.120)	0.023[a]
			OKS	1.054 (1.024-1.084)	< 0.001[b]
Stair climbing	1901	0.05	BMI	0.941 (0.908-0.975)	< 0.001[b]
			Sex	0.499 (0.381-0.653)	< 0.001[b]
			Operative duration	0.987 (0.974-1.000)	0.053
			OKS	1.024 (1.006-1.043)	0.010[a]
Grocery shopping	1901	0.051	Age	0.960 (0.933-0.989)	0.007[b]
			BMI	0.939 (0.886-0.996)	0.037[a]
			EQ-5D descriptive system	0.299 (0.106-0.846)	0.023[a]
			OKS	1.094 (1.052-1.137)	< 0.001[b]
Domestic work	1901	0.05	Age	0.958 (0.940-0.977)	< 0.001[b]
			BMI	0.924 (0.889-0.961)	< 0.001[b]
			NRS pain during activity	1.082 (0.995-1.178)	0.067
			OKS	1.054 (1.031-1.078)	< 0.001[b]
Putting on shoes/socks	1901	0.067	Sex	2.794 (1.366-5.712)	0.005[b]
			OKS	1.106 (1.052-1.163)	< 0.001[b]
Kneeling	1910	0.1	BMI	0.946 (0.917-0.976)	< 0.001[b]
			Sex	0.433 (0.349-0.538)	< 0.001[b]
			Alcohol consumption	1.305 (1.015-1.681)	0.039[a]
			KOOS-PS	0.989 (0.978-1.001)	0.083
			OKS	1.022 (1.000-1.044)	0.048[a]
Driving a car	1811	0.127	Age	0.966 (0.941-0.990)	0.007[b]
			Sex	0.217 (0.140-0.337)	< 0.001[b]
			ASA	0.678 (0.461-0.998)	0.049[a]
			Anesthesia technique	3.815 (0.970-14.998)	0.055
			Charnley classification	1.173 (0.988-1.391)	0.068
			OKS	1.055 (1.028-1.083)	< 0.001[b]
Outdoor cycling	1806	0.123	Age	0.949 (0.931-0.967)	< 0.001[b]
			BMI	0.937 (0.903-0.972)	< 0.001[b]
			Sex	0.347 (0.266-0.452)	< 0.001[b]
			ASA	0.763 (0.580-1.004)	0.053
			Charnley classification	1.175 (1.041-1.326)	0.009[b]

			OKS	1.032 (1.013-1.051)	< 0.001[b]
Work					
Low-impact work	765	0.026	Age	1.032 (0.999-1.065)	0.054
			EQ-5D descriptive system	2.540 (1.150-5.612)	0.021[a]
Medium-impact work	448	0.069	Alcohol consumption	1.497 (0.932-2.406)	0.095
			EQ VAS	1.015 (1.004-1.027)	0.007[b]
			OKS	1.030 (0.997-1.065)	0.075
Sports					
Low-impact sports	1705	0.022	Age	1.038 (1.015-1.062)	0.001[b]
			ASA	0.728 (0.519-1.021)	0.066
			EQ VAS	1.009 (1.001-1.017)	0.032[a]
Medium-impact sports	758	0.028	Operative duration	0.985 (0.971-1.000)	0.044[a]
			EQ VAS	1.007 (0.999-1.016)	0.071
			OKS	1.026 (1.004-1.048)	0.018[a]
Swimming	658	0.013	EQ-5D descriptive system	0.398 (0.164-0.961)	0.041[a]
			OKS	1.039 (1.007-1.071)	0.016[a]

[a]$P < 0.05$.
[b]$P < 0.01$.
ASA: American Society of Anesthesiologists score; BMI: Body mass index; EQ-5D descriptive system: EuroQol five dimensions descriptive system; EQ VAS: EuroQol five dimensions Visual Analogue Scale; KOOS-PS: Knee Injury and Osteoarthritis Outcome Score - Physical Function Short Form; NRS: Numeric rating scale; OKS: Oxford knee score; OR: Odds ratio; TKA: Total knee arthroplasty.

setting uniform definitions for RTW and RTS, finding a consensus on categorizing activity levels for RTW and RTS, and externally validating the data to confirm and generalize the results.

CONCLUSION

Eight of ten patients were able to RTA, RTW, and RTS within 6 mo after TKA. The time to return to these activities ranges from 20 d to 61 d postoperatively. Although factors that influence return to activities were found, they were not at a reliability level that is clinically useful. These findings are useful in creating realistic pre- and postoperative expectations on RTA, RTW, and RTS after TKA.

ACKNOWLEDGEMENTS

We would like to thank all patients who participated in this study.

FOOTNOTES

Author contributions: Peters MCWM, Pronk Y, and Brinkman JM designed the research study; Peters MCWM performed the research, analyzed the data, and drafted the manuscript; Pronk Y and Brinkman JM critically read and revised the manuscript; all authors have read and approved the final manuscript.

Institutional review board statement: The institutional review board declares, after having reviewed the retrospective study (study ID: 2022-6) by the Department of Orthopaedic Surgery, that this study can safely be performed in Kliniek ViaSana, without any special recommendations required.

Informed consent statement: All study participants provided informed written consent for the use of anonymized data for scientific analysis prior to undergoing primary total knee arthroplasty.

Conflict-of-interest statement: All the authors report no relevant conflicts of interest for this article.

Data sharing statement: Technical appendix, statistical code, and dataset available from the corresponding author at m.peters@viasana.nl upon reasonable request. Participants did not give informed consent for data sharing, but the presented data are anonymized and risk of identification is low.

STROBE statement: The authors have read the STROBE Statement—checklist of items, and the manuscript was prepared and revised according to the STROBE Statement—checklist of items.

Country of origin: Netherlands

ORCID number: Maud Cornelia Wilhelmina Maria Peters 0000-0002-9830-8518; Yvette Pronk 0000-0001-5086-1501; Justus-Martijn Brinkman 0000-0002-5862-3484.

S-Editor: Li L
L-Editor: Wang TQ
P-Editor: Zhao S

REFERENCES

1 **Singh JA**, Lewallen DG. Patient-level improvements in pain and activities of daily living after total knee arthroplasty. *Rheumatology (Oxford)* 2014; **53**: 313-320 [PMID: 24162150 DOI: 10.1093/rheumatology/ket325]

2 **Nilsdotter AK**, Toksvig-Larsen S, Roos EM. A 5 year prospective study of patient-relevant outcomes after total knee replacement. *Osteoarthritis Cartilage* 2009; **17**: 601-606 [PMID: 19091604 DOI: 10.1016/j.joca.2008.11.007]

3 **Chang J**, Fu M, Cao P, Ding C, Wang D. Patient-Reported Quality of Life Before and After Total Knee Arthroplasty: A Multicenter Observational Study. *Patient Prefer Adherence* 2022; **16**: 737-748 [PMID: 35345540 DOI: 10.2147/PPA.S357632]

4 **Vzinfo**. Artrose - Ministerie van Volksgezondheid Welzijn en Sport. [cited 28 May 2024]. Available from: https://www.vzinfo.nl/artrose#node-prevalentie-en-aantal-nieuwe-gevallen-van-artrose-huisartsenpraktijk

5 **Nederlandse Orthopaedische Vereniging**. Dossier artrose. *Zorg Voor Beweging* 2019; 22-27

6 **Szychowska A**, Drygas W. Physical activity as a determinant of successful aging: a narrative review article. *Aging Clin Exp Res* 2022; **34**: 1209-1214 [PMID: 34873677 DOI: 10.1007/s40520-021-02037-0]

7 **Van Leemput D**, Neirynck J, Berger P, Vandenneucker H. Return to Work after Primary Total Knee Arthroplasty under the Age of 65 Years: A Systematic Review. *J Knee Surg* 2022; **35**: 1249-1259 [PMID: 33472262 DOI: 10.1055/s-0040-1722626]

8 **Witjes S**, Gouttebarge V, Kuijer PP, van Geenen RC, Poolman RW, Kerkhoffs GM. Return to Sports and Physical Activity After Total and Unicondylar Knee Arthroplasty: A Systematic Review and Meta-Analysis. *Sports Med* 2016; **46**: 269-292 [PMID: 26744336 DOI: 10.1007/s40279-015-0421-9]

9 **Straat AC**, Smit DJM, Coenen P, Kerkhoffs GMMJ, Anema JR, Kuijer PPFM. Large variability in recommendations for return to daily life activities after knee arthroplasty among Dutch hospitals and clinics: a cross-sectional study. *Acta Orthop* 2022; **93**: 568-573 [PMID: 35727108 DOI: 10.2340/17453674.2022.3168]

10 **Williams DH**, Greidanus NV, Masri BA, Duncan CP, Garbuz DS. Predictors of participation in sports after hip and knee arthroplasty. *Clin Orthop Relat Res* 2012; **470**: 555-561 [PMID: 22125250 DOI: 10.1007/s11999-011-2198-y]

11 **Styron JF**, Barsoum WK, Smyth KA, Singer ME. Preoperative predictors of returning to work following primary total knee arthroplasty. *J Bone Joint Surg Am* 2011; **93**: 2-10 [PMID: 21209263 DOI: 10.2106/JBJS.I.01317]

12 **Plassard J**, Masson JB, Malatray M, Swan J, Luceri F, Roger J, Batailler C, Servien E, Lustig S. Factors lead to return to sports and recreational activity after total knee replacement - A retrospective study. *SICOT J* 2020; **6**: 11 [PMID: 32378511 DOI: 10.1051/sicotj/2020009]

13 **McGonagle L**, Convery-Chan L, DeCruz P, Haebich S, Fick DP, Khan RJK. Factors influencing return to work after hip and knee arthroplasty. *J Orthop Traumatol* 2019; **20**: 9 [PMID: 30637571 DOI: 10.1186/s10195-018-0515-x]

14 **Lester D**, Barber C, Sowers CB, Cyrus JW, Vap AR, Golladay GJ, Patel NK. Return to sport post-knee arthroplasty: an umbrella review for consensus guidelines. *Bone Jt Open* 2022; **3**: 245-251 [PMID: 35300532 DOI: 10.1302/2633-1462.33.BJO-2021-0187.R2]

15 **Jassim SS**, Tahmassebi J, Haddad FS, Robertson A. Return to sport after lower limb arthroplasty - why not for all? *World J Orthop* 2019; **10**: 90-100 [PMID: 30788226 DOI: 10.5312/wjo.v10.i2.90]

16 **Lankinen P**, Laasik R, Kivimäki M, Aalto V, Saltychev M, Vahtera J, Mäkelä K. Are patient-related pre-operative factors influencing return to work after total knee arthroplasty. *Knee* 2019; **26**: 853-860 [PMID: 31126842 DOI: 10.1016/j.knee.2019.04.015]

17 **Schatz C**, Klein N, Marx A, Buschner P. Preoperative predictors of health-related quality of life changes (EQ-5D and EQ VAS) after total hip and knee replacement: a systematic review. *BMC Musculoskelet Disord* 2022; **23**: 58 [PMID: 35039045 DOI: 10.1186/s12891-021-04981-4]

18 **Orland MD**, Lee RY, Naami EE, Patetta MJ, Hussain AK, Gonzalez MH. Surgical Duration Implicated in Major Postoperative Complications in Total Hip and Total Knee Arthroplasty: A Retrospective Cohort Study. *J Am Acad Orthop Surg Glob Res Rev* 2020; **4**: e20.00043 [PMID: 33156161 DOI: 10.5435/JAAOSGlobal-D-20-00043]

19 **He Y**, Omar M, Feng X, Neunaber C, Jagodzinski M. Impact of smoking on the incidence and post-operative complications of total knee arthroplasty: A systematic review and meta-analysis of cohort studies. *Bosn J Basic Med Sci* 2022; **22**: 353-365 [PMID: 34923952 DOI: 10.17305/bjbms.2021.6538]

20 **Best MJ**, Buller LT, Gosthe RG, Klika AK, Barsoum WK. Alcohol Misuse is an Independent Risk Factor for Poorer Postoperative Outcomes Following Primary Total Hip and Total Knee Arthroplasty. *J Arthroplasty* 2015; **30**: 1293-1298 [PMID: 25769745 DOI:

10.1016/j.arth.2015.02.028]

21 **Perruccio AV**, Stefan Lohmander L, Canizares M, Tennant A, Hawker GA, Conaghan PG, Roos EM, Jordan JM, Maillefert JF, Dougados M, Davis AM. The development of a short measure of physical function for knee OA KOOS-Physical Function Shortform (KOOS-PS) - an OARSI/OMERACT initiative. *Osteoarthritis Cartilage* 2008; **16**: 542-550 [PMID: 18294869 DOI: 10.1016/j.joca.2007.12.014]

22 **Haverkamp D**, Breugem SJ, Sierevelt IN, Blankevoort L, van Dijk CN. Translation and validation of the Dutch version of the Oxford 12-item knee questionnaire for knee arthroplasty. *Acta Orthop* 2005; **76**: 347-352 [PMID: 16156462]

23 **EuroQol Group**. EuroQol--a new facility for the measurement of health-related quality of life. *Health Policy* 1990; **16**: 199-208 [PMID: 10109801 DOI: 10.1016/0168-8510(90)90421-9]

24 **Wylde V**, Artz N, Howells N, Blom AW. Kneeling ability after total knee replacement. *EFORT Open Rev* 2019; **4**: 460-467 [PMID: 31423329 DOI: 10.1302/2058-5241.4.180085]

25 **Schai PA**, Gibbon AJ, Scott RD. Kneeling ability after total knee arthroplasty. Perception and reality. *Clin Orthop Relat Res* 1999; 195-200 [PMID: 10546615]

26 **Pasqualini I**, Emara AK, Rullan PJ, Pan X, Simmons HL, Molloy RM, Krebs VE, Piuzzi NS. Return to Sports and Return to Work After Total Knee Arthroplasty: A Systematic Review and Meta-Analysis. *JBJS Rev* 2023; **11** [PMID: 37499045 DOI: 10.2106/JBJS.RVW.22.00250]

27 **Scott CEH**, Turnbull GS, MacDonald D, Breusch SJ. Activity levels and return to work following total knee arthroplasty in patients under 65 years of age. *Bone Joint J* 2017; **99-B**: 1037-1046 [PMID: 28768780 DOI: 10.1302/0301-620X.99B8.BJJ-2016-1364.R1]

28 **Bardgett M**, Lally J, Malviya A, Deehan D. Return to work after knee replacement: a qualitative study of patient experiences. *BMJ Open* 2016; **6**: e007912 [PMID: 26832426 DOI: 10.1136/bmjopen-2015-007912]

29 **Boersma AR**, Brouwer S, Koolhaas W, Brouwer RW, Zijlstra WP, van Beveren J, Stevens M. No association between preoperative physical activity level and time to return to work in patients after total hip or knee arthroplasty: A prospective cohort study. *PLoS One* 2019; **14**: e0221932 [PMID: 31479493 DOI: 10.1371/journal.pone.0221932]

30 **Chang MJ**, Kim SH, Kang YG, Chang CB, Kim TK. Activity levels and participation in physical activities by Korean patients following total knee arthroplasty. *BMC Musculoskelet Disord* 2014; **15**: 240 [PMID: 25030804 DOI: 10.1186/1471-2474-15-240]

31 **Konings MJ**, De Vroey H, Weygers I, Claeys K. Effect of knee arthroplasty on sports participation and activity levels: a systematic review and meta-analysis. *BMJ Open Sport Exerc Med* 2020; **6**: e000729 [PMID: 32597907 DOI: 10.1136/bmjsem-2019-000729]

32 **Chatterji U**, Ashworth MJ, Lewis PL, Dobson PJ. Effect of total knee arthroplasty on recreational and sporting activity. *ANZ J Surg* 2005; **75**: 405-408 [PMID: 15943726 DOI: 10.1111/j.1445-2197.2005.03400.x]

33 **Schmier JK**, Halpern MT. Patient recall and recall bias of health state and health status. *Expert Rev Pharmacoecon Outcomes Res* 2004; **4**: 159-163 [PMID: 19807519 DOI: 10.1586/14737167.4.2.159]

WJO World Journal of Orthopedics

Submit a Manuscript: https://www.f6publishing.com

World J Orthop 2024 July 18; 15(7): 618-626

DOI: 10.5312/wjo.v15.i7.618

ISSN 2218-5836 (online)

ORIGINAL ARTICLE

Retrospective Study

Two-stage corrective operation for the treatment of pes cavovarus in patients with spina bifida

Anthony Mack Padgett, Ezan Kothari, Michael J Conklin

Specialty type: Orthopedics

Provenance and peer review: Unsolicited article; Externally peer reviewed.

Peer-review model: Single blind

Peer-review report's classification

Scientific Quality: Grade B, Grade C

Novelty: Grade A, Grade B

Creativity or Innovation: Grade B, Grade B

Scientific Significance: Grade B, Grade B

P-Reviewer: Jamil K, Malaysia; Sato Y, Japan

Received: February 11, 2024

Revised: April 26, 2024

Accepted: June 5, 2024

Published online: July 18, 2024

Processing time: 152 Days and 3.8 Hours

Anthony Mack Padgett, Department of Orthopedics, Indiana University, Indianapolis, IN 46202, United States

Anthony Mack Padgett, Ezan Kothari, Michael J Conklin, Department of Orthopaedic Surgery, University of Alabama at Birmingham, Birmingham, AL 35233, United States

Michael J Conklin, Department of Orthopedic Surgery, Children's of Alabama, Birmingham, AL 35233, United States

Corresponding author: Anthony Mack Padgett, MD, Doctor, Surgeon, Department of Orthopedics, Indiana University, 550 University Blvd #6201, Indianapolis, IN 46202, United States. a.m.padgett2@gmail.com

Abstract

BACKGROUND

Pes cavovarus has an estimated incidence of 8%-17% in patients with spina bifida (SB). The majority of the current literature on surgical treatment of cavovarus feet in children and adolescents includes a variety of diagnoses. There are currently no case series describing a treatment algorithm for deformity correction in this specific patient population. The authors of this study present the results of a retrospective case series performed to assess the radiographic outcomes of two-stage corrective surgery in patients with SB.

AIM

To assess the radiographic outcomes of a staged operation consisting of radical plantar release followed by osteotomy for pes cavovarus in patients with SB.

METHODS

Retrospective chart review was performed on patients with SB with a diagnosis of pes cavovarus at a freestanding children's hospital who underwent surgical correction of the deformity. Patients were excluded for lack of two-stage corrective operation, nonambulatory status, lack of at least six months follow-up, and age > 18 years at the time of surgery. This resulted in a cohort of 19 patients. Radiographic analysis was performed on 11 feet that had a complete series of preoperative and postoperative weightbearing X-rays. Preoperative and postoperative radiographic outcome measurements were compared using a two-sample *t*-test.

RESULTS
Significant changes between the preoperative and postoperative measurements were seen in Meary's angle, the anteroposterior talo-first metatarsal (AP TMT1) angle, and the talonavicular coverage. Mean values of Meary's angle were 17.9 ± 13.1 preoperatively and 4.7 ± 10.3 postoperatively (P = 0.016). Mean AP TMT1 angle was 20.6 ± 15.1 preoperatively and 9.3 ± 5.5 postoperatively (P = 0.011). Mean talonavicular coverage values were -10.3 ± 9.6 preoperatively and -3.8 ± 10.1 postoperatively (P = 0.025).

CONCLUSION
The two-stage corrective procedure demonstrated efficacy in correcting cavovarus deformity in patients with SB. Providers should strongly consider employing the staged surgical algorithm presented in this manuscript for management of these patients.

Key Words: Cavovarus; Spina bifida; Osteotomy; Plantar release; Radiographs; Pediatrics

Core Tip: Currently, there is a paucity of literature on the treatment of pes cavovarus in patients with spina bifida. Cavovarus and cavus are common foot deformities in this patient population. In this article, the authors demonstrate that a two-stage operation consisting of plantar release with subsequent osteotomy demonstrates good correction of the deformity. Outcomes were evaluated by preoperative and postoperative values of six common radiographic measurements.

Citation: Padgett AM, Kothari E, Conklin MJ. Two-stage corrective operation for the treatment of pes cavovarus in patients with spina bifida. *World J Orthop* 2024; 15(7): 618-626
URL: https://www.wjgnet.com/2218-5836/full/v15/i7/618.htm
DOI: https://dx.doi.org/10.5312/wjo.v15.i7.618

INTRODUCTION

Pes cavovarus is a foot deformity defined by a varus hindfoot and a cavus midfoot. The primary deformity results from an elevated longitudinal arch of the foot, also known as cavus. The varus deformity subsequently develops either due to muscle imbalance between the tibialis posterior and the peroneal muscles[1] or due to the tripod effect as the plantar flexed first metatarsal drives the heel into varus[2]. In the pediatric population, cavovarus most commonly occurs secondary to neuropathic disorders[3-5].

Mosca previously elucidated general principles for treatment of the cavus foot[6]. Central to these principles is the need to correct the deformity and balance muscular forces[6,7]. Selected treatment of pes cavovarus largely depends on whether the hindfoot varus deformity is flexible or rigid. Ankle foot orthosis or radical plantar release can be used in the management of flexible cavus deformities, depending on severity[1,8]. If the hindfoot varus is rigid, then the hindfoot will need to be specifically addressed. Muscle forces are balanced with tendon transfers. Tendon transfers should not be performed until the deformity is corrected, so that they are under appropriate tension. The first stage of the two-stage correction, as elucidated by Mosca, involves plantar or plantar-medial release followed by postoperative casting to achieve correction. Casting is performed to achieve adequate soft tissue relaxation so that at the second stage, residual bony deformity is corrected with a plantar opening wedge osteotomy of the medial cuneiform (+/- intermediate cuneiform) and residual hindfoot varus is corrected with calcaneal osteotomy. Tendon transfers are performed at the second stage once the corrected position of the foot is attained[6].

Multiple studies have demonstrated the utility of osteotomies in the management of pes cavovarus[9-11]. It is important to note that fusions should be avoided in patients with neuropathic disorders, except as a salvage procedure in severe cases, due to the high incidence of future skin breakdown[1,8,12,13].

Cavovarus has an estimated incidence of 8%-17% in patients with spina bifida (SB)[1,14,15]. Even though this is a common foot deformity in SB, published studies on surgical management of cavovarus feet in pediatric patients includes variable underlying pathologies[4,5,16-20]. We found no case series specifically addressing the treatment of cavovarus in SB. The authors of this study present the results of a retrospective single-institutional case series designed to evaluate the radiographic outcomes of a two-stage operation consisting of radical plantar release and osteotomy in the treatment of cavovarus in patients with SB.

MATERIALS AND METHODS

Retrospective chart review was performed on SB patients managed at a freestanding children's hospital who underwent surgical intervention performed by a single fellowship-trained pediatric orthopaedic surgeon for a primary diagnosis of

Table 1 Functional motor level of patients (n = 19)

Functional motor level	Number of patients
Mid-lumbar	9
Low-lumbar	2
Sacral	8

cavovarus foot deformity between 2012 and 2021. Patients who underwent two-stage correction for their foot deformity were identified *via* current procedural terminology codes. Patients were excluded for lack of two-stage corrective operation with osteotomy, lack of at least six months follow-up, and age > 18 years at the time of first surgery. This resulted in a cohort of 19 patients. Typical indications for surgery were history of pressure sores or impending pressure sores (hyperkeratotic skin) in the typical location for a cavovarus foot such as the base of the 5th metatarsal, the head of the 5th metatarsal, or the head of the 1st metatarsal. Brace intolerance or gait instability due to the varus hindfoot were additional indications. Functional motor levels of the patients are shown in Table 1.

Radiographic analysis was performed on 11 of 19 (57.9%) patients that had a complete series of preoperative and postoperative weightbearing X-rays. 8 of 19 (42.1%) patients were unable to be included in radiographic analysis due to lack of acquisition of follow-up weightbearing radiographs. These patients had their last radiographs performed non-weightbearing but continue to be followed in the multidisciplinary SB clinic.

Preoperative measurements were based on radiographs obtained prior to the first stage of the operation, while postoperative measurements were based on radiographs obtained after both the first and second stages of the operation. The postoperative radiographic measurements were based on radiographs taken at least 6 months after the second stage of the surgery to ensure that the reported results reflect a lasting correction. 7 of the 11 patients included in the radiographic analysis had X-rays taken between the first and second stage of the operation, while 4 did not. Six radiographic angles were measured on both the preoperative and postoperative weightbearing radiographs. Meary's angle was defined as positive in the case of midfoot cavus and negative in the case of midfoot planus. The anteroposterior talo-first metatarsal (AP TMT1) angle was defined as positive in the case of forefoot adduction and negative in the case of forefoot abduction. The talonavicular coverage angle was defined as positive in the case of midfoot abduction and negative in the case of midfoot adduction. All X-ray imaging analyses were verified by a fellowship-trained pediatric orthopaedic surgeon. PACS software was utilized to analyze all radiographs.

Charts were also reviewed for patient age at the time of surgery, gender, race, and postoperative complications. Preoperative and postoperative radiographic outcome measurements were compared using a two-sample t-test. A P value of 0.05 was considered significant for all analyses. All statistical analysis was performed in R-4.1.2.

RESULTS

Demographics

A total of 19 patients were included in the analysis. 7 (36.8%) patients were male, and 12 (63.2%) were female. 13 (68.4%) patients were Caucasian, 3 (15.8%) were African American, and 3 (15.8%) were Asian. The average age at the time of surgery was 9.9 years (SD = 3.3; range 4 to 17).

Procedural characteristics

All patients in the study population underwent two-stage correction of the cavovarus deformity with radical plantar fascia release and osteotomy. Superficial and deep plantar medial release as described by Mosca were performed at the first stage[6]. This involved release of the three origins of the abductor hallucis, the plantar fascia, the plantar and medial talonavicular capsule and release or lengthening (if innervated) of the posterior tibial tendon. This was followed by one month of weekly serial casting. A plantar opening wedge (with allograft) osteotomy of the medial cuneiform bone and/or a calcaneal slide osteotomy was then performed to correct residual cavus or varus, respectively. Tendon transfers were performed at the second stage and were dependent on functional motor level and the presence or absence of an exaggerated windlass mechanism. Additional soft tissue and osseous procedures are summarized in Table 2. Of the 19 feet analyzed, 13 (68.4%) cases underwent cuneiform osteotomy, and 6 (31.6%) cases underwent calcaneal osteotomy. The cumulative average number of cast changes throughout the postoperative course of the two-stage operation was 4.0 ± 1.2 casts. Average follow-up time was 43.8 ± 33.8 months (range 9-118 months).

Radiographic angle measurements

Significant changes between preoperative and postoperative radiographic angle measurements were seen in Meary's angle, the AP first tarsometatarsal angle, and the talonavicular coverage angle. The average Meary's angle changed from 17.9 ± 13.1 preoperatively to 4.7 ± 10.3 following the second stage of the operation (P = 0.016). The mean AP TMT1 angle changed from 20.6 ± 15.1 preoperatively and 9.3 ± 5.5 following the second stage of the operation (P = 0.011). The mean talonavicular coverage changed from -10.3 ± 9.6 preoperatively to -3.8 ± 10.1 following the second stage of the operation (P = 0.025). No other angle measurements showed significant differences between preoperative and postoperative radiographs. Radiographic angle measurement data is summarized in Table 3. Radiographic examples of sequential

Table 2 Additional soft tissue and osseous procedures performed

Soft tissue and osseous procedures	Number of patients undergoing procedure
Talonavicular joint capsule release	19
Abductor hallucis release	19
Tibialis posterior lengthening/release	18
Peroneus longus to peroneus brevis transfer	13
Jones transfer (extensor hallucis longus transfer to first metatarsal neck)	10
Flexor hallucis longus lengthening/release	9
Flexor digitorum longus lengthening/release	9
Great toe interphalangeal joint fusion	7
Achilles tendon lengthening	6
Calcaneocuboid joint capsule release	4
Extensor hallucis longus to extensor hallucis brevis transfer	2
Tibialis anterior lengthening	1
Split posterior tibial tendon transfer to peroneus brevis	1
Anterior tibial tendon transfer to lateral cuneiform	1

Table 3 Radiographic outcomes data (n = 11)

Angle measurement	Average preoperative value (range)	Average value after stage 1[1] (range)	Average value after stage 2 (range)	P value preoperative to post-stage 1[2]	P value post-stage 1 to post-stage 2[2]	P value preoperative to post-stage 2
Meary's	17.9 ± 13.1 (3.0-50.1)	13.8 ± 7.1 (4.4-25.3)	4.7 ± 10.3 (-8.0 to 21.)	0.47	0.056	0.016[a]
Calcaneal pitch	22.4 ± 4.0 (16.4-29.6)	25.0 ± 6.3 (15.8-32.7)	21.3 ± 7.6 (12.3-32.4)	0.30	0.30	0.53
AP TMT1	20.6 ± 15.1 (6.2-40.8)	8.4 ± 7.4 (1.4-21.5)	9.3 ± 5.5 (1.5-22.9)	0.066	0.78	0.011[a]
Lateral talocal-caneal	43.6 ± 9.8 (22.9-57.9)	42.6 ± 10.7 (26.2-53.0)	41.7 ± 9.2 (27.5-51.1)	0.85	0.86	0.46
AP talocalcaneal	15.8 ± 6.7 (6.3-25.0)	16.7 ± 9.8 (3.5-29.7)	18.9 ± 8.6 (8.7-33.9)	0.81	0.62	0.32
Talonavicular coverage	-10.3 ± 9.6 (-28.3 to 1.2)	-4.0 ± 7.2 (-11.0 to 9.3)	-3.8 ± 10.1 (-22.1 to 16)	0.16	0.97	0.025[a]

[1]7 of 11 patients had available radiographs taken between the first and second stages of the operation.
[2]Values calculated using two-sample t-test with unequal variances.
[a]$P < 0.05$.
AP-TMT1: Anteroposterior talo-first metatarsal.

deformity improvement over the course of the two-stage procedure are shown in Figures 1-3.

Complications

Within the first nine months of follow-up from the second stage of the operation, only 1 (5.3%) patient in our cohort developed a post-operative complication. The patient required reoperation with Z-lengthening of the Achilles tendon due to an equinus contracture. There were no cases of postoperative infections, neuropathic ulcers, nerve injury, or non-union.

DISCUSSION

Pes cavus or cavovarus is a common foot deformity in children and adults with various neurologic disorders[3-5]. The orthopaedic literature discussing the treatment of cavus or cavovarus feet has typically grouped individuals with various diagnoses[4,5,16-20]. However, there is a paucity of literature addressing the correction of cavovarus specifically in children with SB. The two-stage procedure for pes cavovarus correction in pediatric patients was refined by Mosca[6].

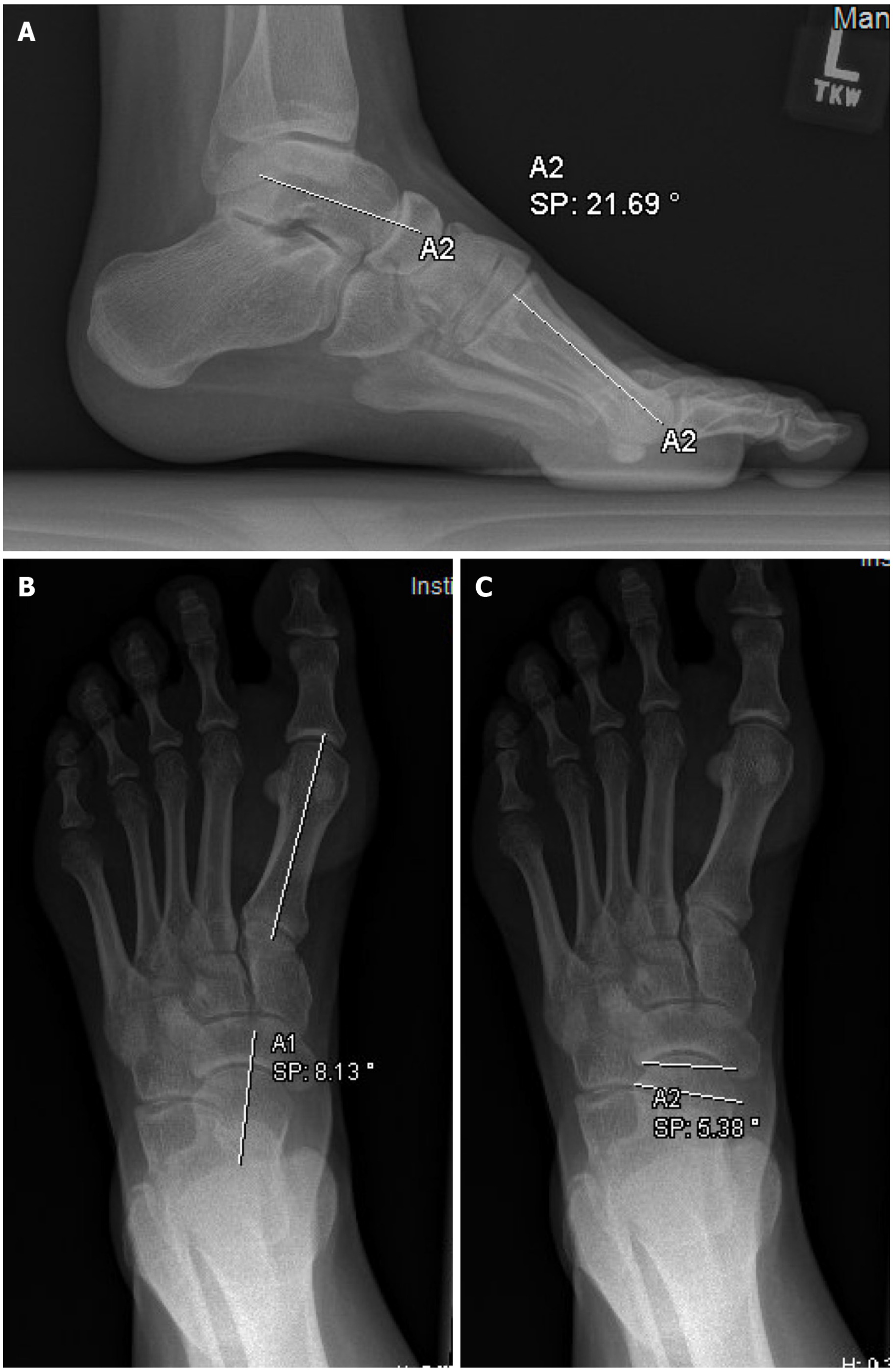

Figure 1 Preoperative lateral and anteroposterior radiographs showing Meary's angle, anteroposterior talo-first metatarsal angle, and talonavicular coverage. A: Meary's angle (lateral talus-first metatarsal angle); B: Anteroposterior talo-first metatarsal angle; C: Talonavicular coverage.

Based on the results of the current study, the authors advocate for the use of a two-stage, rather than single-stage, operation for the correction of these deformities in patients with SB. While muscle imbalance leading to soft tissue contracture may be the primary factor precipitating the deformity, bony deformity develops over time[1]. The results of this study demonstrate the importance of addressing both the soft tissue and osseous elements of the deformity. Radical plantar release, the primary component of the first stage of our treatment algorithm, has been previously validated as an effective procedure for cavus correction[8]. Plantar opening wedge osteotomy of the medial cuneiform may not be feasible at the time of the first stage as relaxation of the soft tissues with serial casting needs to occur to gain length[6]. The second stage addresses residual bony deformity that does not resolve with serial casting after the first stage. This approach substantiates previous literature that has shown positive outcomes when utilizing a combination of soft tissue release and osteotomy[11].

Weightbearing radiographic analysis is the primary determinant of clinical management in pediatric foot deformities [21,22]. In addition to helping guide clinical decision making, analysis of these angles can be used to assess outcomes following corrective procedures for malalignment, including pes cavovarus. Davids *et al*[23] described weight bearing radiographic measurements that assess segmental alignment of the foot. Both intraobserver and interobserver reliability

Figure 2 Lateral, and anteroposterior radiographs obtained after first stage radical plantar fascia release demonstrating improvement in Meary's angle, anteroposterior talo-first metatarsal angle angle, and talonavicular coverage. A: Meary's angle (lateral talus-first metatarsal angle); B: Anteroposterior talo-first metatarsal angle; C: Talonavicular coverage.

of these radiographic measurements is excellent. Utilizing the Wicart grading system for the assessment of therapeutic efficacy of cavovarus foot correction[2] (Table 4), our results demonstrate good correction of the deformity, with the average Meary's angle decreasing from 17.9 ± 13.1 degrees preoperatively to 4.7 ± 10.3 degrees postoperatively (P = 0.016). The results also demonstrate significant improvement of both the AP TMT1 angle (P = 0.011) and talonavicular coverage (P = 0.025), respectively. Furthermore, in 7 of the 11 feet included for radiographic follow-up that had radiographs obtained between the first and second stages, correction of Meary's, AP TMT1 and talonavicular coverage angles were not significant after the first stage but reached statistical significance after the second stage.

The radiological outcomes of this study compare favorably to previous literature assessing these parameters following corrective surgery for pes cavovarus[11,19,20]. In a case series of 24 cavovarus feet undergoing correction *via* plantar fascia release and first metatarsal dorsal hemiepiphysiodesis, Sanpera *et al*[20] report a mean difference of -6.2 and -8.2 degrees in Meary's angle and the AP TMT1 angle, respectively. Our data shows mean differences of -13.2 degrees in Meary's angle and -11.3 degrees in the AP TMT1 angle. Additionally, Chen *et al*[11] report an average postoperative Meary's angle of 6.36 ± 1.810 following a single-stage operation consisting of soft tissue release and osteotomy. The results of our study show an average postoperative Meary's angle of 4.7 ± 10.3 after the two-stage technique described here.

Table 4 Wicart grading system for correction of pes cavovarus with respect to postoperative lateral Meary's angle

Correction score	M
Very good	0 ≤ M < 5
Good	5 ≤ M < 15
Fair	15 ≤ M < 20
Poor	M ≥ 20 or need for revision surgery

M: Meary's angle.

Figure 3 Postoperative lateral and anteroposterior radiographs obtained after second-stage cuneiform osteotomy demonstrating further improvement in Meary's angle, anteroposterior talo-first metatarsal angle angle, and talonavicular coverage. A: Meary's angle (lateral talus-first metatarsal angle); B: Anteroposterior talo-first metatarsal angle; C: Talonavicular coverage.

There was a low incidence of post-operative complications among the patients in our study. Pressure sore development in patients with SB has a reported incidence up to 60%, and the feet are a commonly affected anatomic location[24,25]. Within the first nine months of follow-up after the second stage of the operation, no patients in our cohort developed neuropathic ulceration. There was one patient that required re-operation for correction of an equinus contracture.

To the authors' knowledge, this is the first paper to specifically describe a treatment algorithm for cavus and cavovarus in patients with SB. Limitations of the study include its retrospective nature and relatively small sample size. Also, due to the treatment algorithm, it is impossible to blind stage of treatment in the radiographic analyses. As exemplified in Figure 3, osseous procedures such as the corrective osteotomy and hallux interphalangeal joint arthrodesis are easily identifiable. Therefore, the senior author recognizes that such images must have been obtained after the second stage of the operation. Additionally, the study does not specifically evaluate clinical outcome measures such as the American Orthopedic Foot and Ankle Society score or pedobarographic data. However, efficacy of the operation was evaluated through radiographic parameters which have been shown to correlate with correction[2]. Lastly, a portion of our patients did not have final weightbearing films and thus were not included in the radiographic analysis. Future studies could include a prospective design that would allow for functional scoring both pre- and postoperatively with a larger sample size to better characterize the clinical outcomes of cavovarus correction.

CONCLUSION

Two-stage operation consisting of plantar fascia release followed by osteotomy has been previously described as an effective treatment option for the surgical correction of pediatric pes cavovarus. No study exists, to date, describing the treatment for children and adolescents with SB. The results of this study demonstrate that a two-stage treatment algorithm consisting of plantar fascia release and osteotomy produced good correction of the cavovarus deformity in these patients. The two-stage procedure promoted the sequential correction of residual bony or soft tissue contributions to the deformity that may not be adequately corrected by a single-stage operation. When surgical intervention becomes necessary, the authors advocate for consideration of the two-stage operation presented here.

FOOTNOTES

Author contributions: Padgett AM, Kothari E, Conklin MJ designed the study; Kothari E contributed to the data acquisition; Padgett AM and Conklin MJ participated in the analysis and interpretation of data. All authors were actively involved in manuscript drafting, manuscript revision, and critical review of the manuscript for important intellectual content; and all authors approve the manuscript submitted.

Institutional review board statement: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. This study was approved by the Institutional Review Board.

Informed consent statement: Informed consent was obtained from the parent/legal guardian for the publication of the details of any institutional cases and accompanying images presented in this manuscript.

Conflict-of-interest statement: All the authors report no relevant conflicts of interest for this article.

Data sharing statement: The authors consent to the publication of the data presented in this manuscript. Sharing of other data related to this study may be done upon a reasonable request.

Country of origin: United States

ORCID number: Anthony Mack Padgett 0000-0003-1606-0641; Michael J Conklin 0000-0001-7966-3816.

S-Editor: Wang JJ
L-Editor: A
P-Editor: Zhang XD

REFERENCES

1 **Swaroop VT**, Dias L. Orthopaedic management of spina bifida-part II: foot and ankle deformities. *J Child Orthop* 2011; **5**: 403-414 [PMID: 23205142 DOI: 10.1007/s11832-011-0368-9]

2 **Wicart P**. Cavus foot, from neonates to adolescents. *Orthop Traumatol Surg Res* 2012; **98**: 813-828 [PMID: 23098772 DOI: 10.1016/j.otsr.2012.09.003]

3 **Laurá M**, Singh D, Ramdharry G, Morrow J, Skorupinska M, Pareyson D, Burns J, Lewis RA, Scherer SS, Herrmann DN, Cullen N, Bradish C, Gaiani L, Martinelli N, Gibbons P, Pfeffer G, Phisitkul P, Wapner K, Sanders J, Flemister S, Shy ME, Reilly MM; Inherited Neuropathies Consortium. Prevalence and orthopedic management of foot and ankle deformities in Charcot-Marie-Tooth disease. *Muscle Nerve* 2018; **57**: 255-259 [PMID: 28632967 DOI: 10.1002/mus.25724]

4 **Olney B**. Treatment of the cavus foot. Deformity in the pediatric patient with Charcot-Marie-Tooth. *Foot Ankle Clin* 2000; **5**: 305-315 [PMID: 11232232 DOI: 10.1016/S1083-7515(24)00138-4]

5 **Ziebarth K**, Krause F. Updates in Pediatric Cavovarus Deformity. *Foot Ankle Clin* 2019; **24**: 205-217 [PMID: 31036265 DOI: 10.1016/j.fcl.2019.02.010]

6 **Mosca VS**. The cavus foot. *J Pediatr Orthop* 2001; **21**: 423-424 [PMID: 11433149 DOI: 10.1097/01241398-200107000-00001]

7 **Sanpera I**, Villafranca-Solano S, Muñoz-Lopez C, Sanpera-Iglesias J. How to manage pes cavus in children and adolescents? *EFORT Open Rev* 2021; **6**: 510-517 [PMID: 34267941 DOI: 10.1302/2058-5241.6.210021]

8 **Schwend RM**, Drennan JC. Cavus foot deformity in children. *J Am Acad Orthop Surg* 2003; **11**: 201-211 [PMID: 12828450 DOI: 10.5435/00124635-200305000-00007]

9 **Wicart P**, Seringe R. Plantar opening-wedge osteotomy of cuneiform bones combined with selective plantar release and dwyer osteotomy for pes cavovarus in children. *J Pediatr Orthop* 2006; **26**: 100-108 [PMID: 16439912 DOI: 10.1097/01.bpo.0000189005.78045.17]

10 **Mubarak SJ**, Van Valin SE. Osteotomies of the foot for cavus deformities in children. *J Pediatr Orthop* 2009; **29**: 294-299 [PMID: 19305283 DOI: 10.1097/BPO.0b013e31819aad20]

11 **Chen ZY**, Wu ZY, An YH, Dong LF, He J, Chen R. Soft tissue release combined with joint-sparing osteotomy for treatment of cavovarus foot deformity in older children: Analysis of 21 cases. *World J Clin Cases* 2019; **7**: 3208-3216 [PMID: 31667171 DOI: 10.12998/wjcc.v7.i20.3208]

12 **Wukich DK**, Bowen JR. A long-term study of triple arthrodesis for correction of pes cavovarus in Charcot-Marie-Tooth disease. *J Pediatr Orthop* 1989; **9**: 433-437 [PMID: 2732324 DOI: 10.1097/01241398-198907000-00010]

13 **Maynard MJ**, Weiner LS, Burke SW. Neuropathic foot ulceration in patients with myelodysplasia. *J Pediatr Orthop* 1992; **12**: 786-788 [PMID: 1452751 DOI: 10.1097/01241398-199211000-00016]

14 **Frawley PA**, Broughton NS, Menelaus MB. Incidence and type of hindfoot deformities in patients with low-level spina bifida. *J Pediatr Orthop* 1998; **18**: 312-313 [PMID: 9600554 DOI: 10.1097/01241398-199805000-00007]

15 **Tubbs RS**, Winters RG, Naftel RP, Acharya VK, Conklin M, Shoja MM, Loukas M, Oakes WJ. Predicting orthopedic involvement in patients with lipomyelomeningoceles. *Childs Nerv Syst* 2007; **23**: 835-838 [PMID: 17387484 DOI: 10.1007/s00381-007-0342-5]

16 **Lee MC**, Sucato DJ. Pediatric issues with cavovarus foot deformities. *Foot Ankle Clin* 2008; **13**: 199-219, v [PMID: 18457769 DOI: 10.1016/j.fcl.2008.01.002]

17 **Dreher T**, Beckmann NA, Wenz W. Surgical Treatment of Severe Cavovarus Foot Deformity in Charcot-Marie-Tooth Disease. *JBJS Essent Surg Tech* 2015; **5**: e11 [PMID: 30473919 DOI: 10.2106/JBJS.ST.N.00005]

18 **Lin T**, Gibbons P, Mudge AJ, Cornett KMD, Menezes MP, Burns J. Surgical outcomes of cavovarus foot deformity in children with Charcot-Marie-Tooth disease. *Neuromuscul Disord* 2019; **29**: 427-436 [PMID: 31122830 DOI: 10.1016/j.nmd.2019.04.004]

19 **Simon AL**, Seringe R, Badina A, Khouri N, Glorion C, Wicart P. Long term results of the revisited Meary closing wedge tarsectomy for the treatment of the fixed cavo-varus foot in adolescent with Charcot-Marie-Tooth disease. *Foot Ankle Surg* 2019; **25**: 834-841 [PMID: 30482439 DOI: 10.1016/j.fas.2018.11.005]

20 **Sanpera I Jr**, Frontera-Juan G, Sanpera-Iglesias J, Corominas-Frances L. Innovative treatment for pes cavovarus: a pilot study of 13 children. *Acta Orthop* 2018; **89**: 668-673 [PMID: 29911919 DOI: 10.1080/17453674.2018.1486525]

21 **Mosca VS**. Calcaneal lengthening for valgus deformity of the hindfoot. Results in children who had severe, symptomatic flatfoot and skewfoot. *J Bone Joint Surg Am* 1995; **77**: 500-512 [PMID: 7713966 DOI: 10.2106/00004623-199504000-00002]

22 **Sutherland DH**. Varus foot in cerebral palsy: an overview. *Instr Course Lect* 1993; **42**: 539-543 [PMID: 8463702]

23 **Davids JR**, Gibson TW, Pugh LI. Quantitative segmental analysis of weight-bearing radiographs of the foot and ankle for children: normal alignment. *J Pediatr Orthop* 2005; **25**: 769-776 [PMID: 16294134 DOI: 10.1097/01.bpo.0000173244.74065.e4]

24 **Akbar M**, Bresch B, Seyler TM, Wenz W, Bruckner T, Abel R, Carstens C. Management of orthopaedic sequelae of congenital spinal disorders. *J Bone Joint Surg Am* 2009; **91** Suppl 6: 87-100 [PMID: 19884416 DOI: 10.2106/JBJS.I.00613]

25 **Conklin MJ**, Hopson B, Arynchyna A, Atchley T, Trapp C, Rocque BG. Skin breakdown of the feet in patients with spina bifida: Analysis of risk factors. *J Pediatr Rehabil Med* 2018; **11**: 237-241 [PMID: 30507590 DOI: 10.3233/PRM-170520]

World Journal of Orthopedics

Submit a Manuscript: https://www.f6publishing.com

World J Orthop 2024 July 18; 15(7): 627-634

DOI: 10.5312/wjo.v15.i7.627

ISSN 2218-5836 (online)

ORIGINAL ARTICLE

Retrospective Study

Smoking cessation prior to elective total joint arthroplasty results in sustained abstinence postoperatively

Billy Insup Kim, Jeffrey O'Donnell, Colleen M Wixted, Thorsten Markus Seyler, William A Jiranek, Michael Paul Bolognesi, Sean Patrick Ryan

Specialty type: Orthopedics

Provenance and peer review: Unsolicited article; Externally peer reviewed.

Peer-review model: Single blind

Peer-review report's classification
Scientific Quality: Grade C
Novelty: Grade C
Creativity or Innovation: Grade B
Scientific Significance: Grade B

P-Reviewer: Cabezuelo AS, Spain

Received: March 1, 2024
Revised: May 8, 2024
Accepted: May 27, 2024
Published online: July 18, 2024
Processing time: 132 Days and 8.2 Hours

Billy Insup Kim, Jeffrey O'Donnell, Department of Orthopedic Surgery, Hospital for Special Surgery, New York, NY 10021, United States

Colleen M Wixted, Department of Orthopedic Surgery, New York University, New York, NY 10003, United States

Thorsten Markus Seyler, William A Jiranek, Michael Paul Bolognesi, Sean Patrick Ryan, Department of Orthopedic Surgery, Duke University Hospital, Durham, NC 27560, United States

Corresponding author: Sean Patrick Ryan, MD, Assistant Professor, Department of Orthopedic Surgery, Duke University Hospital, 5601 Arringdon Park Dr. Suite 300, Durham, NC 27560, United States. sean.p.ryan@duke.edu

Abstract

BACKGROUND

Tobacco use is a well-documented modifiable risk factor for perioperative complications.

AIM

To determine the tobacco abstinence rates of patients who made cessation efforts prior to a total joint arthroplasty (TJA) procedure.

METHODS

A retrospective evaluation was performed on 88 self-reported tobacco users who underwent TJA between 2014-2022 and had tobacco cessation dates within 3 mo of surgery. Eligible patients were contacted *via* phone survey to understand their tobacco use pattern, and patient reported outcomes. A total of 37 TJA patients participated.

RESULTS

Our cohort was on average 61-years-old, 60% (n = 22) women, with an average body mass index of 30 kg/m^2. The average follow-up time was 2.9 ± 1.9 years. A total of 73.0% (n = 27) of patients endorsed complete abstinence from tobacco use prior to surgery. Various cessation methods were used perioperatively including prescription therapy (13.5%), over the counter nicotine replacement (18.9%), cessation programs (5.4%). At final follow up, 43.2% (n = 16) of prior tobacco smokers reported complete abstinence. Patients who were able to maintain cessation postoperatively had improved Patient-Reported Outcomes Measurement Information System (PROMIS)-10 mental health scores (49 *vs* 58; P = 0.01), and hip dysfunction and osteoarthritis outcome score for joint replacement (HOOS. JR) scores (63 *vs* 82; P = 0.02). No patients in this cohort had a prosthetic joint infection or required revision surgery.

CONCLUSION

We report a tobacco cessation rate of 43.2% in patients undergoing elective TJA nearly 3 years postoperatively. Patients undergoing TJA who were able to remain abstinent had improved PROMIS-10 mental health scores and HOOS. JR scores. The perioperative period provides clinicians a unique opportunity to assist active tobacco smokers with cessation efforts and improve postoperative outcomes.

Key Words: Smoking cessation; Total joint arthroplasty; Outcomes; Tobacco use; Postoperative abstinence

Core Tip: From a retrospective review of 37 self-reported tobacco users undergoing total joint arthroplasty, we found a tobacco cessation rate of 43.2% at nearly 3 years postoperatively. These patients had improved Patient-Reported Outcomes Measurement Information System-10 mental health scores and hip dysfunction and osteoarthritis outcome score for joint replacement scores.

Citation: Kim BI, O'Donnell J, Wixted CM, Seyler TM, Jiranek WA, Bolognesi MP, Ryan SP. Smoking cessation prior to elective total joint arthroplasty results in sustained abstinence postoperatively. *World J Orthop* 2024; 15(7): 627-634

URL: https://www.wjgnet.com/2218-5836/full/v15/i7/627.htm

DOI: https://dx.doi.org/10.5312/wjo.v15.i7.627

INTRODUCTION

Tobacco use remains the leading cause of preventable disease, morbidity, and mortality in the United States, with estimated healthcare costs exceeding $240 billion dollars annually[1]. Smoking shortens people's lives by an average of 10 years compared to non-smokers. This is secondary to coronary heart disease, aneurysms, atherosclerosis, chronic obstructive pulmonary disease, and cancers associated with tobacco use[2].

Tobacco use is a well-documented modifiable risk factor for many negative outcomes in orthopedic surgery. An increased risk of infection and wound complications is documented in every orthopedic subspecialty with tobacco use perioperatively[3-7]. In total joint arthroplasty (TJA), tobacco users have higher rates of wound complications and prosthetic joint infections (PJI) than non-users[8]. Former smokers have a lower risk of complications after TJA than current smokers, indicating that cessation efforts can have clinically relevant impacts on postoperative outcomes[8].

Smoking cessation's correlation with improved clinical outcomes in TJA is well-recognized[8,9]. While over 50% of adult cigarette smokers attempt to quit each year, only 7.5% of cessation attempts succeed[10]. To aid in cessation efforts, contemporary approaches involve pharmacologic and behavioral support programs. Importantly, many medical centers require smoking cessation for a period before elective surgery to reduce perioperative complications. Thus, elective surgery has been suggested to be an effective and durable method for helping patients abstain from tobacco use[11].

The purpose of the present study was to better understand tobacco use patterns postoperatively after preoperative cessation efforts in patients undergoing elective TJA. Secondary goals were to evaluate postoperative patient-reported outcomes (PROs) and identify effective methods for assisting with cessation efforts. We hypothesize that tobacco cessation prior to elective TJA will lead to lasting abstinence postoperatively for many patients at a higher rate than those undergoing cessation for other reasons, as reported in the literature.

MATERIALS AND METHODS

A retrospective review was undertaken for patients who underwent total hip and knee arthroplasty at a single tertiary referral center. The institutional electronic health record (EHR) database was queried for all primary total knee arthroplasty (TKA) (n = 3499) and primary total hip arthroplasty (THA) (n = 4687) performed by one of five fellowship-trained arthroplasty surgeons between January 2014 and December 2022. Patients less than 18 years of age were excluded. Patients undergoing arthroplasty for fracture or oncologic condition were excluded. Self-reported smoking status (current, former, or never smoker) was available for 1682 TKA and 1250 THA patients. Of these, 33 TKA and 55 THA had cessation dates recorded in the EHR within 3 mo of their TJA, for a cohort of 88 patients. The EHR was used to confirm that all patients in our cohort were smokers prior to surgery and had documented correspondence with their surgeon’s team to either quit or cut back on tobacco use preoperatively.

Demographic information collected at the time of surgery included: age, race, sex, marital status, alcohol use, tobacco use, American Society of Anesthesiologist (ASA) grade, anesthesia type, body mass index (BMI), laterality, procedure details. Patient-Reported Outcomes Measurement Information System (PROMIS)-10, and knee injury and osteoarthritis outcome score for joint replacement (KOOS. JR) or hip dysfunction and osteoarthritis outcome score for joint replacement (HOOS. JR).

Our patient cohort was prospectively contacted to participate in a phone survey (Supplementary material). The survey included questions regarding their tobacco use prior to and after surgery, cessation efforts, current smoking status, as well as PROMIS-10, HOOS. JR or KOOS. JR scores. Patient reported cessation interventions were recorded as free responses and subsequently categorized into no intervention, prescription medication (varenicline, bupropion), nicotine replacement, counseling, and gum or mints. Patients who did not have accurate contact information or who were not able to be reached after three attempts were excluded. Five patients were contacted and declined participation in the survey. A total of 37 TJA patients voluntarily participated and met our inclusion and exclusion criteria. Patient selection is illustrated in Figure 1.

Descriptive statistics were used to interpret the data. Univariable statistics were performed using *t*-tests or chi-square tests. Paired Wilcoxon tests were used to compare individuals' tobacco use before and after surgery and Bonferroni corrections were applied. No a priori power analysis was performed based on study design evaluating a retrospective cohort of patients over a fixed period when smoking cessation was required who were prospectively contacted. Sensitivity analysis performed at a power of 0.8 and alpha of 0.05 for a one-tailed *t*-test demonstrated that the current study group sizes were sufficient to detect large effect size differences ($P > 0.8$). Statistical analysis was performed with SAS 9.4 (SAS Institute Inc, Cary, NC). Significance level was defined as $P < 0.05$. Institutional review board approval was obtained for this study.

Our cohort was on average 60.62 ± 11.90-years-old, 59.5% (n = 22) female, 70.3% (n = 26) Caucasian, 56.8% (n = 21) married, with an average BMI of 29.96 kg/m^2 ± 6.86 kg/m^2. Average ASA score was 2.43 ± 0.55 and average length of hospital stay was 2.76 ± 1.92 d. There were no significant differences in demographic information between those that remained abstinent from tobacco and those that did not postoperatively. Basic demographic information can be seen in Table 1. The average time from surgery to completion of the survey was 2.85 ± 1.93 years.

RESULTS

Out of the 88 eligible patients, 40 (45.5%) were able to be contacted and volunteered to participate in our survey. A total of 37/40 patients confirmed that they were able to reduce or quit tobacco products prior to their elective TJA. All patients (n = 37) reported tobacco use within the year preceding their total joint replacement with 86.5% (n = 32) smoking cigarettes. A total of 83.8% (n = 31) of patients stated that they received a tobacco cessation request from their surgeon prior to their elective total joint surgery. 100% (n = 37) of patients reduced their tobacco use prior to surgery and 73.0% (n = 27) of patients maintained complete abstinence prior to their surgery.

There were various methods used to help abstain from tobacco use perioperatively. The most common method was "cold turkey" with 64.5% (n = 24) of patients not using any cessation aids. 13.5% (n = 5) of patients used prescription pharmacologic therapy, and 18.9% (n = 7) of patients used over the counter nicotine replacement therapy. Only two patients (5.4%) reported using a cessation program to help curb tobacco use perioperatively. At final follow up, 43.2% (n = 16) of prior tobacco smokers maintained complete abstinence. Those that relapsed did so at an average of 2.73 ± 1.82 mo after surgery. Tobacco use and cessation information is illustrated in Table 2.

PROMIS-10 physical and mental health scores were collected along with KOOS. JR for TKAs and HOOS. JR for THAs. Overall, PROMIS-10 mental health scores were significantly higher in those that were able to maintain cessation long-term at the distribution of this survey (48.58 *vs* 57.79; $P < 0.01$). KOOS. JR were also significantly improved in those that maintained tobacco cessation (63.12 *vs* 82.05; $P = 0.02$). Although both the PROMIS-10 physical function score and the KOOS. JR scores were improved with tobacco abstinence at time of the survey, these did not reach statistical significance at $P = 0.09$ and $P = 0.40$, respectively. Patient reported outcomes are documented in Table 3.

Complications related to the TJA were collected. There was one superficial surgical site infection (SSI) that was treated with oral antibiotics. There was one hip dislocation after a fall that required a sedated closed reduction at an outside facility without subsequent dislocations. None of the patients in this cohort had a PJI or required revision surgery on their TJA.

DISCUSSION

Smoking tobacco perioperatively is a modifiable risk factor for surgical complications with associated increased cost of care[3,4,9-11]. In TJA patients, cessation from tobacco use preoperatively has been shown to improve postoperative outcomes and reduce the risk of wound complications and PJI[8,9]. Cessation programs and pharmacologic agents can help with these efforts and have been shown to be efficacious and cost effective[12]. Prior investigations have shown that cessation attempts in the perioperative period can substantially increase success rates in active tobacco users[13].

In our study, 73.0% of patients were able to quit tobacco use prior to surgery, and 43.2% of patients reported continued abstinence at an average follow up of 3.11 years postoperatively. It is estimated that only 7.5% of all tobacco cessation attempts are successful in the general population[10]. However, the present study notes a cessation rate that was nearly six-times higher. This is in line with other studies reporting a high rate of successful tobacco cessation surrounding

Table 1 Basic demographics, *n* (%)

Parameter	Overall cohort	Relapsed postop	Abstinent postop	*P* value
Number of patients	37	21	16	
Total knee replacement	17 (45.9)	12 (57.1)	5 (31.2)	0.22
Average age in yr (SD)	60.62 (11.90)	62.76 (12.32)	57.81 (11.08)	0.22
Male	15 (40.5)	9 (42.9)	6 (37.5)	1.00
Race				0.62
African American	10 (27.0)	5 (23.8)	5 (31.2)	
Caucasian	26 (70.3)	15 (71.4)	11 (68.8)	
Other	1 (2.7)	1 (4.8)	0 (0.0)	
Marital status				0.36
Divorced	6 (16.2)	5 (23.8)	1 (6.2)	
Married	21 (56.8)	10 (47.6)	11 (68.8)	
Single	9 (24.3)	5 (23.8)	4 (25.0)	
Widowed	1 (2.7)	1 (4.8)	0 (0.0)	
Average BMI (SD)	29.96 (6.86)	30.53 (6.75)	29.20 (7.17)	0.58
Average ASA (SD)	2.43 (0.55)	2.52 (0.60)	2.31 (0.48)	0.26
Hospital LOS in d (SD)	2.76 (1.92)	2.90 (2.21)	2.56 (1.50)	0.6
Follow up mean (SD)	2.85 (1.93)	2.65 (2.20)	3.11 (1.53)	0.48

ASA: American Society of Anesthesiologist; BMI: Body mass index; LOS: Length of stay.

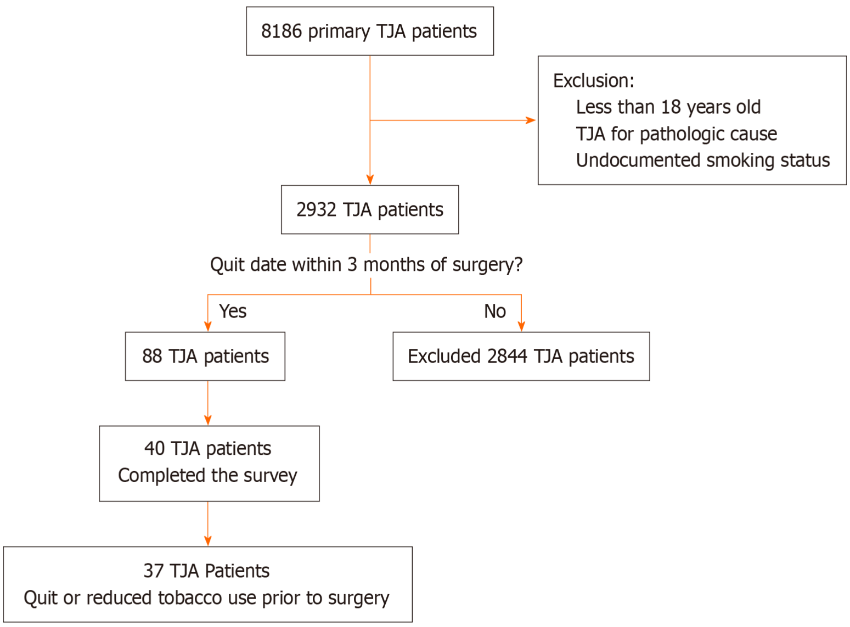

Figure 1 Patient selection diagram. TJA: Total joint arthroplasty.

elective TJA. Smith *et al*[11] reported on 23 patients who underwent lower extremity orthopedic surgery and found that 48% of patients maintained smoking abstinence for at least 1 year postoperatively. Hall *et al*[14] surveyed 124 patients undergoing TJA and found that 23% of patients never resumed smoking at an average follow up of 52 (range 15-126) mo [14]. Perioperative care and timing surgery around smoking cessation provides clinicians with a unique opportunity to assist active tobacco smokers with durable cessation effects.

In our study, methods used to quit or cut back on tobacco use included nicotine replacement, prescription medications, and cessation programs. Most patients reported using no cessation aids. There is a cessation program available at our

Table 2 Tobacco use information, *n* (%)

Parameter	Overall cohort	Relapsed postop	Abstinent postop	*P* value
Number of patients	37	21	16	
Tobacco use preoperatively				0.66
Cigarettes	32 (86.5)	18 (85.7)	14 (87.5)	
Cigars	4 (10.8)	2 (9.5)	2 (12.5)	
Other	1 (2.7)	1 (4.8)	0 (0.0)	
Provider requested tobacco abstinence preoperatively				0.34
Yes	31 (83.8)	19 (90.5)	12 (75.0)	
No	5 (13.5)	2 (9.5)	3 (18.8)	
Can't remember	1 (2.7)	0 (0.0)	1 (6.2)	
PPD prior to cessation efforts (SD)	0.74 (0.52)	0.80 (0.55)	0.68 (0.48)	0.51
Complete tobacco abstinence preoperatively	27 (73.0)	15 (71.4)	12 (75.0)	1.00
PPD preoperatively after cessation efforts	0.06 (0.12)	0.08 (0.14)	0.04 (0.10)	0.49
Time until tobacco relapse in mo (SD)	2.73 (1.82)	2.73 (1.82)	Not Applicable	
Cessation method				0.55
Nothing	24 (64.9)	12 (57.1)	12 (75.0)	
Prescription medication				
Varenicline	2 (5.4)	2 (9.5)	0 (0.0)	
Bupropion	3 (8.1)	1 (4.8)	2 (12.5)	
Nicotine replacement	7 (18.9)	6 (28.6)	1 (6.2)	
Counseling	2 (5.4)	2 (9.5)	0 (0.0)	
Gum or mints	2 (5.4)	0 (0.0)	2 (12.5)	
Current tobacco use	19 (51.4)	19 (90.5)	0 (0.0)	< 0.01
Tobacco use at some point postoperatively	2 (5.4)	2 (9.5)	0 (0.0)	0.59
Average PPD (SD)	0.24 (0.35)	0.44 (0.37)	0.00 (0.00)	< 0.01
Reported complication postoperatively				0.36
SSI	1(2.7)	0 (0.0)	1 (6.2)	
Dislocation	1(2.7)	1 (4.8)	0 (0.0)	
PJI	0 (0.0)	0 (0.0)	0 (0.0)	
Revision surgery	0 (0.0)	0 (0.0)	0 (0.0)	

PJI: Prosthetic joint infections; PPD: Packs per day; SSI: Surgical site infection.

institution, however this was not commonly utilized by patients. There is evidence to suggest that offering smoking interventions, behavioral support, and nicotine replacement therapy are effective at increasing the likelihood of perioperative abstinence, limiting relapse, and reducing postoperative morbidity[13]. This suggests that even higher rates of long-term tobacco abstinence could have been achieved with initiatives or standardized programs for these patients. Targeted therapeutic interventions could provide a secondary benefit of helping prevent relapse postoperatively in active tobacco users.

Preoperative patient reported outcome scores including PROMIS-10, HOOS. JR and KOOS. JR were incomplete and could not be reported. Postoperative PROs showed a statistically significant improvement in PROMIS-10 global mental health scores in patients who maintained cessation until the time of the survey. Additionally, HOOS. JR scores were significantly improved in patients who had a THA and maintained smoking cessation until final follow up. The PROMIS mental health score has not been shown to be independently predictive of postoperative achievement of minimal clinically important difference (MCID) in TJA patients[15]. The MCID for HOOS. JR using an anchor-based approach has been calculated to be 18 points[16]. There was an 18.9-point improvement in HOOS. JR scores in THA patients who were able to maintain tobacco abstinence postoperatively compared to those that resumed tobacco use, suggesting a significant clinical improvement. Aside from the numerous health benefits that can be achieved with tobacco cessation, there is

Table 3 Patient reported outcome scores

Outcome score	Overall cohort	Relapsed postop	Abstinent postop	*P* value
Number of patients	37	21	16	
Promis-10 physical function score, Mean (SD)	46.35 (9.25)	44.12 (9.52)	49.27 (8.27)	0.09
Promis-10 mental health score, Mean (SD)	52.56 (10.60)	48.58 (11.65)	57.79 (6.12)	< 0.01
KOOS. JR, Mean (SD)	80.77 (17.58)	78.36 (19.88)	86.56 (9.52)	0.4
HOOS. JR, Mean (SD)	73.53 (18.02)	63.12 (8.23)	82.05 (19.63)	0.02

KOOS. JR: Knee injury and osteoarthritis outcome score for joint replacement; HOOS. JR: Hip dysfunction and osteoarthritis outcome score for joint replacement.

potential for improvements in TJA outcomes with continued smoking abstinence postoperatively as demonstrated here. We suggest that clinicians should focus equal effort in limiting tobacco use postoperatively as they do preoperatively.

Patients who relapsed postoperatively did so early, at an average of less than 3 mo postoperatively. From a public health perspective, efforts should focus on maintaining smoking cessation in patients in this perioperative period to prevent relapse. Gilpin *et al*[17] reported that there was a lower relapse rate in patients who remained continuously abstinent for longer periods of time. Overall, they showed that the probability of remaining continuously abstinent until final follow-up was around 90% for former smokers who had quit for 3 mo or longer and 95% for those who had quit for 1 year or longer. Concerted efforts by providers and patients in the perioperative period may lead to higher rates of successful cessation long-term.

The limitations of this study are well-recognized. Our study sample is limited by the small number of patients included, limited geographic region, and accuracy and availability of information in the EHR, which may limit the generalizability of our findings. We only reported on patients who had documented smoking status in their record, which confined us to only 35% of the TJA patients and may underestimate the true prevalence of tobacco use within our TJA patient population. Laboratory testing for nicotine in patients is not routine at our institution, and this study relied on patient-reported tobacco use habits. Furthermore, the retrospective nature of patient interviews allows for potential confounding factors through recall and response bias. Despite this, self-reported smoking status has been validated in orthopedic patients compared to objective cotinine measurements[18]. There were five patients who we were able to contact but who declined participation in our survey. Along with this, a large percentage of patients had inaccurate contact information or could not be reached by phone call, which also introduces potential bias into our study. Finally, the present study did not include a control group of patients without preoperative tobacco cessation efforts, limiting the attributability of differences in postoperative outcomes on successful cessation alone. Future studies with larger sample sizes, prospective designs, and inclusion of control groups are warranted to validate the efficacy of preoperative tobacco cessation interventions in the TJA population.

Despite these limitations, the present study showed that patients undergoing TJA who were able to remain abstinent from tobacco products postoperatively had improved PROMIS-10 mental health scores and HOOS. JR with effect sizes large enough to be detected at the present sample sizes. Forty three percent of patients in our cohort reported continued abstinence at an average follow up of nearly 3 years postoperatively. This equates to a nearly six-times higher tobacco cessation rate seen perioperatively compared to attempts made by the general population[10]. Requiring tobacco cessation prior to elective arthroplasty can help patients effectively obtain and maintain tobacco abstinence. This highlights an important opportunity for patients and providers to make concerted efforts towards tobacco cessation to positively impact patient outcomes.

CONCLUSION

Tobacco use is a well-documented modifiable risk factor for many negative outcomes in orthopedic surgery including higher rates of wound complications and infection. Many institutions encourage tobacco cessation prior to elective surgery. It is estimated that only 7.5% of all tobacco cessation attempts are successful. Reports suggest higher rates of abstinence can be achieved surrounding elective surgery[11,14]. Here, we report a cessation rate of 43.2% in patients undergoing elective TJA. Most of these patients did not use cessation aids for assistance. Patients undergoing TJA who were able to remain abstinent from tobacco products postoperatively had improved PROMIS-10 mental health scores and HOOS. JR scores. The perioperative period provides clinicians a unique opportunity to assist active tobacco smokers with durable cessation efforts.

FOOTNOTES

Author contributions: Kim BI was responsible for data collection, data curation, formal analysis, draft writing, draft review and editing; O'Donnell J was responsible for conceptualization, data collection, data curation, draft writing, draft review and editing; Wixted CM was

responsible for data collection, draft review and editing; Seyler TM was responsible for supervision, methodology, draft review and editing; Bolognesi MP was responsible for supervision, methodology, draft review and editing; Jiranek WA was responsible for supervision, methodology, draft review and editing; Ryan SP was responsible for supervision, conceptualization, methodology, resources, draft review and editing.

Institutional review board statement: Institutional Review Board (IRB) approval was obtained prior to conducting this study.

Informed consent statement: Verbal patient consent for phone interview participation in the study was obtained.

Conflict-of-interest statement: The authors report no conflicts of interest related to this study.

Data sharing statement: Please contact the corresponding author for data sharing.

Country of origin: United States

ORCID number: Billy Insup Kim 0000-0002-1519-6566; Thorsten Markus Seyler 0000-0003-1157-132X; Michael Paul Bolognesi 0000-0003-1414-6863; Sean Patrick Ryan 0000-0003-4079-969X.

S-Editor: Luo ML
L-Editor: Filipodia
P-Editor: Zhang XD

REFERENCES

1 **Centers for Disease Control and Prevention**. Smoking and Tobacco Use Fast Facts. Available from: https://www.cdc.gov/tobacco/data_statistics/fact_sheets/fast_facts/index
2 **American Cancer Society**. Health Risks of Smoking Tobacco. Available from: https://www.cancer.org/healthy/stay-away-from-tobacco/health-risks-of-tobacco/health-risks-of-smoking-tobacco
3 **Castillo RC**, Bosse MJ, MacKenzie EJ, Patterson BM; LEAP Study Group. Impact of smoking on fracture healing and risk of complications in limb-threatening open tibia fractures. *J Orthop Trauma* 2005; **19**: 151-157 [PMID: 15758667 DOI: 10.1097/00005131-200503000-00001]
4 **Peng XQ**, Sun CG, Fei ZG, Zhou QJ. Risk Factors for Surgical Site Infection After Spinal Surgery: A Systematic Review and Meta-Analysis Based on Twenty-Seven Studies. *World Neurosurg* 2019; **123**: e318-e329 [PMID: 30496932 DOI: 10.1016/j.wneu.2018.11.158]
5 **Wiewiorski M**, Barg A, Hoerterer H, Voellmy T, Henninger HB, Valderrabano V. Risk factors for wound complications in patients after elective orthopedic foot and ankle surgery. *Foot Ankle Int* 2015; **36**: 479-487 [PMID: 25550453 DOI: 10.1177/1071100714565792]
6 **Cho BH**, Aziz KT, Giladi AM. The Impact of Smoking on Early Postoperative Complications in Hand Surgery. *J Hand Surg Am* 2021; **46**: 336.e1-336.e11 [PMID: 32868099 DOI: 10.1016/j.jhsa.2020.07.014]
7 **Hatta T**, Werthel JD, Wagner ER, Itoi E, Steinmann SP, Cofield RH, Sperling JW. Effect of smoking on complications following primary shoulder arthroplasty. *J Shoulder Elbow Surg* 2017; **26**: 1-6 [PMID: 27810265 DOI: 10.1016/j.jse.2016.09.011]
8 **Bedard NA**, DeMik DE, Owens JM, Glass NA, DeBerg J, Callaghan JJ. Tobacco Use and Risk of Wound Complications and Periprosthetic Joint Infection: A Systematic Review and Meta-Analysis of Primary Total Joint Arthroplasty Procedures. *J Arthroplasty* 2019; **34**: 385-396 [PMID: 30385090 DOI: 10.1016/j.arth.2018.09.089]
9 **Herrero C**, Tang A, Wasterlain A, Sherman S, Bosco J, Lajam C, Schwarzkopf R, Slover J. Smoking cessation correlates with a decrease in infection rates following total joint arthroplasty. *J Orthop* 2020; **21**: 390-394 [PMID: 32921947 DOI: 10.1016/j.jor.2020.08.026]
10 **Creamer MR**, Wang TW, Babb S, Cullen KA, Day H, Willis G, Jamal A, Neff L. Tobacco Product Use and Cessation Indicators Among Adults - United States, 2018. *MMWR Morb Mortal Wkly Rep* 2019; **68**: 1013-1019 [PMID: 31725711 DOI: 10.15585/mmwr.mm6845a2]
11 **Smith DH**, McTague MF, Weaver MJ, Smith JT. Durability of Smoking Cessation for Elective Lower Extremity Orthopaedic Surgery. *J Am Acad Orthop Surg* 2019; **27**: 613-620 [PMID: 30950909 DOI: 10.5435/JAAOS-D-18-00747]
12 **Boylan MR**, Bosco JA 3rd, Slover JD. Cost-Effectiveness of Preoperative Smoking Cessation Interventions in Total Joint Arthroplasty. *J Arthroplasty* 2019; **34**: 215-220 [PMID: 30482665 DOI: 10.1016/j.arth.2018.09.084]
13 **Thomsen T**, Villebro N, Møller AM. Interventions for preoperative smoking cessation. *Cochrane Database Syst Rev* 2014; **2014**: CD002294 [PMID: 24671929 DOI: 10.1002/14651858.CD002294.pub4]
14 **Hall JRL**, Metcalf R, Leisinger E, An Q, Bedard NA, Brown TS. Does Smoking Cessation Prior to Elective Total Joint Arthroplasty Result in Continued Abstinence? *Iowa Orthop J* 2021; **41**: 141-144 [PMID: 34552416]
15 **Darrith B**, Khalil LS, Franovic S, Bazydlo M, Weir RM, Banka TR, Davis JJ. Preoperative Patient-Reported Outcomes Measurement Information System Global Health Scores Predict Patients Achieving the Minimal Clinically Important Difference in the Early Postoperative Time Period After Total Knee Arthroplasty. *J Am Acad Orthop Surg* 2021; **29**: e1417-e1426 [PMID: 34061813 DOI: 10.5435/JAAOS-D-20-01288]
16 **Lyman S**, Lee YY, McLawhorn AS, Islam W, MacLean CH. What Are the Minimal and Substantial Improvements in the HOOS and KOOS and JR Versions After Total Joint Replacement? *Clin Orthop Relat Res* 2018; **476**: 2432-2441 [PMID: 30179951 DOI: 10.1097/CORR.0000000000000456]
17 **Gilpin EA**, Pierce JP, Farkas AJ. Duration of smoking abstinence and success in quitting. *J Natl Cancer Inst* 1997; **89**: 572-576 [PMID: 9106646 DOI: 10.1093/jnci/89.8.572]

18 **Bender D**, Haubruck P, Boxriker S, Korff S, Schmidmaier G, Moghaddam A. Validity of subjective smoking status in orthopedic patients. *Ther Clin Risk Manag* 2015; **11**: 1297-1303 [PMID: 26345646 DOI: 10.2147/TCRM.S86212]

World Journal of Orthopedics

Submit a Manuscript: https://www.f6publishing.com

World J Orthop 2024 July 18; 15(7): 635-641

DOI: 10.5312/wjo.v15.i7.635

ISSN 2218-5836 (online)

ORIGINAL ARTICLE

Retrospective Study

Prevalence and associated factors of clubfoot in the eastern province of Saudi Arabia: A hospital-based study

Ammar K Alomran, Bandar A Alzahrani, Bader S Alanazi, Mohammed A Alharbi, Loay M Bojubara, Eman M Alyaseen

Specialty type: Orthopedics

Provenance and peer review: Unsolicited article; Externally peer reviewed.

Peer-review model: Single blind

Peer-review report's classification

Scientific Quality: Grade C, Grade C, Grade D

Novelty: Grade C, Grade C, Grade C

Creativity or Innovation: Grade C, Grade C, Grade C

Scientific Significance: Grade C, Grade C, Grade C

P-Reviewer: Li XM; Yang LY

Received: March 6, 2024

Revised: May 30, 2024

Accepted: June 18, 2024

Published online: July 18, 2024

Processing time: 127 Days and 15 Hours

Ammar K Alomran, Bandar A Alzahrani, Department of Orthopedic, College of Medicine, Imam Abdulrahman bin Faisal University, Dammam 34212, Saudi Arabia

Bader S Alanazi, Mohammed A Alharbi, Loay M Bojubara, College of Medicine, Imam Abdulrahman bin Faisal University, Dammam 34212, Saudi Arabia

Eman M Alyaseen, College of Medicine, Arabian Gulf University, Manama 329, Bahrain

Corresponding author: Ammar K Alomran, MBBS, Assistant Professor, Department of Orthopedic, College of Medicine, Imam Abdulrahman bin Faisal University, King Faisal St. Dammam 34212, Saudi Arabia. aomran@iau.edu.sa

Abstract

BACKGROUND

Clubfoot, or congenital talipes equinovarus, is a widely recognized cause of disability and congenital deformity worldwide, which significantly impacts the quality of life. Effective management of clubfoot requires long-term, multidisciplinary intervention. It is important to understand how common this condition is in order to assess its impact on the population. Unfortunately, few studies have investigated the prevalence of clubfoot in Saudi Arabia.

AIM

To determine the prevalence of clubfoot in Saudi Arabia *via* the patient population at King Fahad University Hospital (KFUH).

METHODS

This was a retrospective study conducted at one of the largest hospitals in the country and located in one of the most densely populated of the administrative regions.

RESULTS

Of the 7792 births between 2015 to 2023 that were included in the analysis, 42 patients were diagnosed with clubfoot, resulting in a prevalence of 5.3 per 1000 live births at KFUH.

CONCLUSION

The observed prevalence of clubfoot was significantly higher than both global and local estimates, indicating a substantial burden in the study population.

Key Words: Clubfoot; Talipes equinovarus; Congenital talipes equinovarus; Prevalence; Saudi Arabia

Core Tip: Clubfoot, or congenital talipes equinovarus, is a congenital deformity with global impact, but comprehensive prevalence data for Saudi Arabia are lacking. This study at King Fahad University Hospital aimed to address this gap by analyzing 7792 births that occurred between 2015 and 2023. The analysis revealed a prevalence of 5.3 per 1000 live births, which is higher than global estimates and indicates a substantial burden. The findings emphasize the urgency of targeted interventions to address clubfoot in the Eastern Province of Saudi Arabia.

Citation: Alomran AK, Alzahrani BA, Alanazi BS, Alharbi MA, Bojubara LM, Alyaseen EM. Prevalence and associated factors of clubfoot in the eastern province of Saudi Arabia: A hospital-based study. *World J Orthop* 2024; 15(7): 635-641
URL: https://www.wjgnet.com/2218-5836/full/v15/i7/635.htm
DOI: https://dx.doi.org/10.5312/wjo.v15.i7.635

INTRODUCTION

Congenital talipes equinovarus (CTEV), often called clubfoot, is a congenital condition characterized by cavus, adductus, varus, and equinus deformities of the leg. CTEV was first observed by Hippocrates in 300 BC[1]. It is one of the most frequently encountered foot abnormalities, and it can be seen immediately after birth[2]. CTEV patients have been known to have certain tibial and tarsal bone anatomical abnormalities, including mispositioned tarsal bones that result in high metatarsal bone flexion, increased planter arch curvature, equines foot with inverted, adducted calcaneus due to postero-medial foot ligament contracture, calf muscle atrophy, and foot shortening. There are no histologic or electric abnormalities[3,4]. In 80% of cases, it presents by itself as an isolated malformation. It may present as syndromic CTEV secondary to other congenital anomalies such as spina bifida (myelomeningocele), arthrogryposis, or dystrophic dwarfism. That increases the risk of morbidity, mortality, and resistance to treatment[5,6].

CTEV can be a bilateral or unilateral deformity, with the right leg more commonly affected[2]. Despite extensive epidemiological, clinical, and basic science research, the etiology of club foot remains unclear. Most of investigations suggest a genetic component is involved, but that is inconsistent with the Mendelian inheritance pattern. Several studies have observed that CTEV was associated with deletion of *CASP10*, an apoptosis regulatory gene on chromosome 2 (2q31-33)[7]. Other suggested causes include abnormalities of joint and/or bone formation, uterine restriction (oligohydr-amnios), and neurological and vascular abnormalities that occur in the second trimester of pregnancy[1,8]. Numerous studies have reported male sex, maternal age, maternal smoking, maternal marital status, maternal education, and maternal diabetes as associated with increased risk of CTEV[9].

Classification of CTEV is essential to score the severity of CTEV at birth and to assess the outcome of treatment. While several classification systems have been developed in the last 50 years[10], the Dimeglio scale and Pirani score are the most commonly used clinical systems to assess the severity of CTEV[11]. Prognosis depends on associated conditions but is generally excellent for cases of isolated CTEV[12]. Conservative nonsurgical treatments include manipulation and casting. Surgical techniques include soft tissue release and bone procedures[11]. However, conservative management is widely accepted due to the high risk of post-surgical complications[12]. Conservative treatments include the Kite method, physiotherapy, and the Ponseti method. The Ponseti method has recently been recognized as the most effective treatment with minimal complications in both isolated and syndromic cases, including idiopathic or syndromic comorbidities[6,11]. Inadequate treatment of CTEV can lead to lifelong disabilities, chronic pain, and limited opportunities for education and employment[13], King Faisal street[14].

The incidence and prevalence of CTEV vary with race and ethnicity. Globally, there are 0.6-1.5 cases of CTEV per 1000 live births per year, with a total of 150000 infants being affected annually. CTEV is thus one of the most common birth defects in children. Bilateral CTEV occurs in approximately 50% of cases, with a male-to-female ratio of 2:1[4,15,16]. Kruse *et al*[17] described the sex difference as the Carter effect, with girls having more predisposing genes than boys and the ability to transmit them to their offspring. About 80% of CTEV cases have been reported in low-middle income countries [2] and CTEV is estimated to affect 2.3/1000 (0.23%) of Saudis visiting King Saud Medical City[18]. In order to understand the impact and burden of CTEV on the population, it is important to determine its prevalence. Unfortunately, few studies have been conducted on the prevalence of CTEV in Saudi Arabia.

This study investigated the prevalence of CTEV in the Eastern Province of Saudi Arabia, with a specific focus on King Fahad University Hospital (KFUH). The goal was to better understand the prevalence of this condition in this country. The findings of the study increase the understanding of CTEV and can help guide future interventions and healthcare planning.

MATERIALS AND METHODS

Data was collected from patient medical profiles in the QuadraMed system (QuadraMed Corp., Plano, TX, United States) and the database at the KFUH Orthopedic Department.

Study setting/subject

The research was carried out at KFUH. With a capacity of 540 beds, it is the largest university hospital in the Eastern Province of Saudi Arabia. Saudi patients of both sexes who were diagnosed with CTEV between 2015 and 2023, had medical records with complete diagnostic and patient information, and were 0-5 years of age, were eligible to participate in this study. We conducted a comprehensive evaluation that included all instances of isolated CTEV as well as those accompanied by additional idiopathic or syndromic comorbidities.

Study design

This was a retrospective, descriptive, cross-sectional study. This design was chosen because its analytical data capabilities suit the purpose of this study.

Sampling technique

The sample was assessed by examining medical files included in a list provided by the orthopedic department's database and the QuadraMed program at KFUH. There were 42 cases of CTEV, 38 of which had been born in the hospital. Four cases had been born in the Maternal and Child Hospital, which is a part of the University Hospital and is located near the main building. Thirty-nine of the cases were diagnosed clinically by physical examination and three were identified by prenatal ultrasonography. The diagnosis was primarily by physical examination that identified CTEV deformities including midfoot cavus, forefoot adduction, and hindfoot equinus and valgus.

Data collection

Following approval by the hospital's Institutional Review Board, the required data were obtained from medical files by a medical student who was supervised by two orthopedic physicians from KFUH.

Data management

The study results were reported as frequencies and percentages and the analysis were performed with Statistical Package for the Social Sciences version 20 (IBM Corp., Armonk, NY, United States).

RESULTS

Patient characteristics

A total of 7792 births at KFUH between 2015 and 2023 were included in the analysis. CTEV was diagnosed in 42 children, resulting in a prevalence of 5.3 per 1000 live births. The male-to-female ratio was 2.23:1.00 with 69% male and 31% female patients. The epidemiological description of CTEV was obtained from data on these 42 cases that was collected by the Orthopedics Department at KFUH. Table 1 describes the characteristics of the patients and Table 2 lists the associated medical conditions. Stacked bar charts in Figure 1 were used to outline the frequencies of idiopathic and non-idiopathic CTEV from 2016 to 2022. There were no cases in 2015 and 2023.

Analysis of the related factors

A multiple regression analysis was conducted to examine the association of various demographic and clinical parameters and the occurrence of CTEV. The outcomes revealed several significant predictors. Initially, the presence of maternal chronic illness (β coefficient = 0.02 and $P = 0.45$) and familial predisposition to CTEV (β coefficient = 0.08 and $P = 0.29$) were not significantly predictive. Developmental dysplasia of the hip (DDH) (β coefficient = 0.31 and $P < 0.001$) was significantly predictive of CTEV. In particular, CTEV occurrence was estimated to be 2.5-fold more likely in individuals with DDH than in those without DDH. Regarding the sidedness of CTEV, bilateral manifestation was significantly associated with the presence of DDH (β coefficient = 0.22 and $P = 0.003$). In addition, DDH was significantly associated with unilateral CTEV (β coefficient = 0.18 and $P = 0.012$). In the cohort presenting with associated ailments, arthrogryposis, hydrocephalus, myelomeningocele, undescended testicle, sacrococcygeal teratoma, spina bifida, and congenital insensitivity to pain syndrome, all emerged as noteworthy and significant prognosticators of CTEV onset, with varying β-coefficients and corresponding *P* values. Furthermore, the collective presence of these associated maladies explained a substantial proportion of the variance observed in CTEV occurrence ($R^2 = 0.45$, $F_{8,33} = 12.54$, $P < 0.001$).

DISCUSSION

CTEV, or clubfoot, is one of the most common causes of disability and congenital deformity worldwide, and it significantly impacts quality of life. CTEV management requires long-term multidisciplinary intervention. Determining the prevalence of this condition is crucial for assessing the impact of CTEV in Saudi Arabia. The prevalence of CTEV in

Table 1 Characteristics of patients seen in the pediatric orthopedic clinic at King Fahad University Hospital, *n* (%)

Characteristic	Total, *n* = 42
Sex	
Male	29 (69.0)
Female	13 (31.0)
Clubfoot	
Bilateral	27 (64.3)
Unilateral	15 (35.7)
Right	8 (19.0)
Left	7 (16.7)
Developmental dysplasia of the hip	
Yes	4 (9.5)
No	38 (90.5)
Maternal history of chronic disease	
Diabetes mellitus	1 (2.4)
None	41 (97.6)

Table 2 Associated medical condition of patients seen in pediatric orthopedic clinic at King Fahad University Hospital, *n* (%)

Associated medical condition	Total, *n* = 42
Arthrogryposis	3 (7)
Hydrocephalus	3 (7)
Myelomeningocele	3 (7)
Undescended testicle	2 (4)
Sacrococcygeal teratoma	1 (2)
Spina bifida	1 (2)
Congenital insensitivity to pain syndrome	1 (2)
None	28 (67)

this birth cohort at KFUH in Saudi Arabia's Eastern Province was 5-times higher than the global estimate. KFUH is one of the largest hospitals in one of the five most densely populated of the 13 administrative regions in Saudi Arabia.

As shown in this study, the prevalence of CTEV among 7792 births at KFUH was 5.3 per 1000 live births. This result is considerably different from findings of global and local studies. Of the 42 CTEV patients, 7 required surgical intervention owing to a late diagnosis, which is often made after the 1st year of life. At the 5-year follow-up, both the surgically treated and conservatively treated cohorts had similar functional outcomes, including walking age, walking distance, athletic participation, stair climbing ability, and foot pain complaints. Table 3 presents a detailed comparison of the clinical results between patients with clubfoot who underwent surgical intervention and those who underwent conservative treatment. The analysis did identify significant risk factors within the cohort. Parental consanguinity was present in 36 cases. Prolonged labor, exceeding the standard duration of 24 hours, was noted in 33 cases. Breech presentation occurred in 17 cases. Additionally, 28 cases had associated neuromuscular syndromes, as previously detailed. Table 4 highlights these risk factors and their significance. A 2017 estimate of the average global prevalence of CTEV in children less than 5 years of age was 0.9 per 1000 live births, or 675061 cases in a population of 675100000 children[13]. Asia had the highest CTEV prevalence[13]. A study of the prevalence of CTEV in Europe in 2019 estimated that it was 1.13 per 1000 live births [18]. Our study findings revealed a prevalence approximately 5-times higher than the global estimate. A previous study in Saudi Arabia also reported that the overall rates and incidence of congenital disease and malformation were above average compared to the other parts of the world[19]. The high incidence of CTEV is probably related to the high rate of consanguineous marriage, which others have shown to contribute to the prevalence and risk of CTEV. A previous study found that in 31% of the CTEV cases, the parents were related (*i.e.*, first- or second-degree cousins)[15]. In Turkey, where consanguineous marriages are frequent, studies have demonstrated that children born to first-cousin parents had a significantly increased prevalence of CTEV, with a risk of idiopathic CTEV that was over 4-times higher than the average [20,21]. However, a study conducted in China, where consanguinity is uncommon, found a prevalence of 4.27-7.00 per

Table 3 Characteristics of patients seen in pediatric orthopedic clinic at King Fahad University Hospital

Clinical outcome	Surgical treatment (mean ± SD)	Conservative treatment (mean ± SD)	*P* value
Walking age (months)	15 ± 3	16 ± 4	0.01
Walking distance (meters)	500 ± 50	480 ± 70	0.02
Athletic participation	80%	75%	0.02
Stair climbing ability	Good	Good	0.01
Foot pain complaint	30%	27%	0.02

Table 4 Significant risk factors and their statistical significance

Risk factor	Number of cases	SD	*P* value
Parental consanguinity	36	4.2	0.045
Prolonged labor (> 24 hours)	33	3.9	0.021
Breech presentation	17	2.8	0.072
Presence of neuromuscular conditions	28	4.0	0.032

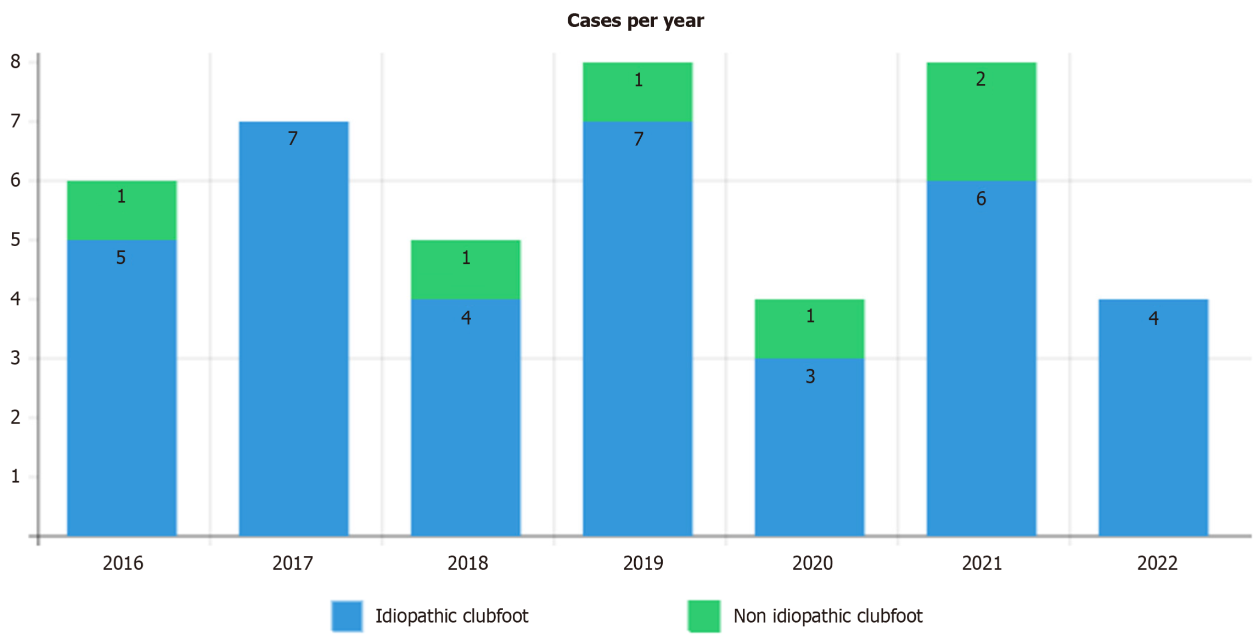

Figure 1 Distribution of cases per year from 2016 to 2022.

1000 live births[22]. A hospital-based study conducted in Riyadh, Saudi Arabia with a sample size of 18515 births found a prevalence of 2.2 per 1000 live births[15]. Studies in China and the United States reported prevalences of congenital CTEV in male and female babies of 5.31 and 4.30 per 10000 births, respectively[22,23]. In our study the male-to-female ratio of 2.23:1.00 indicated that male sex was associated with the risk of CTEV in this birth cohort.

Various factors that may contribute to an increased risk of developing CTEV have been identified. These include maternal and paternal smoking, family history, exposure to amniocentesis and selective serotonin reuptake inhibitors, gestational diabetes, nulliparity, and male sex. A comprehensive meta-analysis and systematic review of 42 studies (28 case-control, 10 cohort, and 4 randomized trial) comprising 31844 CTEV cases and 6604013 controls that was conducted in 2018 confirmed the significance of previously identified risk factors[24]. In it, 10% of the mothers had chronic diseases, with asthma, hypertension, and diabetes mellitus accounting for 5%, 3%, and 2%, respectively. In addition, a family history of CTEV was present in 5% of the cases, a relatively low rate compared to both local and global studies[5,18]. Such a low percentage could have been the consequence of a small sample size, as in a single-hospital based study.

Several associated conditions have been observed among CTEV cases, including asthma, speech difficulties, undescended testis, and DDH. However, all these conditions occur in an insignificant number of CTEV cases, representing only 2% for each[25,26]. First, asthma is among the most common chronic diseases in Saudi Arabia, with an estimated prevalence of 14.3%[21]. Consequently, asthma and CTEV have a weak association, as shown in this study, based on the relatively small sample. Second, speech difficulties and undescended testis also comprised an insignificant percentage. These points should be further investigated in a larger sample to give a well-determined strength of association.

DDH is one of the most critical anomalies associated with CTEV. In a prospective study of 101 cases, 16 were associated with mild DDH and 1 case met the acetabular index criteria of severe DDH (*i.e.*, Tönnis angle)[27]. Moreover, an observational study including 119 cases found that 9 were diagnosed with DDH[26]. In this study, the incidence of DDH was relatively high compared to other studies in which 7% of the cases were diagnosed with DDH. However, another local study showed nearly double this percentage[25]. This study found a significant difference in the laterality of the condition, with 68% of the patients affected bilaterally and 38% unilaterally. The right foot was involved in 19% of the unilateral cases and the left foot was involved in 17%. This difference was not significant in other studies[26,27].

This study has potential limitations. First, it was conducted at a single hospital, focused on a specific region in Saudi Arabia, and may not be represent the entire population. Therefore, caution should be exercised in generalizing the findings to the broader Saudi population. Second, the past medical history of mothers was not adequately documented, which could affect the reliability of the reported chronic diseases. Further study is needed to explore associated conditions and their prevalence in greater detail, using larger sample sizes and more diverse settings.

CONCLUSION

This study provides valuable insights into the prevalence of CTEV in Saudi Arabia, specifically in the Eastern Province. The study population had a significant burden of CTEV, with a higher prevalence than both global and local statistics. Comprehensive interventions and healthcare planning are needed to manage and address the associated conditions of CTEV in Saudi Arabia. More study is needed to better understand the prevalence of CTEV and associated factors in Saudi Arabia.

FOOTNOTES

Author contributions: Alomran AK, Alzahrani BA, and Alanazi BS designed the research study; Alzahrani BA, Alanazi BS, and Alharbi MA performed the research; Alomran AK, Alzahrani BA, Alanazi BS, Alharbi MA, Bojubara LM, and Alyaseen EM analyzed the data and wrote the manuscript; and all authors critically examined and approved the final text, and agreed to be responsible for the manuscript's content and similarity index.

Institutional review board statement: This study was reviewed and approved by the Institutional Review Board of Imam Abdulrahman bin Faisal University (Approval No. HAP-05-D-003).

Informed consent statement: The need for patient consent was waived due to the retrospective nature of the study.

Conflict-of-interest statement: All the authors report having no relevant conflicts of interest for this article.

Data sharing statement: No additional data are available.

Country/Territory of origin: Saudi Arabia

ORCID number: Ammar K Alomran 0000-0001-6659-5105; Bandar A Alzahrani 0009-0000-9911-4179.

S-Editor: Chen YL
L-Editor: A
P-Editor: Zhang XD

REFERENCES

1 **Naveed A**, Fatima SA, Riaz S, Awan SS, Waqas MS, Aslam S. Prevalence of leg pain and knee contractures in children having clubfoot. *Rawal Med J* 2021; **46**: 587-588

2 **Cady R**, Hennessey TA, Schwend RM. Diagnosis and Treatment of Idiopathic Congenital Clubfoot. *Pediatrics* 2022; **149** [PMID: 35104362 DOI: 10.1542/peds.2021-055555]

3 **Mustari MN**, Faruk M, Bausat A, Fikry A. Congenital talipes equinovarus: A literature review. *Ann Med Surg (Lond)* 2022; **81**: 104394 [PMID: 36147065 DOI: 10.1016/j.amsu.2022.104394]

4 **Rendy G**, Dwi Winanto I, Ilham Abdullah Irsyam O. The effect of socioeconomic fac-tors on the first visit of a clubfoot to a health facility.

IJRP 2022; **101** [DOI: 10.47119/IJRP1001011520223187]

5 **Panza R**, Albano F, Casto A, Del Vecchio C, Laforgia N, Dibello D. Incidence and prevalence of congenital clubfoot in Apulia: a regional model for future prospective national studies. *Ital J Pediatr* 2023; **49**: 151 [PMID: 37964341 DOI: 10.1186/s13052-023-01559-9]

6 **Pavone V**, Chisari E, Vescio A, Lucenti L, Sessa G, Testa G. The etiology of idiopathic congenital talipes equinovarus: a systematic review. *J Orthop Surg Res* 2018; **13**: 206 [PMID: 30134936 DOI: 10.1186/s13018-018-0913-z]

7 **Yolaçan H**, Güler S, Özmanevra R. Clubfoot from past to the present: A bibliometric analysis with global productivity and research trends. *Medicine (Baltimore)* 2023; **102**: e32803 [PMID: 36820544 DOI: 10.1097/MD.0000000000032803]

8 **Maghfuri HB**, Alshareef AA. The Efficacy of the Ponseti Method in the Management of Clubfoot: A Systematic Review. *Cureus* 2024; **16**: e52482 [PMID: 38371124 DOI: 10.7759/cureus.52482]

9 **Smythe T**, Rotenberg S, Lavy C. The global birth prevalence of clubfoot: a systematic review and meta-analysis. *EClinicalMedicine* 2023; **63**: 102178 [PMID: 37680947 DOI: 10.1016/j.eclinm.2023.102178]

10 **Arianto HF**, Faesal A Maodah, Yunus Abdul Bari. Talipes Equinovarus (TEV) and VACTREL Associated Anomalies: Narrative Literature Review. *Bioscmed* 2022; **6**: 2014-2022 [DOI: 10.37275/bsm.v6i7.548]

11 **Van Schelven H**, Moerman S, Van der Steen M, Besselaar AT, Greve C. Prognostic factors for recurrent idiopathic clubfoot deformity: a systematic literature review and meta-analysis. *Acta Orthop* 2022; **93**: 11-28 [PMID: 34607499 DOI: 10.1080/17453674.2021.1982576]

12 **Society for Maternal-Fetal Medicine**, McKinney J, Rac MWF, Gandhi M. Congenital talipes equinovarus (clubfoot). *Am J Obstet Gynecol* 2019; **221**: B10-B12 [PMID: 31787157 DOI: 10.1016/j.ajog.2019.09.022]

13 **Dave M**, Rankin J, Pearce M, Foster HE. Global prevalence estimates of three chronic musculoskeletal conditions: club foot, juvenile idiopathic arthritis and juvenile systemic lupus erythematosus. *Pediatr Rheumatol Online J* 2020; **18**: 49 [PMID: 32532304 DOI: 10.1186/s12969-020-00443-8]

14 **Alosaimi MA**, Jawhari AM, Amin OA, Alzahrani ES, Alomar MO, Nouri MT, Altalhi MJ, Marzogi AA. Community Awareness of Congenital Talipes Equinovarus (Clubfoot) in Makkah Region, Saudi Arabia: A Cross-Sectional Study. *Cureus* 2022; **14**: e30602 [PMID: 36420226 DOI: 10.7759/cureus.30602]

15 **Fakeeha JH**, Alessa AE, Alkhaldi MS, Alshathri MH, Althunayyan AN. Prevalence and epidemiological description of clubfoot at King Saud Medical City, Riyadh, Saudi Arabia. *JMSR* 2021; **5**: 246-249 [DOI: 10.25259/JMSR_60_2021]

16 **Stoll C**, Alembick Y, Dott B, Roth MP. Associated anomalies in cases with congenital clubfoot. *Am J Med Genet A* 2020; **182**: 2027-2036 [PMID: 32592281 DOI: 10.1002/ajmg.a.61721]

17 **Kruse LM**, Dobbs MB, Gurnett CA. Polygenic threshold model with sex dimorphism in clubfoot inheritance: the Carter effect. *J Bone Joint Surg Am* 2008; **90**: 2688-2694 [PMID: 19047715 DOI: 10.2106/JBJS.G.01346]

18 **Wang H**, Barisic I, Loane M, Addor MC, Bailey LM, Gatt M, Klungsoyr K, Mokoroa O, Nelen V, Neville AJ, O'Mahony M, Pierini A, Rissmann A, Verellen-Dumoulin C, de Walle HEK, Wiesel A, Wisniewska K, de Jong-van den Berg LTW, Dolk H, Khoshnood B, Garne E. Congenital clubfoot in Europe: A population-based study. *Am J Med Genet A* 2019; **179**: 595-601 [PMID: 30740879 DOI: 10.1002/ajmg.a.61067]

19 **Fida NM**, Al-Aama J, Nichols W, Nichols W, Alqahtani M. A prospective study of congenital malformations among live born neonates at a University Hospital in Western Saudi Arabia. *Saudi Med J* 2007; **28**: 1367-1373 [PMID: 17768462]

20 **Sahin O**, Yildirim C, Akgun RC, Haberal B, Yazici AC, Tuncay IC. Consanguineous marriage and increased risk of idiopathic congenital talipes equinovarus: a case-control study in a rural area. *J Pediatr Orthop* 2013; **33**: 333-338 [PMID: 23482273 DOI: 10.1097/BPO.0b013e3182784af4]

21 **Kurdi AM**, Majeed-Saidan MA, Al Rakaf MS, AlHashem AM, Botto LD, Baaqeel HS, Ammari AN. Congenital anomalies and associated risk factors in a Saudi population: a cohort study from pregnancy to age 2 years. *BMJ Open* 2019; **9**: e026351 [PMID: 31492776 DOI: 10.1136/bmjopen-2018-026351]

22 **Yi L**, Zhou GX, Dai L, Li KS, Zhu J, Wang Y. [An descriptive epidemiological study on congenital clubfoot in China during 2001 to 2010]. *Sichuan Da Xue Xue Bao Yi Xue Ban* 2013; **44**: 606-609 [PMID: 24059118]

23 **Parker SE**, Mai CT, Strickland MJ, Olney RS, Rickard R, Marengo L, Wang Y, Hashmi SS, Meyer RE; National Birth Defects Prevention Network. Multistate study of the epidemiology of clubfoot. *Birth Defects Res A Clin Mol Teratol* 2009; **85**: 897-904 [PMID: 19697433 DOI: 10.1002/bdra.20625]

24 **Chen C**, Kaushal N, Scher DM, Doyle SM, Blanco JS, Dodwell ER. Clubfoot Etiology: A Meta-Analysis and Systematic Review of Observational and Randomized Trials. *J Pediatr Orthop* 2018; **38**: e462-e469 [PMID: 29917009 DOI: 10.1097/BPO.0000000000001191]

25 **Al-Moamary MS**, Alhaider SA, Alangari AA, Idrees MM, Zeitouni MO, Al Ghobain MO, Alanazi AF, Al-Harbi AS, Yousef AA, Alorainy HS, Al-Hajjaj MS. The Saudi Initiative for Asthma - 2021 Update: Guidelines for the diagnosis and management of asthma in adults and children. *Ann Thorac Med* 2021; **16**: 4-56 [PMID: 33680125 DOI: 10.4103/atm.ATM_697_20]

26 **Håberg Ø**, Foss OA, Lian ØB, Holen KJ. Is foot deformity associated with developmental dysplasia of the hip? *Bone Joint J* 2020; **102-B**: 1582-1586 [PMID: 33135434 DOI: 10.1302/0301-620X.102B11.BJJ-2020-0290.R3]

27 **Chou DTs**, Ramachandran M. Prevalence of developmental dysplasia of the hip in children with clubfoot. *J Child Orthop* 2013; **7**: 263-267 [PMID: 24432085 DOI: 10.1007/s11832-013-0523-6]

World Journal of Orthopedics

Submit a Manuscript: https://www.f6publishing.com

World J Orthop 2024 July 18; 15(7): 642-649

DOI: 10.5312/wjo.v15.i7.642

ISSN 2218-5836 (online)

ORIGINAL ARTICLE

Retrospective Study

Arthroscopic M-shaped suture fixation for tibia avulsion fracture of posterior cruciate ligament: A modified technique and case series

Xiao-Hui Zhang, Jian Yu, Meng-Yao Zhao, Jin-Hui Cao, Bing Wu, Dan-Feng Xu

Specialty type: Orthopedics

Provenance and peer review: Unsolicited article; Externally peer reviewed.

Peer-review model: Single blind

Peer-review report's classification

Scientific Quality: Grade C

Novelty: Grade B

Creativity or Innovation: Grade B

Scientific Significance: Grade B

P-Reviewer: Donno L, Italy

Received: March 12, 2024

Revised: May 3, 2024

Accepted: June 11, 2024

Published online: July 18, 2024

Processing time: 121 Days and 18 Hours

Xiao-Hui Zhang, Jian Yu, Meng-Yao Zhao, Jin-Hui Cao, Bing Wu, Dan-Feng Xu, Department of Orthopaedic Surgery, Shaoxing Central Hospital, Shaoxing 312000, Zhejiang Province, China

Xiao-Hui Zhang, Jian Yu, Meng-Yao Zhao, Jin-Hui Cao, Bing Wu, Dan-Feng Xu, Department of Orthopaedic Surgery, The Central Hospital of Shaoxing University, Shaoxing 312000, Zhejiang Province, China

Bing Wu, Dan-Feng Xu, Central Laboratory, Shaoxing Central Hospital, Shaoxing 312000, Zhejiang Province, China

Co-corresponding authors: Jian Yu and Dan-Feng Xu.

Corresponding author: Dan-Feng Xu, MD, PhD, Professor, Surgeon, Department of Orthopaedic Surgery, Shaoxing Central Hospital, No. 1 Hua-yu Road, Keqiao, Shaoxing 312000, Zhejiang Province, China. xdf@zju.edu.cn

Abstract

BACKGROUND

Tibial avulsion fractures of the posterior cruciate ligament (PCL) are challenging to treat and compromise knee stability and function. Traditional open surgery often requires extensive soft tissue dissection, which may increase the risk of morbidity. In response to these concerns, arthroscopic techniques have been evolving. The aim of this study was to introduce a modified arthroscopic technique utilizing an M-shaped suture fixation method for the treatment of tibial avulsion fractures of the PCL and to evaluate its outcomes through a case series.

AIM

To evaluate the effects of arthroscopic M-shaped suture fixation on treating tibia avulsion fractures of the PCL.

METHODS

We developed a modified arthroscopic M-shaped suture fixation technique for tibia avulsion fractures of the PCL. This case series included 18 patients who underwent the procedure between January 2021 and December 2022. The patients were assessed for range of motion (ROM), Lysholm score and International knee documentation committee (IKDC) score. Postoperative complications were also recorded.

RESULTS
The patients were followed for a mean of 13.83 ± 2.33 months. All patients showed radiographic union. At the final follow-up, all patients had full ROM and a negative posterior drawer test. The mean Lysholm score significantly improved from 45.28 ± 8.92 preoperatively to 91.83 ± 4.18 at the final follow-up (P < 0.001), and the mean IKDC score improved from 41.98 ± 6.06 preoperatively to 90.89 ± 5.32 at the final follow-up (P < 0.001).

CONCLUSION
The modified arthroscopic M-shaped suture fixation technique is a reliable and effective treatment for tibia avulsion fractures of the PCL, with excellent fracture healing and functional recovery.

Key Words: Posterior cruciate ligament; Avulsion fracture; Arthroscopic; Case series; Suture fixation

Core Tip: In this study, we describe a novel modification to the arthroscopic M-shaped suture fixation approach for tibial avulsion fractures of the posterior cruciate ligament (PCL), which emphasizes the creation of a suture fixation configuration resembling the letter "M", intended to achieve a more secure anatomical fixation of the avulsed bony fragment to the tibia. And we evaluate its outcomes through a case series. Our results showed that our modified arthroscopic treatment of PCL tibial avulsion fractures provides good clinical outcomes, radiologic healing, and knee stability. This fixation technique is worthy of widespread promotion.

Citation: Zhang XH, Yu J, Zhao MY, Cao JH, Wu B, Xu DF. Arthroscopic M-shaped suture fixation for tibia avulsion fracture of posterior cruciate ligament: A modified technique and case series. *World J Orthop* 2024; 15(7): 642-649
URL: https://www.wjgnet.com/2218-5836/full/v15/i7/642.htm
DOI: https://dx.doi.org/10.5312/wjo.v15.i7.642

INTRODUCTION

The posterior cruciate ligament (PCL) is a critical stabilizer of the knee that maintains posterior and rotational stability during motion[1]. Injury to the PCL disrupts this normal kinetic functionality, leading to altered joint mechanics and increased joint instability, particularly in the anterior-posterior direction[2,3]. The PCL avulsion fracture is a rare form of PCL injury that is usually caused by high-energy events, such as motorcycle accidents, dashboard contact and hyper-flexion[4]. Tibial avulsion fractures, wherein the PCL is intact but its bony attachment to the tibia is compromised, necessitate timely and effective treatment to restore joint stability and prevent the development of chronic knee issues, such as osteoarthritis[5].

While conservative management may be considered for nondisplaced avulsion fractures, surgical intervention is typically indicated for displaced fractures to re-establish joint stability and function[6,7]. Traditionally, open surgical techniques have been the mainstay for the fixation of tibial avulsion fractures. However, with advancements in arthroscopic technology, minimally invasive approaches have evolved[8]. Arthroscopy offers the benefits of minimal soft tissue dissection, lower infection risk, faster recovery, and the ability to assess and address intra-articular pathology concurrently.

Despite these advantages, arthroscopic fixation of tibial avulsion fractures has several challenges, including difficulty in reliably securing the avulsion fracture, as well as the high technical demands of the procedure. Various suture and fixation techniques have been described in the literature, and they have all been proven to be effective[9-13]. Nevertheless, the evolution of this technique continues as improvements are sought to optimize clinical outcomes and address technical limitations. Hence, we introduce a novel modification to the arthroscopic M-shaped suture fixation approach for tibial avulsion fractures of the PCL, which emphasizes the creation of a suture fixation configuration resembling the letter "M", intended to achieve more secure anatomical fixation of the avulsed bony fragment to the tibia.

In this study, we describe the modified technique, present a case series, delineate its surgical principles, and share our clinical outcomes with a focus on the safety, efficiency and stability imparted by this approach.

MATERIALS AND METHODS

This case series included patients with tibia avulsion fractures of the PCL who underwent arthroscopic M-shaped suture fixation at our institution between January 2021 and December 2022. The inclusion criteria were as follows: (1) Tibia avulsion fracture of the PCL confirmed by X-ray, computed tomography (CT) scan, or magnetic resonance imaging (MRI); (2) Meyers-McKeever class II or III fracture[14]; (3) Waiting time from injury to operation less than 3 weeks; and (4) No preoperative joint dysfunction or history of knee injury. The exclusion criteria were as follows: (1) Anterior cruciate ligament (ACL) injuries, collateral ligament injuries, or severe multiple-ligament injuries; (2) Distal femoral or proximal tibial fractures; (3) Severe neurovascular injury; and (4) Follow-up periods < 12 months. Ethical approval was obtained from the Ethics Committee of our hospital, and informed consent was obtained from all patients.

Surgical technique

All surgeries were performed by the same experienced orthopedic surgeon. The surgery was performed under general or spinal anesthesia with the patient in the supine position.

An anterolateral portal was established at the inferior level of the patella and slightly superior to the lateral aspect of the patellar tendon, and a conventional anteromedial portal (AM) was created. An arthroscope was used to inspect the joint space and to diagnose concomitant intra-articular ligament and meniscal lesions. The space between the ACL and PCL was opened carefully using a shaver, and then the arthroscope was passed through the anterior and PCL space to the posterior joint capsule. The affected limb was placed in the 4-font position. Afterward, two posterior medial incisions, upper and lower, were made under direct arthroscopic visualization. The posterior joint capsule was appropriately opened, and the gastrocnemius tendon was protected.

The arthroscope was inserted into the posterior joint cavity through the upper posteromedial portal, and both the upper and lower posteromedial portals were used to clean out the posterior joint cavity and expose the PCL avulsion bone fragment. After cleaning the bone bed, the PCL tibia guide was introduced into the posterior compartment through the AM portal. The tips of the guide were placed at the inferolateral or inferomedial corners of the tibial fracture bed. The tips were separated medially and laterally as much as possible and distributed on both sides of the distal bone bed. A 2.5 mm Kirschner guide wire was drilled into the anteromedial tibial cortex (Figure 1A and B). Two tibial tunnels were established.

A hollow catheter was used to pass polydioxanone (PDS) through the front of the PCL through the AM, which was subsequently removed through the posterior medial portal. This PDS suture was used to introduce two Ethicon MB66 sutures (Figure 1C). An epidural needle was used to introduce a PDS suture through one of the tibial tunnels (Figure 1D). This PDS suture was used to draw out both ends of one of the Ethicon MB66 sutures to the tibial tunnel opening (Figure 1E). In the same way, a PDS suture was introduced from another bone tunnel, and this PDS suture was utilized to draw out the two ends of another Ethicon MB66 suture to the tibial tunnel opening.

A suture grasper was used to adjust the position of the two Ethicon MB66 sutures so that the two sutures pressed on the fracture fragment in an "M" shape (Figure 1F). The bone fragments were reduced with the assistance of a probe (Figure 1G and H). The assistant performed the anterior tibial drawer test and tightened the two sutures. The avulsed bone fragment was observed and evaluated. After the fracture fragment was satisfactorily reduced (Figure 1I) and the PCL tension was restored, the sutures were knotted in pairs on the metal button. (The final fixation construct is shown in Figure 2).

Postoperative rehabilitation

The knee was immobilized in full extension for the first 3 weeks. Quadriceps exercises, straight leg raising, and ankle extension training were started immediately after surgery. After 3 weeks, protected passive flexion and extension with a knee brace were permitted. Partial weight bearing using crutches was allowed after 6 weeks. Full weight bearing was allowed after 8 weeks. Patients were encouraged to increase their activity gradually and resume normal life activities 3 months after surgery. Patients were allowed to resume sports activities 6 months after surgery.

Outcome measures

Patients were followed up at regular intervals: 2 weeks, 4 weeks, 2 months, 3 months, 6 months, and 1 year postoperatively. Radiographic assessment (X-ray or CT) was performed immediately after surgery and at each follow-up visit to evaluate the reduction and healing of the fracture. MRI was performed on selected patients. The International knee documentation committee (IKDC) score[15], Lysholm score[16] and range of motion (ROM) were used to evaluate knee joint function. The posterior drawer test was performed to evaluate knee joint laxity.

Statistical analysis

Statistical analyses were performed using SPSS software. Continuous variables are expressed as the mean ± SD, and categorical variables are expressed as counts and percentages. Paired t tests were used to compare the preoperative and postoperative scores. Statistical significance was set at $P < 0.05$.

RESULTS

Patient characteristics

A total of 18 patients (9 males and 9 females) with tibial avulsion fractures of the PCL were included in this case series. The mean age of the patients was 49.72 ± 10.75 years. The injury mechanism was traffic accidents in 15 patients and falls from a height in 3 patients. Patient characteristics are summarized in Table 1.

Surgical outcomes

All patients successfully underwent the modified M-shaped suture fixation technique without intraoperative complications. The average surgical time was 55.28 ± 7.57 minutes, and intraoperative blood loss was minimal, with an average of

Table 1 Patient characteristics data

Characteristics	Summary data
Number of patients (*n*)	18
Age (years)	49.72 ± 10.75
Gender, *n* (%)	
Female	9 (50.0)
Male	9 (50.0)
Body mass index	24.32 ± 2.8
Side, *n* (%)	
Left	13 (72.2)
Right	5 (27.8)
Cause of injury, *n* (%)	
Traffic accident	15 (83.3)
Falls from height	3 (16.7)
Meyers-McKeever classification, *n* (%)	
Type II	7 (38.9)
Type III	11 (61.1)
Operation delay (day)	6.56 ± 3.09
Operation time (minute)	55.28 ± 7.57
Intraoperative blood loss (mL)	11.94 ± 5.46
Follow up (month)	13.83 ± 2.33

11.94 ± 5.46 mL.

Radiographic examination revealed anatomical reduction (Figure 3) and solid union in all patients at the final follow-up. Three patients were selected for postoperative MRI. No displacement or nonunion of the fracture was found.

Functional outcomes

The mean IKDC score improved from 41.98 ± 6.06 preoperatively to 90.89 ± 5.32 at the final follow-up ($P < 0.001$). The mean Lysholm score also significantly improved from 45.28 ± 8.92 preoperatively to 91.83 ± 4.18 at the final follow-up ($P < 0.001$; Table 2).

ROM

The mean ROM improved from 59.17 ± 12.04 degrees preoperatively to 128.6 ± 4.79 degrees at the final follow-up ($P < 0.001$; Table 2). All patients regained full ROM, comparable to that of the uninjured leg. All patients had a negative posterior drawer test at the final follow-up.

Complications

One patient developed mild transient knee effusion, which resolved with conservative management. During the follow-up period, no infections, neurovascular injuries, deep vein thrombosis, or recurrent instabilities were observed.

DISCUSSION

In our case series, we described a modified arthroscopic M-shaped suture fixation technique for the management of tibial avulsion fractures of the PCL. Our results showed that our modified arthroscopic treatment of PCL tibial avulsion fractures provides good clinical outcomes, radiologic healing, and knee stability. This fixation technique is simple, relatively fast, and easily reproducible in routine clinical practice.

The traditional management of displaced PCL tibial avulsion fractures often relies upon open reduction and internal fixation. Although it allows direct visualization and manipulation of the fracture site, it is associated with larger incisions, increased soft tissue damage, and a greater risk of infection, popliteal neurovascular structures, and postoperative stiffness. In contrast, patients who undergo arthroscopic techniques recover faster and have less postoperative pain due to reduced tissue trauma[17]. In our case series, patients showed a favorable recovery trajectory, with a return to preinjury levels of activity within the expected timeframe. This finding was in line with that of a prior study that underscored the

Table 2 Outcomes at the final follow-up

	Preoperative	Final follow-up	*P* value
Lysholm score	45.28 ± 8.92	91.83 ± 4.18	< 0.001
IKDC score	41.98 ± 6.06	90.89 ± 5.32	< 0.001
ROM (degree)	59.17 ± 12.04	128.6 ± 4.79	< 0.001

IKDC: International knee documentation committee; ROM: Range of motion.

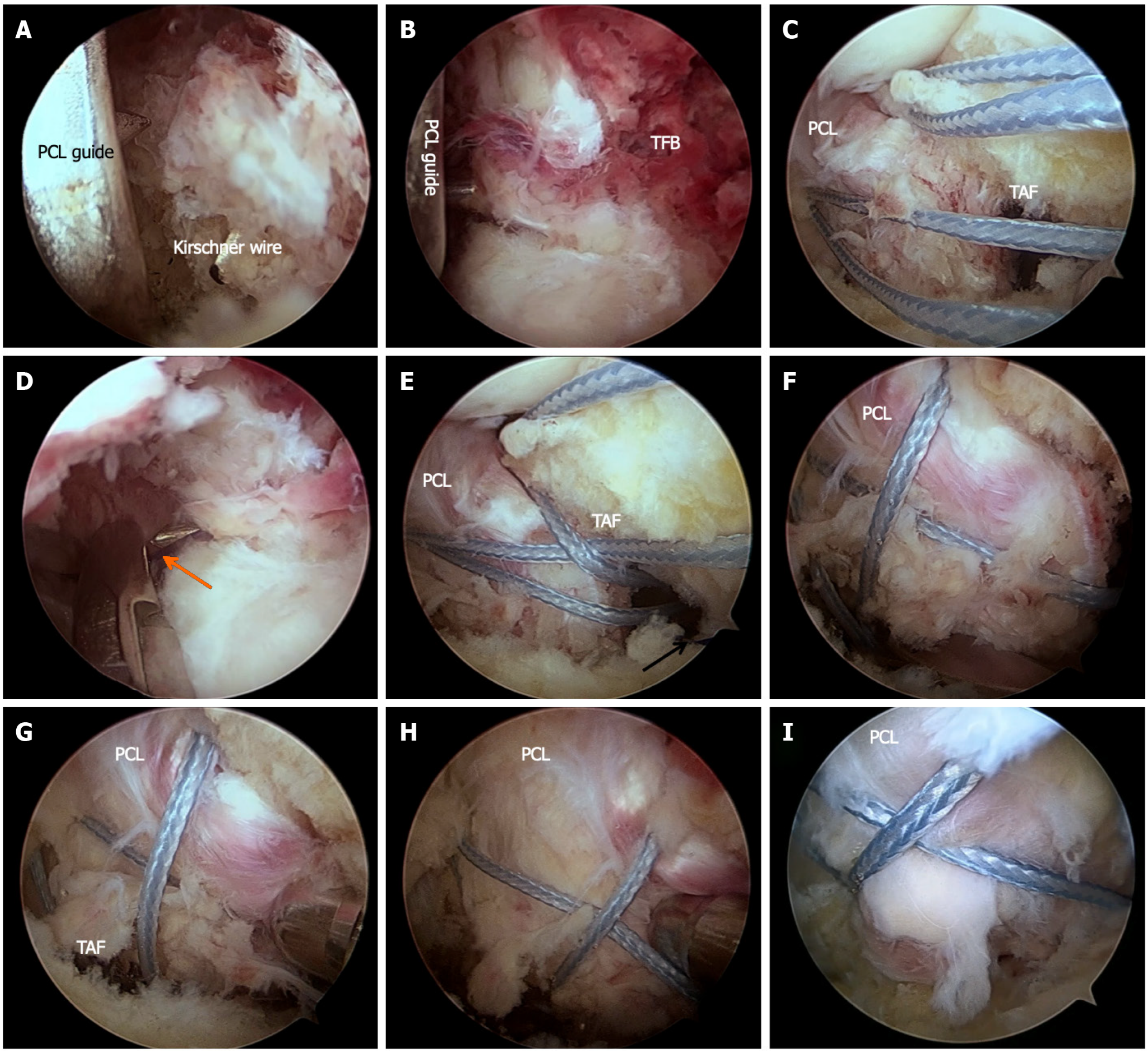

Figure 1 Intraoperative arthroscopic views. A and B: The tips of the guide were placed at the inferolateral or inferomedial corners of the tibial fracture bed. A 2.5 mm Kirschner guide wire was drilled to established two tibial tunnels; C: Two Ethicon MB66 sutures were introduced by polydioxanone (PDS) suture; D: An epidural needle was used to introduce a PDS suture through one of the tibial tunnels; E: Use the PDS suture to draw out both ends of one of the Ethicon MB66 sutures to the tibial tunnel opening; F: A suture grasper was used to adjust the position of the two Ethicon MB66 sutures so that the two sutures pressed on the fracture fragment in an "M" shape; G and H: The bone fragments were reduced with the assistance of a probe; I: The reduction of avulsion fracture was achieved with the tightened suture. PCL: Posterior cruciate ligament; TFB: Tibial fracture bed; TAF: Tibia avulsion fracture; PDS: Polydioxanone.

benefits of arthroscopic approaches for treating PCL injuries[17].

Under arthroscopy, the clinical management of avulsion fractures commonly involves the use of screws[18], wires[19], or sutures[17,20,21]. These methods have all been proven to be effective. Several studies have assessed the outcomes of arthroscopic suture fixation for the treatment of PCL tibial avulsion. Sasaki *et al*[22] showed that there was no significant difference in biomechanical properties between fixations using screws and those using sutures. As the suture fixation

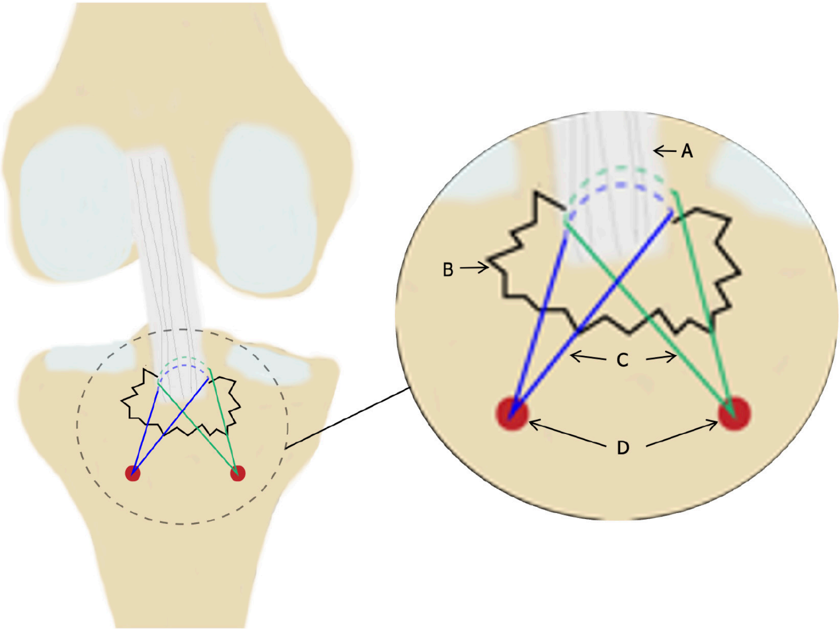

Figure 2 Illustration showing the final fixation constructs. A: Posterior cruciate ligament; B: Fracture fragment; C: Two Ethicon MB66 sutures; D: Two posterior tibial tunnel openings.

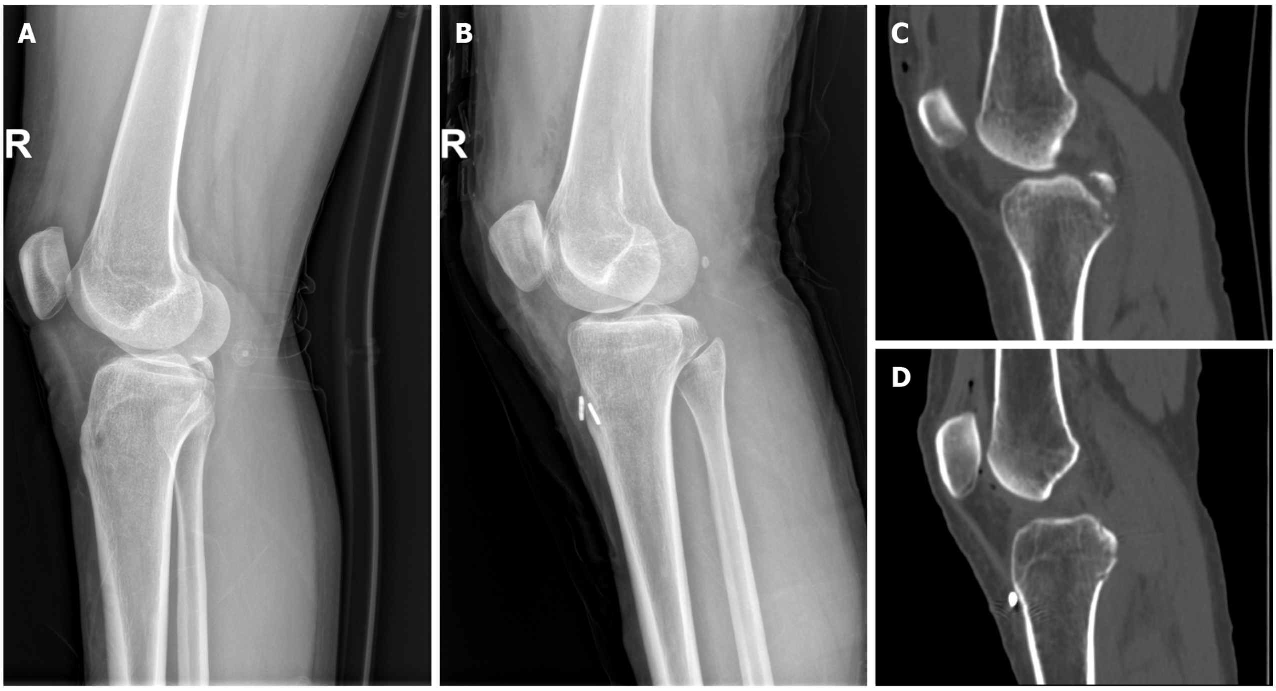

Figure 3 Preoperative and postoperative radiographic examination. A and C: preoperative X-ray and computed tomography (CT) scans showed posterior cruciate ligament tibial avulsion fractures; B and D: postoperative X-ray and CT scans showed the satisfactory reduction of the fracture.

technique is simple to perform and requires no secondary procedures, it has become the method of choice.

Various suture techniques for arthroscopic fixation, each with unique suture arrangements, have been documented. Xu *et al*[11] evaluated the outcome of arthroscopic treatment of PCL tibial avulsion fractures with the cinch knot technique. A total of 28 patients were followed up for a mean of 19 months. The mean Lysholm score was 96.96±3.62, and all patients had a normal ROM in the knee. Tao *et al*[23] treated PCL tibial avulsion using direct anterior-to-posterior suture suspension fixation. Compared with screw-suture fixation, anterior-to-posterior suture suspension fixation also showed satisfactory clinical results. Seifeldin *et al*[13] treated PCL tibial avulsion fractures with arthroscopic reduction and fixation by holding the PCL with two "cinch knots". Fifteen patients were followed up for approximately 40 months. The results showed that the mean Lysholm score was 90.27 (range: 67-99), and the mean postoperative flexion was 134.7 degrees (range: 120-150). However, some of the configurations are complex and difficult to execute.

Our modified M-shaped suture technique is an extension of these foundational methods and addresses some limitations observed in prior studies. This technique offers several potential advantages. First, the configuration used in our fixation technique maximizes the contact area between the fracture fragment and the tibial bed, providing more stable fixation and hence promoting healing. It opposes the deforming forces of the natural tension of the PCL, resisting vertical and horizontal displacement. This stability is critical for early mobilization, which is a key factor in preventing joint stiffness and facilitating the return of function. Second, we relied on suture pressure on the fracture fragment and ligament tension to fix the PCL avulsion fracture fragment. The suture threads that are not passed through the fracture fragment or ligament prevent unnecessary damage to the PCL fibers and help maintain the integrity of the ligament. This approach simplified the operation process. The technical bottleneck of ligament sutures under arthroscopy is avoided. Third, the use of double bone channel fixation does not affect the contact area of the fracture fragment, and double suture arm compression fixation can effectively control rotation. The two bone channels should be spaced apart and away from the tibial fracture bed during the operation, which can reduce the number of sutures cutting bone channels and is more conducive to controlling rotation. Fourth, dual medial access simplifies the operation and eliminates the need to frequently switch accesses during the operation.

However, we acknowledge certain limitations within our study. First, this study included a small sample of patients and lacked a comparative group. Future studies with larger populations and longer follow-up durations are necessary to validate the long-term efficacy and safety of the M-shaped suture technique. Additionally, because of the rarity of PCL tibial avulsion fractures[4,5], multicenter studies or meta-analyses might be required to accumulate sufficient data to draw more generalized conclusions. Second, this study was deficient in associated biomechanical research. Future studies should be conducted to gather pertinent mechanical data to reinforce the validity of the findings.

CONCLUSION

In conclusion, the arthroscopic M-shaped suture fixation technique for tibial avulsion fractures of the PCL presented here is a reliable and effective treatment option that combines the benefits of both minimally invasive surgery and secure fixation. This fixation technique is simple, easily reproducible and worthy of widespread promotion.

FOOTNOTES

Author contributions: Zhang XH, Yu J and Xu DF contributed to the study's conception and design; Data collection were performed by Zhao MY, Cao JH and Wu B; Data were analyzed by Zhang XH and Zhao MY; The first draft of the manuscript was written by Xu DF; Xu DF and Yu J edited the draft and revised it; all the authors read and approved the final manuscript. Xu DF and Yu J contributed equally to this work as co-corresponding authors.

Institutional review board statement: The protocols of study were approved by the Ethics Committee of The Central Hospital of Shaoxing University, Shaoxing, People's Republic of China (Approval No. 2024007).

Informed consent statement: Informed consent was obtained from all individual participants included in the study.

Conflict-of-interest statement: The authors declare that there is no conflict of interest.

Data sharing statement: No additional data are available.

Country of origin: China

ORCID number: Jian Yu 0000-0001-8915-3668; Bing Wu 0000-0002-4518-5542; Dan-Feng Xu 0000-0002-4764-5282.

S-Editor: Lin C
L-Editor: A
P-Editor: Zhang XD

REFERENCES

1 **Griffith JF**, Antonio GE, Tong CW, Ming CK. Cruciate ligament avulsion fractures. *Arthroscopy* 2004; **20**: 803-812 [PMID: 15483540 DOI: 10.1016/S0749-8063(04)00592-4]

2 **LaPrade CM**, Civitarese DM, Rasmussen MT, LaPrade RF. Emerging Updates on the Posterior Cruciate Ligament: A Review of the Current Literature. *Am J Sports Med* 2015; **43**: 3077-3092 [PMID: 25776184 DOI: 10.1177/0363546515572770]

3 **Wang D**, Graziano J, Williams RJ 3rd, Jones KJ. Nonoperative Treatment of PCL Injuries: Goals of Rehabilitation and the Natural History of Conservative Care. *Curr Rev Musculoskelet Med* 2018; **11**: 290-297 [PMID: 29721691 DOI: 10.1007/s12178-018-9487-y]

4 **White EA**, Patel DB, Matcuk GR, Forrester DM, Lundquist RB, Hatch GF 3rd, Vangsness CT, Gottsegen CJ. Cruciate ligament avulsion fractures: anatomy, biomechanics, injury patterns, and approach to management. *Emerg Radiol* 2013; **20**: 429-440 [PMID: 23525909 DOI: 10.1007/s10140-013-1121-0]

5 **Katsman A**, Strauss EJ, Campbell KA, Alaia MJ. Posterior Cruciate Ligament Avulsion Fractures. *Curr Rev Musculoskelet Med* 2018; **11**: 503-509 [PMID: 29869136 DOI: 10.1007/s12178-018-9491-2]

6 **Gopinatth V**, Mameri ES, Casanova FJ, Khan ZA, Jackson GR, McCormick JR, Brophy RH, Knapik DM, LaPrade RF, Chahla J. Systematic Review and Meta-analysis of Clinical Outcomes After Management of Posterior Cruciate Ligament Tibial Avulsion Fractures. *Orthop J Sports Med* 2023; **11**: 23259671231188383 [PMID: 37724253 DOI: 10.1177/23259671231188383]

7 **Hooper PO 3rd**, Silko C, Malcolm TL, Farrow LD. Management of Posterior Cruciate Ligament Tibial Avulsion Injuries: A Systematic Review. *Am J Sports Med* 2018; **46**: 734-742 [PMID: 28437619 DOI: 10.1177/0363546517701911]

8 **Song JG**, Nha KW, Lee SW. Open Posterior Approach versus Arthroscopic Suture Fixation for Displaced Posterior Cruciate Ligament Avulsion Fractures: Systematic Review. *Knee Surg Relat Res* 2018; **30**: 275-283 [PMID: 30466249 DOI: 10.5792/ksrr.17.073]

9 **Rhee SJ**, Jang JH, Choi YY, Suh JT. Arthroscopic reduction of posterior cruciate ligament tibial avulsion fracture using two cross-linked pull-out sutures: A surgical technique and case series. *Injury* 2019; **50**: 804-810 [PMID: 30447986 DOI: 10.1016/j.injury.2018.11.022]

10 **Madi S S**, Pandey V, Reddy B, Acharya K. Clinical and Radiological Outcomes Following Arthroscopic Dual Tibial Tunnel Double Sutures Knot-bump Fixation Technique for Acute Displaced Posterior Cruciate Ligament Avulsion Fractures. *Arch Bone Jt Surg* 2021; **9**: 50-57 [PMID: 33778115 DOI: 10.22038/abjs.2020.47089.2300]

11 **Xu Z**, Dong Y, Feng YE, Xie P, Gu J, Kang K, Gao S, Zheng X. A simple arthroscopic technique for treatment of displaced "hinged" type of posterior cruciate ligament avulsion fractures. *BMC Musculoskelet Disord* 2022; **23**: 841 [PMID: 36057656 DOI: 10.1186/s12891-022-05795-8]

12 **Chen LB**, Wang H, Tie K, Mohammed A, Qi YJ. Arthroscopic fixation of an avulsion fracture of the tibia involving the posterior cruciate ligament: a modified technique in a series of 22 cases. *Bone Joint J* 2015; **97-B**: 1220-1225 [PMID: 26330588 DOI: 10.1302/0301-620X.97B9.35765]

13 **Seifeldin AF**, Abdel-Kader KFM, Abdel Meguid KS, Wahsh M, Fekry AR. Arthroscopic management of avulsion fractures of the tibial attachment of the posterior cruciate ligament: A novel technique and mid-term outcomes. *J Clin Orthop Trauma* 2023; **42**: 102177 [PMID: 37529547 DOI: 10.1016/j.jcot.2023.102177]

14 **Meyers MH**, McKeever FM. Fracture of the intercondylar eminence of the tibia. *J Bone Joint Surg Am* 1970; **52**: 1677-1684 [PMID: 5483091 DOI: 10.2106/00004623-197052080-00024]

15 **Hefti F**, Müller W, Jakob RP, Stäubli HU. Evaluation of knee ligament injuries with the IKDC form. *Knee Surg Sports Traumatol Arthrosc* 1993; **1**: 226-234 [PMID: 8536037 DOI: 10.1007/BF01560215]

16 **Lysholm J**, Gillquist J. Evaluation of knee ligament surgery results with special emphasis on use of a scoring scale. *Am J Sports Med* 1982; **10**: 150-154 [PMID: 6896798 DOI: 10.1177/036354658201000306]

17 **Chen SY**, Cheng CY, Chang SS, Tsai MC, Chiu CH, Chen AC, Chan YS. Arthroscopic suture fixation for avulsion fractures in the tibial attachment of the posterior cruciate ligament. *Arthroscopy* 2012; **28**: 1454-1463 [PMID: 22929009 DOI: 10.1016/j.arthro.2012.04.141]

18 **Martinez-Moreno JL**, Blanco-Blanco E. Avulsion fractures of the posterior cruciate ligament of the knee. An experimental percutaneous rigid fixation technique under arthroscopic control. *Clin Orthop Relat Res* 1988; 204-208 [PMID: 3191630 DOI: 10.1097/00003086-198812000-00029]

19 **Kim SJ**, Shin SJ, Choi NH, Cho SK. Arthroscopically assisted treatment of avulsion fractures of the posterior cruciate ligament from the tibia. *J Bone Joint Surg Am* 2001; **83**: 698-708 [PMID: 11379739 DOI: 10.2106/00004623-200105000-00008]

20 **Wu L**, Xu H, Li B, Xu B. Improved arthroscopic high-strength suture fixation for the treatment of posterior cruciate ligament avulsion fracture. *J Orthop Surg (Hong Kong)* 2022; **30**: 10225536221101701 [PMID: 35596555 DOI: 10.1177/10225536221101701]

21 **Gui J**, Wang L, Jiang Y, Wang Q, Yu Z, Gu Q. Single-tunnel suture fixation of posterior cruciate ligament avulsion fracture. *Arthroscopy* 2009; **25**: 78-85 [PMID: 19111222 DOI: 10.1016/j.arthro.2008.08.011]

22 **Sasaki SU**, da Mota e Albuquerque RF, Amatuzzi MM, Pereira CA. Open screw fixation versus arthroscopic suture fixation of tibial posterior cruciate ligament avulsion injuries: a mechanical comparison. *Arthroscopy* 2007; **23**: 1226-1230 [PMID: 17986411 DOI: 10.1016/j.arthro.2007.06.012]

23 **Tao T**, Yang W, Tao X, Li Y, Zhang K, Jiang Y, Gui J. Arthroscopic Direct Anterior-to-Posterior Suture Suspension Fixation for the Treatment of Posterior Cruciate Ligament Tibial Avulsion Fracture. *Orthop Surg* 2022; **14**: 2031-2041 [PMID: 35894145 DOI: 10.1111/os.13401]

World Journal of Orthopedics

Submit a Manuscript: https://www.f6publishing.com

World J Orthop 2024 July 18; 15(7): 650-659

DOI: 10.5312/wjo.v15.i7.650

ISSN 2218-5836 (online)

ORIGINAL ARTICLE

Observational Study

Epidemiology of work-related hand and wrist injuries in a referral center: A descriptive study

Angélica M Rodríguez, Ginna P Tocanchón, Jessica T Villalba, Luis M Pombo, Aníbal A Teherán, Gabriel Camero-Ramos, Karen P Ayala, Gerhard M Acero

Specialty type: Orthopedics

Provenance and peer review: Unsolicited article; Externally peer reviewed.

Peer-review model: Single blind

Peer-review report's classification

Scientific Quality: Grade C

Novelty: Grade B

Creativity or Innovation: Grade B

Scientific Significance: Grade B

P-Reviewer: Wang ZJ, China

Received: April 16, 2024

Revised: May 17, 2024

Accepted: June 6, 2024

Published online: July 18, 2024

Processing time: 86 Days and 8.1 Hours

Angélica M Rodríguez, Ginna P Tocanchón, Jessica T Villalba, Luis M Pombo, Aníbal A Teherán, Karen P Ayala, Research Center, Fundación Universitaria Juan N. Corpas, Bogotá 111321, Colombia

Gabriel Camero-Ramos, Red Cross, Cruz Roja Colombiana-Seccional Cundinamarca Bogotá, Bogotá 111221, Colombia

Gerhard M Acero, Vigilancia Epidemiológica, Instituto Nacional de Salud, Bogotá 111321, Colombia

Corresponding author: Aníbal A Teherán, MD, MSc, Professor, Senior Researcher, Senior Statistician, Research Center, Fundación Universitaria Juan N. Corpas, Cra. 111 159a-61, Bogotá 111321, Colombia. anibal.teheran@juanncorpas.edu.co

Abstract

BACKGROUND

Occupational hand and wrist injuries (OHWIs) account for 25% of work-related accidents in low- and middle-income countries. In Colombia, more than 500000 occupational accidents occurred in 2021, and although the rate declined to less than 5% in 2020 and 2021, at least one in four accidents involved a hand or wrist injury.

AIM

To describe the OHWIs in workers seen at the emergency room at a second-level hospital in Colombia.

METHODS

An observational study was performed using data from workers who experienced OHWIs and attended a second-level hospital, between June, 2020 and May, 2021. The overall frequency of OHWIs, as well as their distribution by sociodemographic, clinical, and occupational variables, are described. Furthermore, association patterns between sex, anatomical area (fingers, hand, wrist), and type of job were analyzed by correspondence analysis (CA).

RESULTS

There were 2.101 workers treated for occupational accidents, 423 (20.3%) were cases of OHWIs, which mainly affected men (93.9%) with a median age of 31 years and who worked mainly in mining (75.9%). OHWIs were more common in the right upper extremity (55.3%) and comprised different types of injuries, such as contusion (42.1%), laceration (27.9%), fracture (18.7%), and crush injury (15.6%). They primarily affected the phalanges (95.2%), especially those of the first finger (25.7%). The CAs showed associations between the injured anatomical area and the worker's job that differed in men and women (explained variance > 90%).

CONCLUSION

One out of five workers who suffered occupational accidents in Cundinamarca, Columbia had an OHWI, affecting mainly males employed in mining. This occupational profile is likely to lead to prolonged rehabilitation, and permanent functional limitations. Our results might be useful for adjusting preventive measures in cluster risk groups.

Key Words: Accidents; Occupational; Epidemiology; Hand injuries; Wrist injuries; Occupational health

Core Tip: Colombia is a developing industrial country where most occupational activities are performed manually. Throughout 2021, one in four workers had occupational hand or wrist injuries, often resulting in injuries with a high probability of prolonged rehabilitation, and permanent sequelae. The findings of this research might be useful in improving preventive strategies in the groups with the highest occurrence.

Citation: Rodríguez AM, Tocanchón GP, Villalba JT, Pombo LM, Teherán AA, Camero-Ramos G, Ayala KP, Acero GM. Epidemiology of work-related hand and wrist injuries in a referral center: A descriptive study. *World J Orthop* 2024; 15(7): 650-659

URL: https://www.wjgnet.com/2218-5836/full/v15/i7/650.htm

DOI: https://dx.doi.org/10.5312/wjo.v15.i7.650

INTRODUCTION

Approximately 340 million work-related accidents occur annually, and 160 million victims develop an occupational disease worldwide[1]. The frequency of occupational hand or wrist injuries (OHWIs) that individuals experience ranges from 10% to 90%. This variability depends on the population at risk used as the denominator, *i.e.*, whether it refers to workers in general or workers with specific types of manual tasks[2-4].

In Colombia, the level of technological implementation in several industrial sector subcategories is lower than it is in other countries with a similar economic status. As a result, workers may be more exposed to occupational injuries, particularly injuries that affect the upper limbs-especially hands and wrists[5].

From 1990 to 2017, OHWIs accounted for 25% of work-related accidents in low- and middle-income countries and nearly half of the injured workers experienced a significant decline in wages. The average emergency room visit cost was estimated to be between US$ 394 and US$ 421 not to mention the medium and long-term financial impact on companies, and the effect on workers' quality of life and productivity[6-8].

In Colombia, more than 500,000 occupational accidents occurred in 2021. Although the rate declined to less than 5% in 2020 and 2021, at least one in four accidents involved a hand or wrist injury[9].

The aim of this research is to describe the sociodemographic, clinical, and occupational characteristics of workers who experienced OHWIs and were treated in the emergency department at a second-level hospital in Colombia. The results of this research may help to provide ways to prevent injuries and give workers with OHWIs timely and comprehensive care.

MATERIALS AND METHODS

Design and setting

A descriptive retrospective study was conducted using the medical records of workers treated for OHWIs in the Emergency Department of the El Salvador Hospital, a second-level institution, in Cundinamarca, Colombia between June 1, 2020 and May 29, 2021. Occupational accidents reported to the epidemiological surveillance program in occupational health (Sistema de Vigilancia de Salud Laboralacronym in Spanish, SIVISALA) during the study period were identified. They involved patients diagnosed at admission with International Classification of Diseases, version 10 (ICD-10) S60-S69 and T23. Patients treated for a complication, polytrauma, multiple trauma, or those attending a follow-up consultation were excluded[10,11].

Variables

The variables studied were age, sex; day, weekend *vs* weekdays, and month; history of OHWI; job, employment injury insurance (EII); type of injury (burn, crush injury, contusion, dislocation, fracture, laceration, puncture, amputation), laterality of the affected limb, injured anatomical area (hand, wrist, fingers), injured anatomical region (phalanges, carpus, metacarpus), injured finger (first, second, third, fourth, fifth, multiple), anatomic characteristics (fracture, nerve, tendon and/or vascular involvement), X-ray findings, care by an orthopedist or plastic surgeon, time to specialist care, medical-surgical treatment or intervention, sick leave, and ICD-10 code.

Data analysis

Data analysis was summarized with descriptive statistics. Variables were described as counts, proportions, and medians (25th and 75th percentiles) using the RStudio® (Version 2022.07.2). We calculated the injury frequency *per* anatomical region (%), describing whether it occurred exclusively in the wrist or hand area (isolated injuries). The frequency of lesions in men and women by anatomical area and type of lesion was represented with Sankey plots [Sankey MATIC (BETA)]. Bar plots were used to show the monthly distribution of lesions. Associations between case frequency and sex, type of work, and anatomical area affected were evaluated by correspondence analysis (CA) using the orange (Data Mining and Fruitful Fun® software, V.3.32). The statistical methods used in this study were reviewed by Aníbal A Teherán, MD, Epidemiologist, MSc-Biostatistics from Fundación Universitaria Juan N. Corpas.

RESULTS

General characteristics

During the study period, 2101 occupational accidents were reported to the SIVISALA. Most of these cases were excluded from the investigation as they were assigned ICD-10 codes other than those for hand and wrist trauma or they involved follow-up of trauma or treatment of a medical complication. Finally, 423 individuals who suffered occupational accidents resulting in hand or wrist injuries (coded according to ICD-10) were included in the study (Figure 1).

Clinical records that met the eligibility criteria (423/2021; 20.1% 95%CI: 18.2%–22.0%) were analyzed. The median age of individuals with OHWIs was 31 years (min = 19, max = 66), most were males and worked in mining, and more than 95% had an EII. They received medical care mainly during daytime; at least one in ten received medical care during the night, and one in four during the weekend (Table 1, Supplementary Figure 1).

Clinical features of the injured workers

Table 2 describes the clinical characteristics of the workers with OHWIs. The right hand and wrist were the most frequently affected anatomical areas; fewer than 1% of the individuals had bilateral trauma, and fewer than 10% had a history of trauma to the hand or wrist. Eight types of injuries were identified, the most frequent being contusions, lacerations, fractures, and crush injuries. One in ten workers had fractures which coincided with amputations, contusions, crush injuries, or lacerations.

The injuries mainly affected skin, connective tissue, and phalanges; in fewer than 5%, there was nerve, tendon, joint, or vascular involvement. One in four workers had an injury of the first finger, and this was the most commonly injured finger, followed by the second finger.

Most patients had X-rays taken. One in four individuals with an OHWI required suturing, and one in five required closed reduction or immobilization. In addition, fewer than 20% of the injured individuals were seen by an orthopedist. A minority required surgical management, plastic surgery, or referral to a high complexity hospital (Table 2).

Fingers were the most affected anatomical area, followed by hand injuries without finger involvement (Figure 2). A significant relationship was observed between the anatomical area injured and the type of injury in the male group (χ^2 = 43.802; *P* value = 0.002). Contusion was the most prevalent injury in the three anatomical areas analyzed, especially in the wrists and in the male group. Lacerations and crush injuries were also frequent among men with isolated hand or finger injuries or concurrent hand and wrist injuries. Similarly, fractures were most common in isolated hand or finger injury cases but not in cases of isolated wrist injuries.

Supplementary Figure 2 shows the distribution of OHWIs based on the anatomical areas affected and the month of accident occurrence. When grouped by sex, a significant relationship was identified between the anatomical area injured and the month of accident occurrence χ^2 = 57.195; *P* value = 0.004). OHWIs occurred in all anatomical areas described during the last half of 2020, but isolated wrist injuries were only seen in September and October. Similarly, isolated hand injuries in the male group occurred in June, July, September, and October. Concurrent hand and wrist injuries, in turn, were only observed in the male group during the first half of 2021 and isolated hand injuries during January, April, and May.

Finally, a relationship between the injured anatomical area and the worker's job was noted in the male group (χ^2 = 22.204; *P* value = 0.026). Therefore, CAs were carried out to identify possible statistical associations between these variables in men and women separately (Figure 3). In both sexes, the cumulative percentage of variance explained by the CAs was > 90%; the first component explained 77% and 68% of the variance in males and females, respectively. In the male group, an association was found between isolated finger or hand (without finger involvement) injuries and mining.

Concurrent hand and wrist injuries, in turn, were associated with farming, hunting, and personal services (hairdressing, manicure, pedicure, massaging, and other similar jobs). In contrast, in the female group, an association was observed between isolated hand injuries and work in the manufacturing industry. Similarly, there was an association

Table 1 General characteristics of the patients with occupational hand and wrist injuries, *n* (%)/median (25th and 75th percentiles)

Variables	Number (*n* = 423)
Age (years)	31 (25-39)
Sex	
Male	397 (93.9)
Female	26 (6.1)
Type of job	
Mining	321 (75.9)
Personal service[1] personal	57 (13.5)
Manufacturing industries	17 (4.0)
Agriculture, livestock, and hunting	15 (3.5)
Other[2]	13 (3.1)
Employment Injury Insurance	409 (96.7)
Time of day	
Day (7:00 to 18:59)	361 (85.3)
Night (19:00 to 6:59)	62 (14.7)
Day of the week	
Monday	59 (13.9)
Tuesday	73 (17.3)
Wednesday	90 (21.3)
Thursday	80 (18.9)
Friday	69 (16.3)
Saturday	44 (10.4)
Sunday	8 (1.9)

[1]Personal service: Hairdressing, manicure, pedicure, massaging, and other similar jobs.
[2]Other: Other economic activities, including wholesale and retail trade, repair of motor vehicles and motorcycles, accommodation and food services, financial and insurance activities, professional scientific and technical activities, construction, transportation, and warehousing.

between finger lesions or concurrent hand and wrist injuries with farming and hunting.

DISCUSSION

This research described the frequency of OHWIs in workers seen at a referral hospital in Cundinamarca, Colombia, during a 12-month period between 2020 and 2021, thus facilitating the identification of injury patterns related to sociodemographic features.

It is well known that OHWIs and occupational diseases occur in most jobs; however, the annual frequency of hand and wrist injuries has risen in low-income or industrially developing countries. This rise has been attributed to several factors associated with industrial globalization that may expose workers to new occupational hazards (new industrial tasks, persistence of manufacturing), poor preventive education, and deficiencies in the provision of safety equipment or the application of international standards on risk prevention[6,12-14].

In Colombia, one in four workers (26.1%) (insured and uninsured) suffered an OHWI in 2021, and one of the effects of health insurance is the promotion of safe work environments and working conditions to prevent accidents[9]. In comparison, in the present study OHWIs were found to occur in one out of five (20.1%) work-related accidents. The difference between these values is significant (P value < 0.001; data not shown) and could be attributed to the fact that more than 95% of the workers in the present study were insured individuals[15].

The type of work and the main economic activity in the geographic region could explain the frequency and distribution of OHWIs observed in this research. Previous investigations that included patients from urban and rural areas showed differences in the economic and social activities of workers as well as in the characteristics of the injuries they suffered[1-3,6,16].

Table 2 Clinical characteristics of the patients with occupational hand and wrist injuries, *n* (%)/median (25th and 75th percentiles)

Clinical variables	Number (*n* = 423)
Sick leave (days)	5 (3-8)
History of OHWI	39 (9.2)
Laterality of injury	
Right	234 (55.3)
Left	186 (44.0)
Bilateral	3 (0.7)
Type of injury Anatomical features	
Contusion	178 (42.1)
Laceration	118 (27.9)
Fracture	79 (18.7)
Crush	66 (15.6)
Dislocation/Luxation	9 (2.1)
Amputation	5 (1.2)
Burn	5 (1.2)
Puncture	5 (1.2)
Fracture and other injury(s)	43 (10.1)
Anatomical features	
Skin/Connective tissue injuries	306/315 (97.1)
Bone	313/423 (74.0)
Nerve injury[1]	5/100 (5.0)
Tendon injury[1]	3/133 (2.3)
Vascular injury[1]	5/235 (2.1)
Joint injury	9/208 (4.3)
Two or more	233/423 (55.1)
Injured anatomical region	
Phalanges[1]	315/331 (95.2)
Metacarpus[1]	14/331 (4.2)
Carpus[1]	2/331 (0.6)
Injured finger	
First[1]	81/315 (25.7)
Second[1]	60/315 (14.2)
Third[1]	52/315 (12.3)
Fourth[1]	39/315 (9.2)
Fifth[1]	45/315 (10.6)
Multiple[1]	38/315 (9.0)
Procedures in the ED (diagnosis, interventions)	
X-ray	379 (89.6)
Suture	111 (26.2)
Closed reduction/Immobilization	89 (21.0)
Orthopedic consultation	74 (17.5)

Surgery	25 (5.9)
Plastic surgery consultation	20 (4.7)
Referral to a higher-level ED	3 (0.7)

[1]The denominator used to calculate proportions differed for each variable as data were not available or not applicable.
ED: Emergency department; OHWI: Occupational hand or wrist injury.

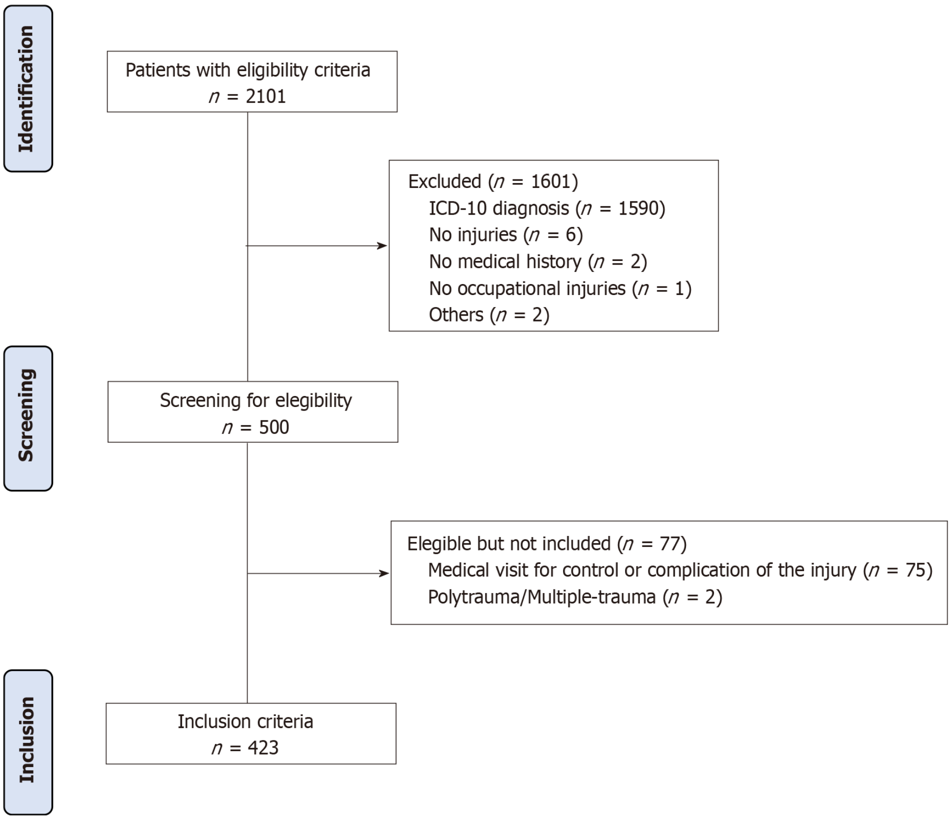

Figure 1 Patient selection flowchart. This flowchart was adjusted to STROBE guidelines. ICD-10: International Classification of Diseases, version 10.

Mining in Colombia generated 350000 direct jobs and 1000000 indirect jobs in 2020 and 237858 direct jobs in the first quarter of 2022[17]. In the department of Cundinamarca, coal mining and the extraction of other subsoil products, such as emeralds, generate more than 18000 jobs *per* year. This study found that three out of every four workers treated for an OHWI worked in mining[18].

Our results on the demographic characteristics of the injured workers showed an interquartile range of age similar to the age interval of the economically active Colombian population. However, it should be noted that mining was also the most frequent type of work, even among workers aged 50 years or older (23/33; data not shown). The majority of workers with OHWIs (> 90%) were men. Additionally, this observation could be a confounding factor as, since 2010, the overall male participation rate in the Colombian rural market has been predominant. Many of the jobs described in this research correspond to jobs traditionally performed by men[18,19].

Moreover, hospital stay, sick leave duration, and risk of death have been shown to be higher in workers who receive care for acute occupational injuries during dead time[20,21]. However, no relationship was observed between sick leave and caring for individuals with OHWI either at night (15%) or on weekends (30%) (data not shown). It should be noted that this investigation excluded patients with polytrauma and those who died, and that more than 80% of the injured individuals were treated by general practitioners. These factors may have modified the mean duration of sick leave.

Distribution of the most frequent injuries (contusions, lacerations, fractures, crush injuries), anatomical areas affected, and the occupational categories showed differential patterns for both sexes. Our findings are consistent with previous studies that identified a higher risk of OHWIs in women resulting in wrist injuries for those working in agriculture or hunting, and finger injuries for those who work in the manufacturing industry[22,23].

In contrast, crush injuries, lacerations, amputations, and burns to wrists, hands, and fingers were more frequent in men, possibly due to direct manual exposure in activities with higher potential and kinetic energy, such as industrial mechanics, electricity, and mining[12-14,16,22].

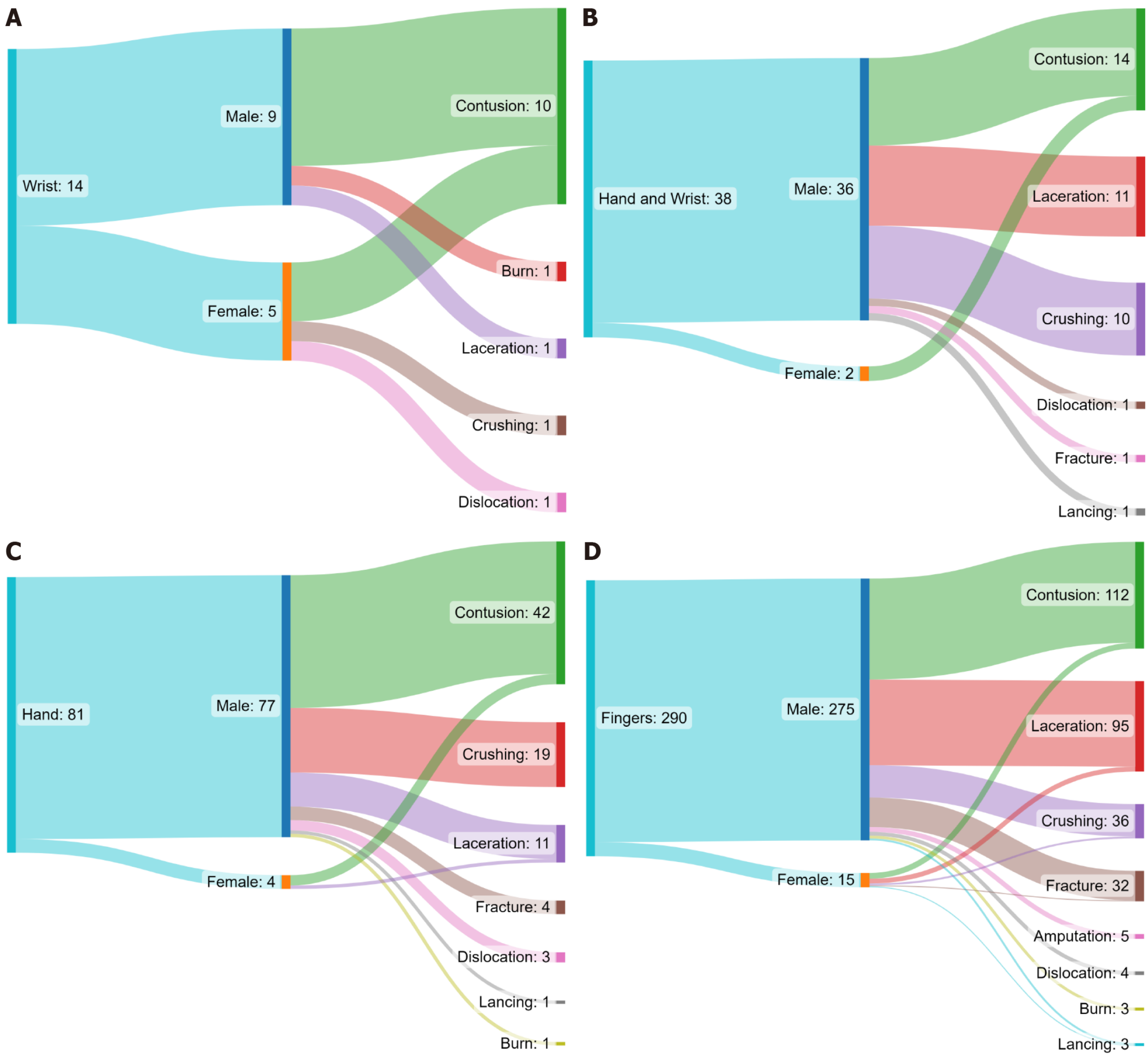

Figure 2 Sankey plot diagram shows the distribution (number of cases) of occupational hand and wrist injuries by sex and type of injury in the anatomical areas affected. A: Wrist; B: Hand; C: Hand and wrist; D: Fingers.

In addition, we observed that one in four workers had a first finger injury. This type of injury is a relevant indicator among OHWIs as it harmfully impacts rehabilitation by temporarily or permanently limiting grip function and other job-related tasks[6,8].

The results of this research can be extrapolated mainly to men and workers employed in mining. However, the study is subject to the limitations of a retrospective design based on clinical registry data. These studies are prone to reporting bias and confounding, have low statistical power, and are limited to establishing causal relationships and for analysis using specific statistical tests[24,25].

OHWIs can simultaneously affect two or more anatomical regions (phalanges, metacarpus, carpus); however, information was only collected from each region separately. Furthermore, although the laterality of the trauma is relevant and was reported, it should be complemented with the dominant laterality of the worker. Finally, simultaneous associations between sex, job, and anatomical area were not explored by multiple CA, given the high probability of a type II error.

CONCLUSION

Hand and wrist injuries occurred in 20% of the workers seen for occupational accidents at El Salvador Hospital in Ubaté, Cundinamarca, during a 12-month period between 2020 and 2021. OHWIs occurred mainly in adult men employed in mining. Patterns of association between sex, type of injury, and type of job were identified. The above findings can help to provide ways to prevent occupational accidents, by implementing measures such as educational campaigns, expanding

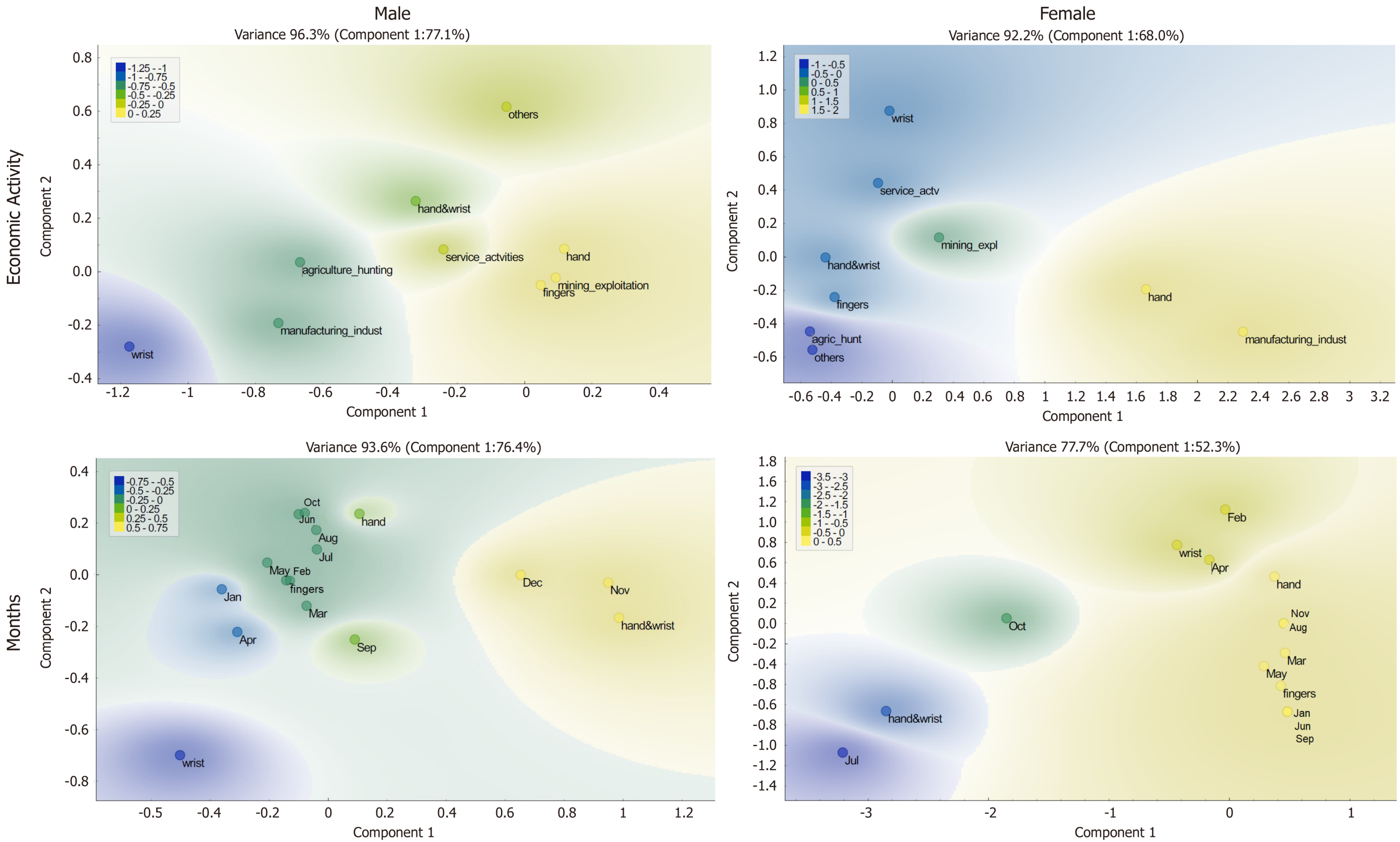

Figure 3 Correspondence analysis between job and injured anatomical area variables when grouping by sex. Men (upper panel); women (lower panel). The color scale corresponds to the value of the first component for the categories that compose the type of job and the anatomical area injured.

health-insurance coverage, providing high-quality work-tools according to engineering standards to diminish injury risk, and monitoring the mandatory use of protective equipment, especially among mining workers in Colombia and other developing countries[26]. In these regions, mining generates an increasing or at least constant number of jobs each year. Future research should determine the probability or risk of different hand or wrist injuries according to sex and job because it could substantially modify insurance policies and strategic prevention plans.

ACKNOWLEDGEMENTS

Thanks to the Research Center of the Fundación Universitaria Juan N. Corpas, and the staff of the Department of Extramural Care (Preventive and Occupational Medicine Service) of the Colombian Red Cross, Section Cundinamarca-Bogotá, for methodological and technical assistance.

FOOTNOTES

Author contributions: Rodríguez AM, Tocanchón GP, Villalba JT, Teherán AA, Pombo LM, Camero-Ramos G, Ayala KP, Acero GM contributed to methodology, writing (original draft), writing (review and editing), supervision, funding acquisition, and research; Rodríguez AM, Tocanchón GP, Villalba JT, Teherán AA, Acero GM contributed to conceptualization, and project administration; Teherán AA, Pombo LM, Camero-Ramos G, Ayala KP, Acero GM contributed to formal analysis, data curation, and visualization; Rodríguez AM, Tocanchón GP, Villalba JT, Teherán AA, Pombo LM, Camero-Ramos G, Ayala KP, Acero GM contributed to validation, resources, and project administration.

Institutional review board statement: As the database was anonymized and data were obtained retrospectively, this research was classified as “without-risk” and approved by the local ethical regulation in force (notice number OFC-GHSU-227-2023).

Informed consent statement: As the database was anonymized and data were obtained retrospectively, this research was classified as “without-risk” and approved by the local ethical regulation in force (notice number OFC-GHSU-227-2023), and did not require signed inform consent.

Conflict-of-interest statement: The author(s) declare(s) that there is no conflict of interest regarding the publication of this article.

Data sharing statement: Technical appendix, statistical code, and dataset available from the corresponding author at (https://doi.org/10.7910/DVN/KPTO4T). Consent was not obtained but the presented data are anonymized, and risk of identification is low. No additional data are available.

STROBE statement: The authors have read the STROBE Checklist, and the manuscript was prepared and revised according to the STROBE Checklist.

Country of origin: Colombia

ORCID number: Luis M Pombo 0000-0002-7277-1838; Aníbal A Teherán 0000-0002-7666-8766; Gabriel Camero-Ramos 0009-0005-0546-2890; Karen P Ayala 0000-0001-7229-1589; Gerhard M Acero 0000-0002-8341-5281.

S-Editor: Liu H
L-Editor: Webster JR
P-Editor: Che XX

REFERENCES

1 **International Labour Organization (ILO)**. The enormous burden of poor working conditions. 2022. Available from: https://www.ilo.org/moscow/areas-of-work/occupational-safety-and-health/WCMS_249278/Lang--en/index.htm

2 **Arroyo-Berezowsky C**, Quinzaños-Fresnedo J. Epidemiology of hand and wrist injuries treated in a reference specialty center over a year. *Acta Ortop Mex* 2021; **35**: 429-435 [PMID: 35451252 DOI: 10.35366/104570]

3 **Durusoy R**, Davas A, Kayalar M, Bal E, Aksu F, Ada S. What kinds of hand injuries are more likely to result in amputation? An analysis of 6549 hand injuries. *J Hand Surg Eur Vol* 2011; **36**: 383-391 [PMID: 21406567 DOI: 10.1177/1753193411400520]

4 **Panagopoulou P**, Antonopoulos CN, Dessypris N, Kanavidis P, Michelakos T, Petridou ET. Epidemiological patterns and preventability of traumatic hand amputations among adults in Greece. *Injury* 2013; **44**: 475-480 [PMID: 23122997 DOI: 10.1016/j.injury.2012.10.008]

5 **Becerra-peña DL**, Lemos Mejía MX. La productividad del sector manufacturero: caso Colombia 2005-2016. *REMEF* 2021; **16**: 1-27 [DOI: 10.21919/remef.v16i4.527]

6 **Crowe CS**, Massenburg BB, Morrison SD, Chang J, Friedrich JB, Abady GG, Alahdab F, Alipour V, Arabloo J, Asaad M, Banach M, Bijani A, Borzì AM, Briko NI, Castle CD, Cho DY, Chung MT, Daryani A, Demoz GT, Dingels ZV, Do HT, Fischer F, Fox JT, Fukumoto T, Gebre AK, Gebremichael B, Haagsma JA, Haj-Mirzaian A, Handiso DW, Hay SI, Hoang CL, Irvani SSN, Jozwiak JJ, Kalhor R, Kasaeian A, Khader YS, Khalilov R, Khan EA, Khundkar R, Kisa S, Kisa A, Liu Z, Majdan M, Manafi N, Manafi A, Manda AL, Meretoja TJ, Miller TR, Mohammadian-Hafshejani A, Mohammadpourhodki R, Mohseni Bandpei MA, Mokdad AH, Naimzada MD, Ndwandwe DE, Nguyen CT, Nguyen HLT, Olagunju AT, Olagunju TO, Pham HQ, Pribadi DRA, Rabiee N, Ramezanzadeh K, Ranganathan K, Roberts NLS, Roever L, Safari S, Samy AM, Sanchez Riera L, Shahabi S, Smarandache CG, Sylte DO, Tesfay BE, Tran BX, Ullah I, Vahedi P, Vahedian-Azimi A, Vos T, Woldeyes DH, Wondmieneh AB, Zhang ZJ, James SL. Global trends of hand and wrist trauma: a systematic analysis of fracture and digit amputation using the Global Burden of Disease 2017 Study. *Inj Prev* 2020; **26**: i115-i124 [PMID: 32169973 DOI: 10.1136/injuryprev-2019-043495]

7 **Robinson LS**, O'Brien L. Description and cost-analysis of emergency department attendances for hand and wrist injuries. *Emerg Med Australas* 2019; **31**: 772-779 [PMID: 30811868 DOI: 10.1111/1742-6723.13246]

8 **Robinson LS**, Brown T, O'brien L. Capturing the costs of acute hand and wrist injuries: Lessons learnt from a prospective longitudinal burden of injury study. *Hand Therapy* 2020; **25**: 119-129 [DOI: 10.1177/1758998320952815]

9 **El Sistema General de Riesgos Laborales Prevencia 2021**. Accidentes de trabajo y enfermedades laborales en Colombia 2021. Available from: https://oiss.org/wp-content/uploads/2022/01/Colombia-fasecolda.pdf

10 **Rajasekaran S**. Updates and best practices in polytrauma. *J Clin Orthop Trauma* 2021; **12**: 8 [PMID: 33519135 DOI: 10.1016/j.jcot.2020.12.031]

11 **Frink M**, Lechler P, Debus F, Ruchholtz S. Multiple Trauma and Emergency Room Management. *Dtsch Arztebl Int* 2017; **114**: 497-503 [PMID: 28818179 DOI: 10.3238/arztebl.2017.0497]

12 **Hämäläinen P**. The effect of globalization on occupational accidents. *Saf Sci* 2009; **47**: 733-742 [DOI: 10.1016/j.ssci.2008.01.011]

13 **Arnold SM**, Wickrematilake MSK, Fernando RMSD, Sampath HMRC, Karunapema RPP, Mahesh PKB, Munasinghe PM, Denawaka CJ. Occupational hazards in medium and large scale industrial sectors in Sri Lanka: experience of a developing country. *BMC Res Notes* 2019; **12**: 755 [PMID: 31747965 DOI: 10.1186/s13104-019-4790-2]

14 **Suraweera IK**, Wijesinghe SD, Senanayake SJ, Herath HD, Jayalal TB. Occupational health issues in small-scale industries in Sri Lanka: An underreported burden. *Work* 2016; **55**: 263-269 [PMID: 27689580 DOI: 10.3233/WOR-162397]

15 **Berkowitz SA**, Gold R, Domino ME, Basu S. Health insurance coverage and self-employment. *Health Serv Res* 2021; **56**: 247-255 [PMID: 33146406 DOI: 10.1111/1475-6773.13598]

16 **DavasAksan A**, Durusoy R, Bal E, Kayalar M, Ada S, Tanik FA. Risk factors for occupational hand injuries: relationship between agency and finger. *Am J Ind Med* 2012; **55**: 465-473 [PMID: 22334304 DOI: 10.1002/ajim.22016]

17 **Ospina-correa JD**, Osorio-cachaya JG, Henao-arroyave AM, Palacio-acevedo DA, Giraldo-builes J. Retos y oportunidades para la industria minera como potencial impulsor del desarrollo en Colombia. *TecnoL* 2021; **24**: e1683 [DOI: 10.22430/22565337.1683]

18 **Fuentes López HJ**, Ferrucho-parra CC, Martínez-gonzález WA. La minería y su impacto en el desarrollo económico en Colombia. *Apuntes CENES* 2021; **40**

19 **Otero-cortés A**, Acosta-ariza E. Desigualdades en el mercado laboral urbano-rural en Colombia, 2010-2019. *Rev CS* 2022 [DOI: 10.18046/recs.iEspecial.4939]

20 **Härmä M**, Koskinen A, Sallinen M, Kubo T, Ropponen A, Lombardi DA. Characteristics of working hours and the risk of occupational injuries among hospital employees: a case-crossover study. *Scand J Work Environ Health* 2020; **46**: 570-578 [PMID: 32515483 DOI: 10.5271/sjweh.3905]

21 **Tiruneh A**, Siman-Tov M, Radomislensky I, Peleg K; Israel Trauma Group. Are injury admissions on weekends and weeknights different from weekday admissions? *Eur J Trauma Emerg Surg* 2020; **46**: 197-206 [PMID: 30350004 DOI: 10.1007/s00068-018-1022-8]

22 **Islam SS**, Velilla AM, Doyle EJ, Ducatman AM. Gender differences in work-related injury/illness: analysis of workers compensation claims. *Am J Ind Med* 2001; **39**: 84-91 [PMID: 11148018 DOI: 10.1002/1097-0274(200101)39:1<84::aid-ajim8>3.0.co;2-t]

23 **Chen N**, Li G, Sun X, Zhang M, Zhang H, Ling R, Liu Y, Li G, Ren Z, Yin Y, Shao H, Zhang H, Li J, Qiu B, Wang D, Zeng Q, Liang Z, Wang R, Chen J, Zhang D, Mei L, Liu Y, Liu J, Zhang C, Li T, Wang Z, Chen Q, Jia N. Prevalence status and associated factors of wrist postural injury in the Chinese occupational population. *Front Public Health* 2022; **10**: 1047814 [PMID: 36504943 DOI: 10.3389/fpubh.2022.1047814]

24 **Sauerland S**, Lefering R, Neugebauer EA. Retrospective clinical studies in surgery: potentials and pitfalls. *J Hand Surg Br* 2002; **27**: 117-121 [PMID: 12027483 DOI: 10.1054/jhsb.2001.0703]

25 **Worster A**, Bledsoe RD, Cleve P, Fernandes CM, Upadhye S, Eva K. Reassessing the methods of medical record review studies in emergency medicine research. *Ann Emerg Med* 2005; **45**: 448-451 [PMID: 15795729 DOI: 10.1016/j.annemergmed.2004.11.021]

26 **Heberger JR**, Nasarwanji MF, Pollard JP, Kocher LM. The Necessity for Improved Hand and Finger Protection in Mining. *Min Metall Explor* 2022; **39**: 507-520 [PMID: 35836426 DOI: 10.1007/s42461-022-00557-5]

World Journal of Orthopedics

Submit a Manuscript: https://www.f6publishing.com

World J Orthop 2024 July 18; 15(7): 660-667

DOI: 10.5312/wjo.v15.i7.660

ISSN 2218-5836 (online)

SYSTEMATIC REVIEWS

Intraoperative application of three-dimensional printed guides in total hip arthroplasty: A systematic review

Tim P Crone, Bart M W Cornelissen, Jakob Van Oldenrijk, Pieter Koen Bos, Ewout S Veltman

Specialty type: Orthopedics

Provenance and peer review: Invited article; Externally peer reviewed.

Peer-review model: Single blind

Peer-review report's classification

Scientific Quality: Grade B, Grade C

Novelty: Grade B, Grade B

Creativity or Innovation: Grade B, Grade B

Scientific Significance: Grade B, Grade B

P-Reviewer: Lu YX

Received: April 11, 2024

Revised: May 23, 2024

Accepted: June 24, 2024

Published online: July 18, 2024

Processing time: 91 Days and 15.4 Hours

Tim P Crone, Jakob Van Oldenrijk, Pieter Koen Bos, Ewout S Veltman, Department of Orthopedic Surgery and Sports Medicine, Erasmus Medical Center, Rotterdam 3015 GD, Netherlands

Bart M W Cornelissen, Department of Oral and Maxillofacial Surgery, Erasmus Medical Center, Rotterdam 3015 GD, Netherlands

Corresponding author: Ewout S Veltman, MD, PhD, Doctor, Department of Orthopedic Surgery and Sports Medicine, Erasmus Medical Center, Dr. Molewaterplein 40, Rotterdam 3015 GD, Netherlands. e.veltman@erasmusmc.nl

Abstract

BACKGROUND

Acetabular component positioning in total hip arthroplasty (THA) is of key importance to ensure satisfactory post-operative outcomes and to minimize the risk of complications. The majority of acetabular components are aligned freehand, without the use of navigation methods. Patient specific instruments (PSI) and three-dimensional (3D) printing of THA placement guides are increasingly used in primary THA to ensure optimal positioning.

AIM

To summarize the literature on 3D printing in THA and how they improve acetabular component alignment.

METHODS

PubMed was used to identify and access scientific studies reporting on different 3D printing methods used in THA. Eight studies with 236 hips in 228 patients were included. The studies could be divided into two main categories; 3D printed models and 3D printed guides.

RESULTS

3D printing in THA helped improve preoperative cup size planning and post-operative Harris hip scores between intervention and control groups (P = 0.019, P = 0.009). Otherwise, outcome measures were heterogeneous and thus difficult to compare. The overarching consensus between the studies is that the use of 3D guidance tools can assist in improving THA cup positioning and reduce the need for revision THA and the associated costs.

CONCLUSION

The implementation of 3D printing and PSI for primary THA can significantly improve the positioning accuracy of the acetabular cup component and reduce the number of complications caused by malpositioning.

Key Words: Total hip arthroplasty; Three-dimensional printing; Hip replacement surgery; Three-dimensional planning; Surgical guides

Core Tip: This study aimed to assess and summarize the current use of three-dimensional (3D) printing in total hip arthroplasty (THA) surgery. Eight studies discussing different implementations of 3D printing in THA were included and analyzed. The implementation of 3D printing and patient specific instruments for primary THA can significantly improve the positioning accuracy of the acetabular cup component and reduce the number of complications caused by malpositioning.

Citation: Crone TP, Cornelissen BMW, Van Oldenrijk J, Bos PK, Veltman ES. Intraoperative application of three-dimensional printed guides in total hip arthroplasty: A systematic review. *World J Orthop* 2024; 15(7): 660-667
URL: https://www.wjgnet.com/2218-5836/full/v15/i7/660.htm
DOI: https://dx.doi.org/10.5312/wjo.v15.i7.660

INTRODUCTION

Total hip arthroplasty (THA) significantly improves the quality of life in patients with end stage hip osteoarthritis[1]. Acetabular component positioning is of key importance to ensure satisfactory post-operative outcomes and to minimize the risk of complications[2,3]. Malalignment of the acetabular component in any particular way can increase the risk of dislocation, wear, loosening, impingement and overall patient dissatisfaction[2,4]. Malpositioning of the implants through freehand component positioning, even with an aiming device or navigation, can result in premature implant failure requiring revision[5,6]. To prevent hip dislocation and subsequent revision arthroplasty, surgeons strive for optimal acetabular component positioning, for which use of the "Lewinnek safe zone" was formerly advised. This safe zone is set at an anteversion angle of 15° ± 10° and an inclination angle of 40° ± 10°, with a reported increased chance of dislocation outside this range[7]. Several studies have recently shown that this generalized safe zone is non-existent, and that the safe zone for acetabular alignment is patient specific and dependent on multiple factors[8,9]. Moreover, the angle measurements of the acetabular component are highly dependent on spinopelvic mobility and the position of the patient [10,11].

Currently the majority of acetabular components are aligned freehand, without the use of navigation methods[3]. The position of the acetabular component is estimated using anatomical landmarks such as the transverse acetabular ligament and the posterior acetabular wall[12]. Callanan *et al*[13] reported that only 50% of acetabular components were positioned within 10 degrees of the surgeons' aimed acetabular position. The use of surgical navigation has shown to significantly improve accuracy of acetabular component positioning and to reduce the number and severity of outliers during acetabular component positioning in primary THA[14,15].

Bishi *et al*[16] and Moralidou *et al*[17] compared the accuracy of two-dimensional (2D) preoperative planning methods with three-dimensional (3D) preoperative planning methods and concluded that 3D preoperative planning helps the surgeons to visualize the pelvic anatomy and accurately plan the required implant size and orientation. With the rise of these 3D planning methods and the increase of computational power, various intraoperative navigational systems have been introduced over the years with the aim of improving the accuracy of acetabular component positioning and reducing postoperative complications from cup malalignment in primary and revision THA. 3D printed patient specific instruments (PSIs) are modelled after computed tomography (CT) or magnetic resonance imaging scans of a patient and can be designed in whichever way the surgery requires. PSIs are generally made of polylactic acid and are designed to precisely fit the bone structure at or around the surgical region of interest, in order to guide screw placement, saw or drill direction or implant positioning[18]. PSIs have already been used as guides during various types of surgical procedures, including osteotomy and/or arthroplasty of the knee, shoulder, wrist, ankle, and spine[19,20]. However, it has not yet been determined how the use of PSI improves cup positioning accuracy and clinical outcomes.

The aim of this systematic review was to summarize the existing literature on the use of PSI and 3D printing of THA placement guides in primary THA and how they contribute to improved acetabular component alignment accuracy. We hypothesize that the use of 3D guides leads to an improved accuracy of acetabular component positioning with less outliers compared to free-hand component positioning.

MATERIALS AND METHODS

Search strategy and study design

This systematic review was conducted according to the preferred reporting items for systematic reviews and meta-analysis guidelines. PubMed was used to identify and access scientific studies reporting on different 3D printing methods used in THA. The systematic search was performed on 30 March 2023, with the following search query:

["Arthroplasty, Replacement, Hip" (mj) or Hip-Replacement (ti) or Hip Prosthe (ti) or Prosthetic-Hip (ti) or Hip Arthroplast (ti) or tha (ti)] and ["Printing, Three-Dimensional" (mj) or Three-Dimension (ti) or 3-Dimension (ti) or 3d (ti) or 3-d (ti)] and ["Patient-Specific Modeling" (mj) or "Surgical Navigation Systems" (mj) or Patient-specific (ti) or navigat (ti) or guide (ti) or templat (ti) or planning (ti) and 2010:2023 (dp)] not [animals (mh) not humans(mh) and English (la)].

All papers reporting on 3D printing for clinical use during THA performed in adult humans were included in the study. Each study was analyzed for inclusion eligibility by the first and last author, based on title, abstract and full text analysis. The lists of references of retrieved publications were manually checked for additional studies potentially meeting the inclusion criteria and not found by the electronic search.

Studies that did not report postoperative cup angles or cup position were excluded as the accuracy could not be reported on. Studies regarding different, non-3D printed preoperative planning techniques were excluded as these planning techniques are not regarded as intraoperative surgical navigation techniques, and therefore do not add to the subject of this study.

An adaptation of the QUADAS-2 quality assessment tool[21] was used to assess the quality of the included studies.

RESULTS

Search results

The literature search resulted in 86 studies, of which 8 studies including 236 hips in 228 patients could be included[22-29]. Figure 1 depicts a detailed overview of the selection procedure.

Table 1 provides a detailed overview of the study characteristics of the included studies. The studies can be divided into two main categories, based on the 3D print application used. Table 2 provides the quality assessment of each study.

3D printed models

Three studies analyzed the use of 3D printed models as a method of preoperative planning of THA. The models were based on CT scans and used by surgeons to make a surgical plan ahead of THA and intraoperatively as a reference tool for anatomical landmarks. Table 3 provides an overview of the outcome measures of the three studies.

Dos Santos-Vaquinhas *et al*[22] compared the use of 3D models with conventional free hand component positioning and found superior outcome for THA after preoperative planning with 3D printed models (Table 3). They reported a significantly shorter operating time between groups, a significant increase in post-operative Harris hip scores (HHS), and a significant decrease in intraoperative complications.

All studies found higher correspondence between the 3D planned cup size and the implanted cup than for the cup size planned on 2D X-ray imaging. However, the included studies did not find any significant improvement in horizontal or vertical distance, in relation to the teardrop, between the cup and the original center of rotation between the intervention and control groups.

3D printed guides

Five studies reported on the use of 3D printed surgical guides, which are patient specific devices that use the anatomical landmarks of the acetabulum to guide intraoperative positioning of the cup component. The studies provide heterogeneous outcome measures and are provided in Table 4.

Cup angles were either provided as absolute angles with the range/SD or as absolute error of the angle and were measured on 2D X-ray images, by 3D matching using ZedView, or with CT images. Chen *et al*[25] reported a significant difference in absolute error of the cup inclination angles and the cup anteversion angles between both groups. The other studies found no significant differences in cup angles between intervention and control. Yan *et al*[29] found that the intervention group reported higher HHS postoperatively, significantly shorter operating time and significantly lower intraoperative blood loss compared to the control group. However, these significant results for mean operating time and intraoperative blood loss were not found by the other studies.

DISCUSSION

This study aimed to review the literature on the use of PSI and 3D printing for component positioning in THA. Only a limited number of studies were eligible for inclusion as the use of PSI in acetabular component positioning has not yet been frequently described.

The use of 3D printed models for preoperative planning and intraoperative referencing enables the surgeon to plan the required implant sizes more accurately than based on conventional x-ray imaging. However, the included studies did not find a significant improvement in horizontal or vertical distance of the cup from the center of ration between the intervention and control groups. Zhang *et al*[24] did report significant postoperative improvements in horizontal and

Table 1 Study characteristics of included studies

Ref.	Year	Study design	Navigation type	Patients, *n*	Hips, *n*
Dos Santos-Vaquinhas *et al*[22]	2022	Comparative study with retrospective cohort	3D model print	45	45
Xu *et al*[23]	2015	Retrospective cohort	3D model print	10	14
Zhang *et al*[24]	2022	Retrospective cohort	3D model print	17	21
Chen *et al*[25]	2022	RCT	3D printed Guides	60	60
Kida *et al*[26]	2023	Prospective cohort	3D printed Guides	23	23
Mishra *et al*[27]	2020	RCT	3D printed Guides	36	36
Tu *et al*[28]	2022	Prospective cohort	3D printed Guides	12	12
Yan *et al*[29]	2020	RCT	3D printed Guides	25	25

3D: Three-dimensional; RCT: Randomized controlled trial.

Table 2 Tubular presentation of QUADAS-2 results for included studies

Ref.	Risk of bias				Applicability concerns		
	Patient selection	Index test	Reference standard	Flow and timing	Patient selection	Index test	Reference standard
Dos Santos-Vaquinhas *et al*[22]	+	+	+	+	+	+	+
Xu *et al*[23]	+	+	+	+	+	+	+
Zhang *et al*[24]	+	-	-	-	+	+	+
Chen *et al*[25]	+	+	+	+	+	+	+
Kida *et al*[26]	+	+	+	+	+	+	+
Mishra *et al*[27]	+	+	+	+	+	+	+
Tu *et al*[28]	?	-	-	-	+	+	+
Yan *et al*[29]	+	+	+	+	+	+	+
	+	Low risk	-	High risk	?	Unknown risk	

vertical distance within their population, with the aid of their self-developed acetabular center locator. The HHS improved significantly in all study populations that used the 3D models, but only Dos Santos-Vaquinhas *et al*[22] compared the postoperative HHS of the intervention group with a control group and found a significant improvement there.

As mentioned prior, the 3D printed acetabular cutting and positioning guides use heterogeneous outcome measures. Kida *et al*[26] and Tu *et al*[28] do not compare the results with any control groups. Despite these limitations, PSIs seemingly improve component position, based on the significant difference in absolute error found by Chen *et al*[25] and the smaller positioning ranges reported by Mishra *et al*[27]. Furthermore, the use of PSI significantly increases the HHS, as found by Yan *et al*[29]. Yan *et al*[29] performed THA on unilateral developmental dysplasia of the hip patients and did not directly compare both groups with each other, but they compared the anteversion angle, abduction angle and the distance from the rotation center to the ischial tuberosity connection of the ipsilateral side with the contralateral side. When comparing these values they found no significant differences between both sides within the intervention group, but they did find significantly smaller anteversion angles (P = 0.015) and a larger distance from center of rotation (P = 0.002) between both sides within the control group. This suggests that component positioning in the intervention group is more similar to the natural anatomy of the healthy contralateral hip of the patient and thus better than component positioning in the control group. Outcome measures such as mean operating time and intraoperative blood loss varied widely between studies and therefore it is difficult to predict, based on these studies alone, if and how the use of PSI will improve these outcome measures.

The overarching conclusion between the studies is that the use of 3D guidance tools can assist in improving THA cup positioning. Henckel *et al*[30] performed a literature study regarding 3D printed PSI in THA and found similar results supporting the superiority of THA performed with PSI, albeit most of their included studies consist of THA performed on dry bone models or cadavers. Additionally, they analyzed the cost of producing PSIs and they concluded that it would add approximately $371 per surgical procedure. However, as the THA positioning improved, these additional costs

Table 3 Outcome measures of articles reporting three-dimensional printed models

Ref.	Outcomes							
	Number of hips	Mean (range) follow-up in months	Cup size planning accuracy[1]	Mean operating time in min	HHS[2]	Complications[1]	Vertical distance in mm[3]	Horizontal distance in mm[3]
Dos Santos-Vaquinhas *et al*[22]	45	32.4 (12-60)	19/21 *vs* 14/24 (*P* = 0.045)	156.15 ± 43.03 *vs* 187.5 ± 54.38 (*P* = 0.045)	57.15 ± 15.41–83.74 ± 8.49 *vs* 53.12 ± 15.62–75.59 ± 11.46 (*P* = 0.019)	Intraoperative 4/21 *vs* 10/24 (*P* = 0.003)	0.7 [(-5.0)-15] *vs* -3.3 [(-32.0)-8.0] (*P* = 0.102)	1.2 [(-9.0)-7.0)] *vs* 1.0 [(-8.0)-15.0] (*P* = 0.884)
Xu *et al*[23]	14	23.1 ± 5.9 (14-30)	10/14 (3/14 < 2 mm diff) *vs* 1/14 (5/14 < 2 mm diff)		37.7 ± 6.8–83.3 ± 5.7 (*P* < 0.01)		18.8 (11.5-25.8)	21.7 (15.0-31.2)
Zhang *et al* [24]	21	18.35 ± 6.86 (12-36)	15/17 (ICC = 0.930)		38.33 ± 6.07–88.61 ± 3.44 (*P* < 0.05)		40.48 ± 8.42–15.12 ± 1.25 (*P* < 0.05)	41.49 ± 5.17–32.49 ± 2.83 (*P* < 0.05)

[1]Intervention *vs* control.

[2]Harris hip score (preoperative–postoperative; intervention *vs* control; *P* value between postoperative values for intervention *vs* control or preoperative-postoperative when no control group was used).

[3]Distance to center of rotation of the hip (preoperative–postoperative; intervention *vs* control).

ICC: Intraclass correlation coefficient.

Table 4 Outcome measures of articles reporting three-dimensional printed acetabular guides

Ref.	Outcomes							
	Number of hips	Mean (range) follow-up in months	Cup size planning accuracy[1]	Postoperative cup inclination angle as °[1]	Postoperative cup anteversion angle as °[1]	Mean operating time in min[1]	HHS[2]	Intraoperative blood loss in mL[1]
Chen *et al*[25]	60	3	83.3% (93.3% < 2 mm) *vs* 73.3% (80% < 2 mm) (*P* = 0.532)	Absolute error: 2.6 (0-8.0) *vs* 5.0 (0-15.0) (*P* = 0.004)	Absolute error: 2.5 (0.3-7.3) *vs* 5.2 (0.1-14.0) (*P* < 0.001)	100.2 ± 13.4 *vs* 106.7 ± 24.4		290 ± 70.3 *vs* 251.7 ± 93.3
Kida *et al*[26]	23	0.5		39.37 ± 8.18	25.86 ± 7.87			
Mishra *et al*[27]	36		18/18 *vs* 6/18	43.28 (38-46) *vs* 44.11 (34-50)	14.22 (8-27) *vs* 13.42 (5-36)	99.39 *vs* 92.33		519.44 *vs* 495.56
Tu *et al* [28]	12	72.42 (38–135)		42.6 ± 4.2	12.5 ± 3.6	280.8 ± 106.8	34.2 ± 3.7-85.2 ± 4.2 (*P* < 0.001)	590.35 ± 112.47
Yan *et al* [29]	25	19.2 (14.4–45.6)		42.25 ± 4.55 *vs* 38.60 ± 3.25	17.30 ± 5.12 *vs* 15.01 ± 5.68	57.8 ± 3.73 *vs* 62.1 ± 4.19 (*P* = 0.008)	93.9 ± 2.87 *vs* 91.8 ± 3.69 (*P* = 0.009)	169 ± 34.1 *vs* 219 ± 38.0 (*P* = 0.002)

[1]Intervention *vs* control.

[2]Harris hip score (preoperative–postoperative; intervention *vs* control; *P* value between postoperative values). *P* values are displayed for all studies that provided *P* values in their comparisons.

would be relatively small compared to potential additional costs of possible revision surgery caused by early failure or poor positioning of freehand THA. Similarly with our findings, Henckel *et al*[30] could not find significant differences in intraoperative blood loss between PSI and conventional THA groups. They found one complication in a total of 128 patients in whom PSI was used during THA.

Constantinescu *et al*[31] also conducted a literature study on PSI in THA and supported previous results regarding the efficacy of PSI in THA. However, they found PSI to be most useful in patients with larger acetabular defects where traditional landmarks were difficult to identify.

While the focus of this study was on the use of 3D printing in THA, other navigation methods such as imageless navigation and surgical robots are also available. The use of navigation and/or robotic assistance during THA has shown to improve accuracy of acetabular component positioning[14,32]. However, these devices often require a major

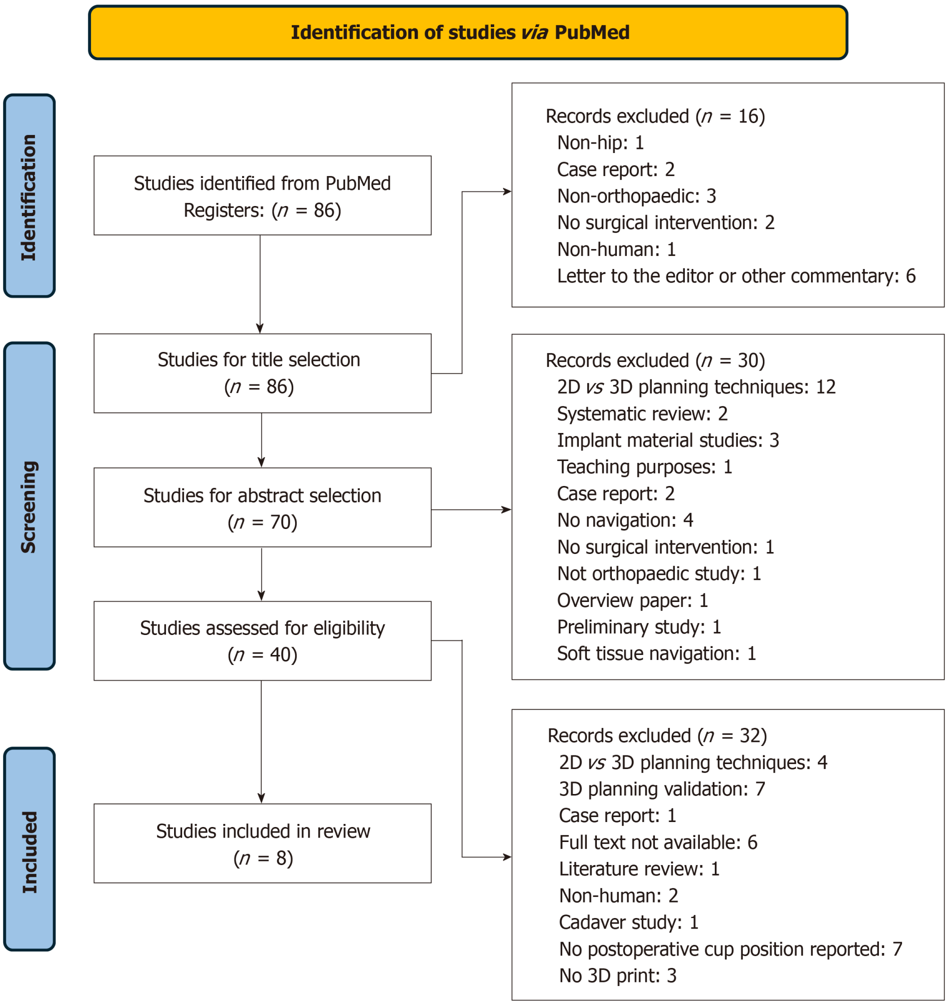

Figure 1 PRISMA Flowchart of study inclusion. 2D: Two-dimensional; 3D: Three-dimensional.

investment and are not yet widely used for THA[33]. When 3D planning software, knowledge and printers are readily available in-house, the use of 3D printed models can be a relatively cheap method of improving surgical outcome without needing major investment in navigational devices such as robots or imageless navigation.

Despite the promising postoperative results of PSI assisted THA, this review does not report on long-term functional outcome, complications and patient satisfaction. Also, this review focusses only on the positioning of the acetabular cup component and one could argue that accurate positioning of the femoral component is as important as the accuracy of the cup position and should therefore be analyzed together to find the optimal methodology. Furthermore, only eight studies were included and subcategorized into different 3D print applications that did not use uniform outcome measures. On the other hand, the limited existing literature on PSI and 3D printing for THA, with promising improved outcome for patients, underscores the significance and amplifies the importance of this systematic literature review. What is more, this review summarizes existing knowledge and provides insight into combining different applications of 3D printing. The use of 3D printed models for preoperative planning can easily be combined with 3D printed acetabular cutting and positioning guides to improve the preoperative planning, understanding of the anatomical landmarks and finding the optimal position of the cup component.

In revision arthroplasty, the anatomical landmarks used for free-hand acetabular component alignment are more difficult to use or absent due to bone loss and scar tissue formation. Acetabular component positioning can be very difficult, as there can be little anatomical landmarks to use as feedback during surgery. The most frequently used commercially available navigation systems are not yet officially available for revision THA, or lack a revision module. In these cases, 3D printed guides could provide the necessary aid to improve acetabular component positioning, however to date this has not yet been described.

CONCLUSION

In conclusion, the implementation of 3D printing and PSI for primary THA can significantly improve the positioning accuracy of the acetabular cup component and reduce the number of complications caused by malpositioning. Future studies should further explore the possibilities of implementing PSIs in primary and revision THA with a focus on patient reported outcome and postoperative complication rate reduction.

FOOTNOTES

Author contributions: Crone TP and Veltman ES designed the study; Crone TP reviewed the data and wrote the manuscript; Cornelissen BMW, Van Oldenrijk J, Bos PK and Veltman ES read the primary draft critically and provided feedback; All the authors read and approved the final manuscript.

Conflict-of-interest statement: The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

PRISMA 2009 Checklist statement: The authors have read the PRISMA 2009 Checklist, and the manuscript was prepared and revised according to the PRISMA 2009 Checklist.

Country of origin: Netherlands

ORCID number: Ewout S Veltman 0000-0001-6334-0967.

S-Editor: Fan M
L-Editor: Filipodia
P-Editor: Che XX

REFERENCES

1 **Chang RW**, Pellisier JM, Hazen GB. A cost-effectiveness analysis of total hip arthroplasty for osteoarthritis of the hip. *JAMA* 1996; **275**: 858-865 [PMID: 8596224 DOI: 10.1001/jama.1996.03530350040032]

2 **Kennedy JG**, Rogers WB, Soffe KE, Sullivan RJ, Griffen DG, Sheehan LJ. Effect of acetabular component orientation on recurrent dislocation, pelvic osteolysis, polyethylene wear, and component migration. *J Arthroplasty* 1998; **13**: 530-534 [PMID: 9726318 DOI: 10.1016/s0883-5403(98)90052-3]

3 **Agarwal S**, Eckhard L, Walter WL, Peng A, Hatton A, Donnelly B, de Steiger R. The Use of Computer Navigation in Total Hip Arthroplasty Is Associated with a Reduced Rate of Revision for Dislocation: A Study of 6,912 Navigated THA Procedures from the Australian Orthopaedic Association National Joint Replacement Registry. *J Bone Joint Surg Am* 2021; **103**: 1900-1905 [PMID: 34143758 DOI: 10.2106/JBJS.20.00950]

4 **Biedermann R**, Tonin A, Krismer M, Rachbauer F, Eibl G, Stöckl B. Reducing the risk of dislocation after total hip arthroplasty: the effect of orientation of the acetabular component. *J Bone Joint Surg Br* 2005; **87**: 762-769 [PMID: 15911655 DOI: 10.1302/0301-620X.87B6.14745]

5 **Bozic KJ**, Kurtz SM, Lau E, Ong K, Vail TP, Berry DJ. The epidemiology of revision total hip arthroplasty in the United States. *J Bone Joint Surg Am* 2009; **91**: 128-133 [PMID: 19122087 DOI: 10.2106/JBJS.H.00155]

6 **Nishii T**, Sugano N, Miki H, Koyama T, Takao M, Yoshikawa H. Influence of component positions on dislocation: computed tomographic evaluations in a consecutive series of total hip arthroplasty. *J Arthroplasty* 2004; **19**: 162-166 [PMID: 14973858 DOI: 10.1016/j.arth.2003.09.005]

7 **Lewinnek GE**, Lewis JL, Tarr R, Compere CL, Zimmerman JR. Dislocations after total hip-replacement arthroplasties. *J Bone Joint Surg Am* 1978; **60**: 217-220 [PMID: 641088]

8 **Abdel MP**, von Roth P, Jennings MT, Hanssen AD, Pagnano MW. What Safe Zone? The Vast Majority of Dislocated THAs Are Within the Lewinnek Safe Zone for Acetabular Component Position. *Clin Orthop Relat Res* 2016; **474**: 386-391 [PMID: 26150264 DOI: 10.1007/s11999-015-4432-5]

9 **Dorr LD**, Callaghan JJ. Death of the Lewinnek "Safe Zone". *J Arthroplasty* 2019; **34**: 1-2 [PMID: 30527340 DOI: 10.1016/j.arth.2018.10.035]

10 **Dennis DA**, Smith GH, Phillips JLH, Ennis HE, Jennings JM, Plaskos C, Pierrepont JW. Does Individualization of Cup Position Affect Prosthetic or Bone Impingement Following Total Hip Arthroplasty? *J Arthroplasty* 2023; **38**: S257-S264 [PMID: 37100096 DOI: 10.1016/j.arth.2023.04.031]

11 **Heckmann N**, Trasolini NA, Stefl M, Dorr L. The Effect of Spinopelvic Motion on Implant Positioning and Hip Stability Using the Functional Safe Zone of THR. 2020 Jul 1. In: Personalized Hip and Knee Joint Replacement [Internet]. Cham (CH): Springer; 2020– [PMID: 33347123]

12 **Sotereanos NG**, Miller MC, Smith B, Hube R, Sewecke JJ, Wohlrab D. Using intraoperative pelvic landmarks for acetabular component placement in total hip arthroplasty. *J Arthroplasty* 2006; **21**: 832-840 [PMID: 16950035 DOI: 10.1016/j.arth.2005.12.001]

13 **Callanan MC**, Jarrett B, Bragdon CR, Zurakowski D, Rubash HE, Freiberg AA, Malchau H. The John Charnley Award: risk factors for cup malpositioning: quality improvement through a joint registry at a tertiary hospital. *Clin Orthop Relat Res* 2011; **469**: 319-329 [PMID: 20717858 DOI: 10.1007/s11999-010-1487-1]

14 **Xu J**, Veltman ES, Chai Y, Walter WL. Accuracy of acetabular component alignment with surgical guidance systems during hip arthroplasty. *SICOT J* 2023; **9**: 12 [PMID: 37144949 DOI: 10.1051/sicotj/2023010]

15 **Ando W**, Takao M, Hamada H, Uemura K, Sugano N. Comparison of the accuracy of the cup position and orientation in total hip arthroplasty

for osteoarthritis secondary to developmental dysplasia of the hip between the Mako robotic arm-assisted system and computed tomography-based navigation. *Int Orthop* 2021; **45**: 1719-1725 [PMID: 33880612 DOI: 10.1007/s00264-021-05015-3]

16 **Bishi H**, Smith JBV, Asopa V, Field RE, Wang C, Sochart DH. Comparison of the accuracy of 2D and 3D templating methods for planning primary total hip replacement: a systematic review and meta-analysis. *EFORT Open Rev* 2022; **7**: 70-83 [PMID: 35076413 DOI: 10.1530/EOR-21-0060]

17 **Moralidou M**, Di Laura A, Henckel J, Hothi H, Hart AJ. Three-dimensional pre-operative planning of primary hip arthroplasty: a systematic literature review. *EFORT Open Rev* 2020; **5**: 845-855 [PMID: 33425373 DOI: 10.1302/2058-5241.5.200046]

18 **Bagaria V**, Bhansali R, Pawar P. 3D printing- creating a blueprint for the future of orthopedics: Current concept review and the road ahead! *J Clin Orthop Trauma* 2018; **9**: 207-212 [PMID: 30202150 DOI: 10.1016/j.jcot.2018.07.007]

19 **Roth K**, van Es E, Kraan G, Eygendaal D, Colaris J, Stockmans F. Accuracy of 3D Corrective Osteotomy for Pediatric Malunited Both-Bone Forearm Fractures. *Children (Basel)* 2022; **10** [PMID: 36670572 DOI: 10.3390/children10010021]

20 **Stolarczyk A**, Nagraba L, Mitek T, Stolarczyk M, Deszczyński JM, Jakucinski M. Does Patient-Specific Instrumentation Improve Femoral and Tibial Component Alignment in Total Knee Arthroplasty? A Prospective Randomized Study. *Adv Exp Med Biol* 2018; **1096**: 11-17 [PMID: 29623574 DOI: 10.1007/5584_2018_193]

21 **Whiting PF**, Rutjes AW, Westwood ME, Mallett S, Deeks JJ, Reitsma JB, Leeflang MM, Sterne JA, Bossuyt PM; QUADAS-2 Group. QUADAS-2: a revised tool for the quality assessment of diagnostic accuracy studies. *Ann Intern Med* 2011; **155**: 529-536 [PMID: 22007046 DOI: 10.7326/0003-4819-155-8-201110180-00009]

22 **Dos Santos-Vaquinhas A**, López-Torres II, Matas-Diez JA, Calvo-Haro JA, Vaquero J, Sanz-Ruiz P. Improvement of surgical time and functional results after do-it-yourself 3D-printed model preoperative planning in acetabular defects Paprosky IIA-IIIB. *Orthop Traumatol Surg Res* 2022; **108**: 103277 [PMID: 35331922 DOI: 10.1016/j.otsr.2022.103277]

23 **Xu J**, Li D, Ma RF, Barden B, Ding Y. Application of Rapid Prototyping Pelvic Model for Patients with DDH to Facilitate Arthroplasty Planning: A Pilot Study. *J Arthroplasty* 2015; **30**: 1963-1970 [PMID: 26129852 DOI: 10.1016/j.arth.2015.05.033]

24 **Zhang H**, Guan JZ, Zhang Z, Chen XT, Ma XD, Zhao JN, Zhou JS. Restoring Rotation Center in Total Hip Arthroplasty for Developmental Dysplasia of the Hip with the Assistance of Three Dimensional Printing Technology: A Pilot Study. *Orthop Surg* 2022; **14**: 119-128 [PMID: 34898037 DOI: 10.1111/os.13183]

25 **Chen X**, Li S, Wang Y, Liu X, Zhang Y, Qiu G, Qian W. Artificially Intelligent Three-Dimensionally-Printed Patient-Specific Instrument Improves Total Hip Arthroplasty Accuracy. *J Arthroplasty* 2023; **38**: 2060-2067.e1 [PMID: 36535443 DOI: 10.1016/j.arth.2022.12.017]

26 **Kida D**, Hashimoto H, Ito N, Kito Y, Mori K, Hattori Y, Takahashi N, Matsubara M. Patient-Specific Femoral Guide with 3-Dimensional Support Software in Anterolateral Supine Approach of Total Hip Arthroplasty: A Single-Arm Trial. *Kurume Med J* 2023; **68**: 1-8 [PMID: 36754380 DOI: 10.2739/kurumemedj.MS681003]

27 **Mishra A**, Verma T, Rajkumar, Agarwal G, Sharma A, Maini L. 3D Printed Patient-Specific Acetabular Jig for Cup Placement in Total Hip Arthroplasty. *Indian J Orthop* 2020; **54**: 174-180 [PMID: 32257035 DOI: 10.1007/s43465-020-00061-2]

28 **Tu Q**, Ding HW, Chen H, Shen JJ, Miao QJ, Liu B, Yu GW, Huang XH, Zhu CR, Tang Y, Xia H, Xu JZ. Preliminary application of 3D-printed individualised guiding templates for total hip arthroplasty in Crowe type IV developmental dysplasia of the hip. *Hip Int* 2022; **32**: 334-344 [PMID: 32750257 DOI: 10.1177/1120700020948006]

29 **Yan L**, Wang P, Zhou H. 3D Printing Navigation Template Used in Total Hip Arthroplasty for Developmental Dysplasia of the Hip. *Indian J Orthop* 2020; **54**: 856-862 [PMID: 33133409 DOI: 10.1007/s43465-020-00093-8]

30 **Henckel J**, Holme TJ, Radford W, Skinner JA, Hart AJ. 3D-printed Patient-specific Guides for Hip Arthroplasty. *J Am Acad Orthop Surg* 2018; **26**: e342-e348 [PMID: 30052547 DOI: 10.5435/JAAOS-D-16-00719]

31 **Constantinescu DS**, Costello JP 2nd, Dalling AD, Wagner JD, Al-Hardan W, Carvajal JA. The efficacy of patient specific instrumentation (PSI) in total hip arthroplasty (THA): A systematic review and meta-analysis. *J Orthop* 2022; **34**: 404-413 [PMID: 36325516 DOI: 10.1016/j.jor.2022.10.001]

32 **Buchan GBJ**, Hecht CJ 2nd, Liu D, Mokete L, Kendoff D, Kamath AF. Improved accuracy of a novel fluoroscopy-based robotically assisted THA system compared to manual THA. *J Robot Surg* 2023; **17**: 2073-2079 [PMID: 37209355 DOI: 10.1007/s11701-023-01623-w]

33 **Banerjee S**, Cherian JJ, Elmallah RK, Pierce TP, Jauregui JJ, Mont MA. Robot-assisted total hip arthroplasty. *Expert Rev Med Devices* 2016; **13**: 47-56 [PMID: 26592900 DOI: 10.1586/17434440.2016.1124018]

W J O World Journal of Orthopedics

Submit a Manuscript: https://www.f6publishing.com

World J Orthop 2024 July 18; 15(7): 668-674

DOI: 10.5312/wjo.v15.i7.668

ISSN 2218-5836 (online)

CASE REPORT

Bone graft incorporation failure with inappropriate limb load transfer can lead to aseptic acetabular loosening of metal-on-metal prosthesis: A case report

Rafał Stanisław Domagalski, Bogdan Dugiełło, Sonia Rokicka, Szymon Czech, Rafał Skowroński, Dominika Rokicka, Marta Patrycja Wróbel, Krzysztof Strojek, Tomasz Stołtny

Specialty type: Orthopedics

Provenance and peer review: Unsolicited article; Externally peer reviewed.

Peer-review model: Single blind

Peer-review report's classification

Scientific Quality: Grade C

Novelty: Grade B

Creativity or Innovation: Grade B

Scientific Significance: Grade B

P-Reviewer: Zhang JW, China

Received: January 2, 2024

Revised: February 11, 2024

Accepted: May 9, 2024

Published online: July 18, 2024

Processing time: 191 Days and 11.6 Hours

Rafał Stanisław Domagalski, Szymon Czech, Tomasz Stołtny, District Hospital of Orthopaedics and Trauma Surgery in Piekary Śląskie, Piekary Śląskie 41-940, Poland

Bogdan Dugiełło, District Railway Hospital, Medical University of Silesia, Katowice 40-760, Poland

Sonia Rokicka, Faculty of Medicine, Medical University of Gdańsk, Gdańsk 80-210, Poland

Rafał Skowroński, "ALFA" Orthopaedics and Traumatology Center, Białystok 15-763, Poland

Dominika Rokicka, Marta Patrycja Wróbel, Krzysztof Strojek, Department of Internal Medicine, Diabetology and Cardiometabolic Disorders, Faculty of Medical Sciences Zabrze, Medical University of Silesia, Zabrze 41-800, Poland

Corresponding author: Bogdan Dugiełło, MD, Doctor, District Railway Hospital, Medical University of Silesia, Panewnicka Street 65, Katowice 40-760, Poland. bogdan.dugiello@gmail.com

Abstract

BACKGROUND

Aseptic acetabular loosening can result from various factors that can be categorized into groups: patient-related, surgeon-related and implant-related. We present a case of a 63-year-old patient who at first underwent a total hip arthroplasty (THA) using a metal-on-metal bearing due to hip arthrosis. Follow-up visits revealed no complications after the procedure. Two years after the THA, acetabular component loosening occurred due to subsequent trauma of the opposite hip, necessitating a revision THA using a ceramic-on-ceramic bearing.

CASE SUMMARY

We aim to illustrate a rare case where the primary reason for undergoing THA revision was not only incomplete bone graft incorporation but also improper limb load distribution. Following the revision arthroplasty, a 9-year follow-up visit revealed improvements in all evaluation measures on questionnaire compared to the state before surgery: Harris Hip Score (before surgery: 15; after surgery: 95), Western Ontario and McMaster Universities Arthritis Index (before surgery: 96; after surgery: 0), and Visual Analogue Scale (before surgery: 10; after surgery: 1).

CONCLUSION
Opposite-hip trauma caused a weight transfer to the limb after a THA procedure. This process led to a stress shielding effect, resulting in acetabular component loosening.

Key Words: Acetabular loosening; Limb load; Stress shielding effect; Revision hip arthroplasty; Case report

Core Tip: This article explores a rare case of acetabular loosening following total hip arthroplasty (THA) due to improper limb load transfer after hip trauma. A 63-year-old patient underwent THA with a metal-on-metal bearing, initially showing no complications. However, 2 years later, acetabular component loosening occurred, requiring revision THA with a ceramic-on-ceramic bearing. The study emphasizes the impact of limb load distribution on hip arthroplasty outcomes. Post-revision, the patient showed significant improvement in clinical parameters. This case underscores the need for careful consideration of limb load transfer after THA to mitigate risks of loosening.

Citation: Domagalski RS, Dugiełło B, Rokicka S, Czech S, Skowroński R, Rokicka D, Wróbel MP, Strojek K, Stołtny T. Bone graft incorporation failure with inappropriate limb load transfer can lead to aseptic acetabular loosening of metal-on-metal prosthesis: A case report. *World J Orthop* 2024; 15(7): 668-674
URL: https://www.wjgnet.com/2218-5836/full/v15/i7/668.htm
DOI: https://dx.doi.org/10.5312/wjo.v15.i7.668

INTRODUCTION

Revision hip arthroplasty occurs in approximately 13% of all hip arthroplasty procedures in the United States, and the demand for hip revision procedures is predicted to double by the year 2026[1,2]. There are many potential causes of hip joint acetabulum loosening including polyethylene wear, aseptic and mechanical loosening, pseudotumor, osteolysis around the implant, periprosthetic fracture, infection and bone necrosis[3]. Understanding the factors of hip loosening may lead to better prevention in the majority of instances. Here, we present a case rarely described in the literature: a patient who underwent a hip revision possibly due to improper limb load transfer after a trauma of the opposite hip.

CASE PRESENTATION

Chief complaints

A 63-year-old male patient presented to the Orthopaedic Trauma Emergency Room with severe right lower limb pain in a flexion contraction. He did not associate the occurrence of symptoms with an injury.

History of present illness

The patient-reported trauma to the hip joint occurred 1 year after total hip arthroplasty (THA) on the opposite hip. However, X-ray imaging revealed no fractures in either lower limb nor loosening of the right hip endoprosthesis (Figure 1A). Seeking relief from discomfort, the patient underwent rehabilitation for the left lower limb. Unfortunately, this resulted in a gradual increase in pain in the right hip joint over time.

History of past illness

The patient underwent THA due to reduced mobility of the right hip and increased pain especially while walking. Physical examination before the procedure revealed positive Trendelenburg and Duchenne signs. The anti-inflammatory medications had a small impact on pain relief. Using X-ray imaging, hip arthrosis was diagnosed (Figure 2). He was then referred for total hip replacement surgery using a metal-on-metal (MOM) bearing. After 4 months a follow-up examination showed no complications. The inclination angle and limb movements were in the normal range (Figure 1B and C). The patient's wound had properly healed and he was able to walk without any support.

Personal and family history

No significant personal or family history was reported.

Physical examination

Physical examination showed right limb in a flexion contraction at an angle of about 30 degrees with total right hip endoprosthesis acetabular component loosening (Figure 3).

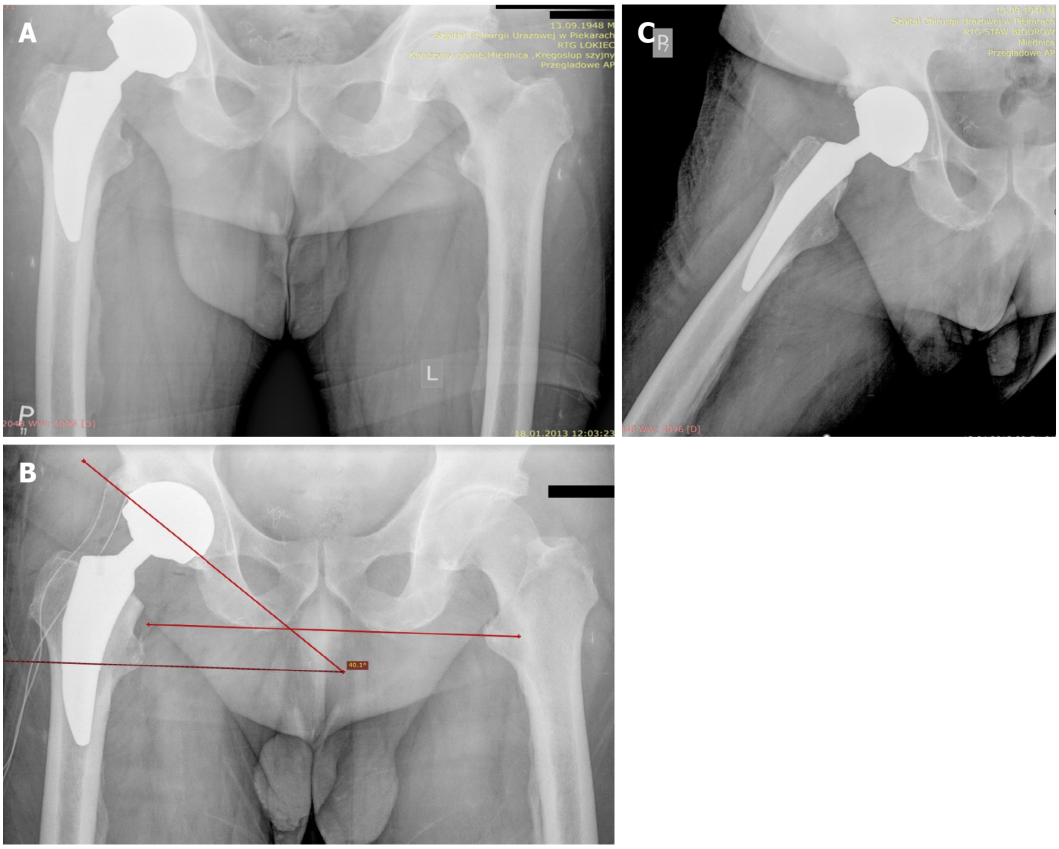

Figure 1 X-ray images after total right hip replacement surgery. A: At 1 yr postoperative; B: At 4 months postoperative, the inclination angle before revision arthroplasty was 40.1°; C: In lateral view at 4 months postoperative.

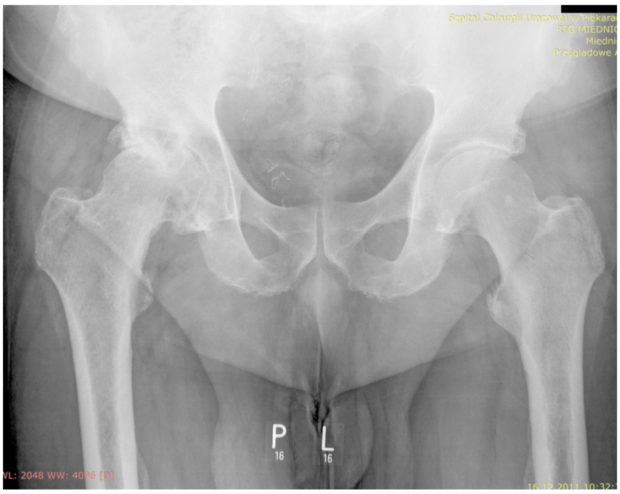

Figure 2 X-ray image showing hip arthrosis before total hip replacement surgery.

Laboratory examinations

The patient's laboratory test findings were within normal ranges.

Imaging examinations

The X-ray images after right hip endoprosthesis acetabular component loosening are shown on Figure 3 and after the revision in Figure 4A and B, confirming the correct positioning of the prosthesis components.

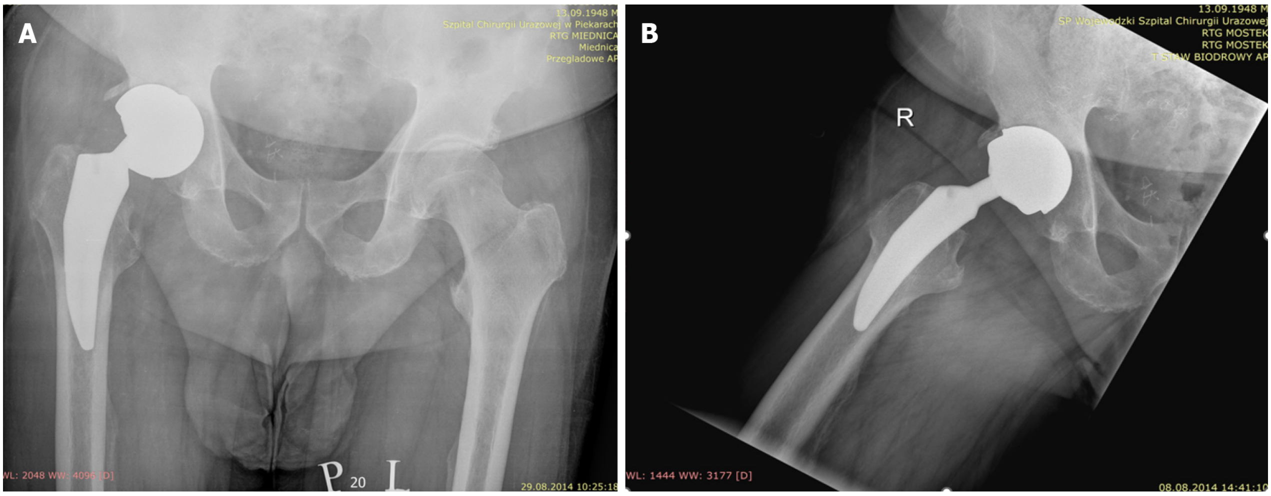

Figure 3 X-ray images of total right hip endoprosthesis acetabular component loosening. A: Right hip joint; B: Right hip joint in lateral view.

FINAL DIAGNOSIS

Inappropriate limb load transfer along with failure of bone graft incorporation led to aseptic acetabular component loosening of the right hip joint endoprosthesis.

TREATMENT

In 2012, a cementless endoprosthesis of the right hip was implanted using a Biomet Recap-Magnum 54 mm acetabulum and a microplastic metaphyseal stem with a 48 mm metal head. Bone defects mainly around the medial acetabular wall and trochanteric region were filled with an autologous cancellous bone transplantation taken from the femoral head. In 2014, due to the patient's symptoms and X-ray findings (Figure 3), he was immediately referred for revision arthroplasty of the right hip joint. During the procedure, the cementless Biomet Recup-Magnum system was removed. There was no evidence of metallosis intraoperatively. This time, a cementless 62 mm Biomet Exceed acetabulum was implanted supported by an acetabular screw (30 mm × 6.5 mm) with a ceramic liner (62/36 mm). A decision was made to perform plastic surgery with allogenic cancellous bone from the Tissue Bank in a volume of 20 cm^3. A ceramic 36 mm head-cap of the J&J DePuy system (DePuy Synthes, The Orthopaedics Company of Johnson & Johnson MedTech, Warsaw, IN, United States) was implanted. At the end of the procedure, the surgeons observed no hip joint luxation and normal limb movements.

OUTCOME AND FOLLOW-UP

X-ray imaging after the procedure confirmed the correct positioning of the prosthesis components (see Figure 4A and B). The patient underwent rehabilitation in the ward and was discharged with the support of two elbow crutches. After 3 months an orthopedic examination showed negative Trendelenburg and Duchenne signs and a significant improvement in clinical parameters compared to the state before revision arthroplasty. Moreover, a 9-year follow-up visit revealed similar results (Figure 4C and D). The postoperative wound healed correctly by primary adhesion and the patient was able to walk without any support, properly transferring the load between both hip joints. The acetabular inclination angle of the prosthesis before revision arthroplasty was 40.1° (Figure 1B) and after surgery 48.2° (Figure 4C). Right lower limb flexion was at 120˚, internal rotation 20˚, external 30˚, adduction 30˚, and abduction 40˚. The patient scored 5 points on the Lovett muscle strength scale for both limbs, 0 points on Western Ontario and McMaster Universities Arthritis Index (WOMAC), Harris Hip Score of 95, and 1 point on the Visual Analogue Scale. All results before and after revision arthroplasty are shown in Table 1.

DISCUSSION

Aseptic acetabular loosening after THA is one of the most common causes of both patient and surgeon disappointment, which can occur even when the primary procedure was performed with no complications. All factors can be divided into three groups: patient, surgeon and implant causes. Patient factors include age, body mass index, female sex, patient's education, level of activity or comorbidities such as infection or aseptic loosening. Surgeon factors include experience and surgical approach. Implant factors include type of alloy, type of articulation, head design and neck or component

Table 1 Results before and after total hip arthroplasty revision

Scoring system	Before revision	After revision 9-yr follow-up
WOMAC	96	0
HHS	15	95
VAS	10	1

HHS: Harris Hip Score; VAS: Visual Analogue Scale; WOMAC: Western Ontario and McMaster Universities Arthritis Index.

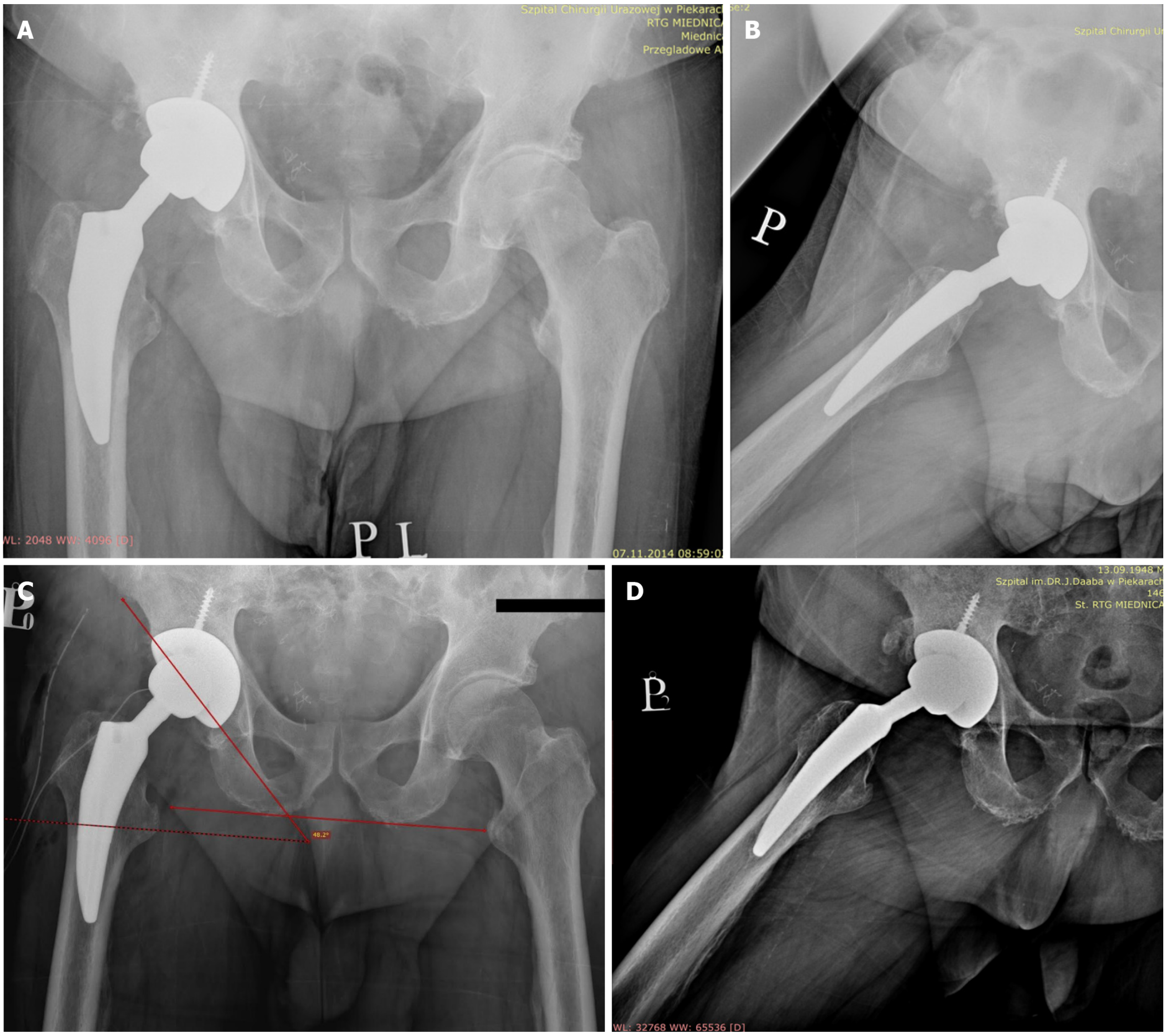

Figure 4 X-ray images of the right hip joint after total hip arthroplasty revision. A: After total hip arthroplasty revision; B: In lateral view after total hip arthroplasty revision; C: At 9 years after total hip arthroplasty revision showing acetabular cup at an inclination angle of 48.2°; D: In lateral view at 9 years after total hip arthroplasty revision.

positioning. Identification of risk factors is difficult because revision arthroplasty is relatively infrequent, with late occurrence[4,5].

Here, we present a case report of a patient who underwent revision THA even though total hip replacement surgery had been performed successfully and follow-up visits 1 year after the procedure showed no complications in physical examination. Consequently, based on clinical data and X-ray imaging, inappropriate weight bearing in addition to inadequate bone graft healing seemed most likely responsible for the mechanical loosening. Due to a trauma of the left lower limb, the right hip joint was severely overloaded, which may have led to a stress shielding effect. It is a process in which bone tissue adapts to increased weight distribution by creating new cells to withstand excessive load and by resorbing bone tissue when it is unloaded. This process is called mechanosensation. Only when the body weight is equally distributed over the limbs will the remodeling be properly regulated. Formation of atrophic bone in the region close to the hip prosthesis can occur when it is no longer physiologically loaded. This process negatively affects the implant's lifespan[6]. There are a few ways to guarantee proper limb load transfer after a THA and reduce the risk of future hip joint revision arthroplasty. Some manufacturers propose changing the prosthesis design. Larger head sizes have been found to reduce the dislocation rate, shortening the stem may allow more uniform distribution of the load, and using other biomaterials with mechanical features replicating those of the bone tissue such as porous titanium can also reduce the stress shielding effect and osteolysis by 75% compared to traditional implants[7,8].

The other possible cause of our THA revision is the type of bearing. MOM and ceramic-on-ceramic (COC) bearings were developed to reduce polyethylene wear osteolysis. In a meta-analysis by Lee *et al*[9], MOM showed a higher revision rate than COC, possibly due to a lower wear rate of COC bearings and ceramic particles being more biocompatible than metallic. It is worth highlighting that in our case, the presence of bone defects primarily located around the medial acetabular wall in conjunction with a MOM articulation has the potential to exacerbate the development of a pseudotumor, which could negatively impact the overall results[10].

According to Higgins *et al*[11], both COC and ceramic-on-metal bearings in 211 patients had the same functional outcomes and radiographic parameters, but the latter had an increased revision rate due to the adverse reaction to metal debris. Moreover, a 20-year follow-up of COC bearings showed that they gave better results in terms of survivorship, complication rate and WOMAC scores, especially among younger patients[12].

In our case, we did not measure the level of metals in blood, but there were no signs of metallosis intraoperatively, which is also a well-known cause of acetabular loosening. According to Crawford *et al*[13], out of 188 patients with failed MOM THA revisions, the most common causes were acetabular or femoral aseptic loosening, infection and metallosis. Kelmer *et al*[14] reported that among 535 THA revisions, metallosis was the second major cause of this procedure (95 cases), occurring mostly 2 or more years after the primary THA. According to Stryker *et al*[15], 107 patients underwent 114 revisions of monoblock MOM THAs, mainly due to metallosis, aseptic loosening or infection.

Within the spectrum of methods available for addressing bone defects in revision THA, inlay bone grafting emerges as a viable and efficacious choice for the restoration of bone integrity and biological reconstruction[16]. One of the causes of acetabular loosening may be improper healing of the bone graft around the acetabulum. In our case, there were no indications for a computed tomography scan, which is a useful method in diagnosing bone graft abnormalities. However, according to our X-ray scans and clinical results, it is more likely that improper limb load transfer led to an incomplete bone graft incorporation and its improper remodeling. We would also like to emphasize the importance of graft vascularization following THA procedures, as achieving adequate vascular *de novo* development within regenerating bone tissues remains an ongoing challenge. Moreover, it is noteworthy that the COC bearing configuration is bioinert due to less harmful ceramic wear debris, which makes it the safest articulation choice, with a lesser negative impact on bone graft healing and vascularization when compared to the MOM bearing[17].

Furthermore, it is also worth noting that patients of advanced age over 75 years have a higher risk of cognitive problems and muscular tone deficits, which may cause inability to follow the postoperative protocols and increase dislocation rates[18].

Hopefully, further clinical studies revealing new causes of acetabular loosening, technological developments in component design and surgical techniques will continuously reduce the number of THA revision procedures. Due to the long (9-year) follow-up period of our patient, who did not report any trauma or complications after the revision THA, we believe that the most likely factor responsible for acetabular loosening was the stress shielding effect altering bone graft structure caused by inappropriate limb load transfer.

CONCLUSION

It should be noted that even when the primary procedure is performed without complications, there are numerous circumstances and triggering factors that can lead to a need for revision arthroplasty. In our case, the patient did not exhibit any symptoms or radiological findings, suggesting possible loosening of the acetabular component during the 2-year follow-up. However, most likely due to a trauma to the opposite hip joint, an inappropriate distribution of limb load led to mechanical loosening of the endoprosthesis. Following the revision arthroplasty, an improvement in the evaluation results was observed. These results indicate a significant improvement in the patient's condition after the revision surgery.

FOOTNOTES

Author contributions: All authors discussed the results and contributed to the final manuscript; Domagalski RS, Dugiełło B and Rokicka S wrote the draft of the manuscript and participated in the follow-up examination of the patient and clinical materials; Czech S, Skowroński R, Rokicka D, Wróbel MP and Strojek K were involved in drafting the manuscript and critically revising it; Stołtny T performed the surgery, and coordinated and helped to draft and finalize the manuscript.

Informed consent statement: Informed written consent was obtained from the patient for publication of this anonymized report and any accompanying images.

Conflict-of-interest statement: The authors declare that they have no conflicts of interest to disclose.

CARE Checklist (2016) statement: The authors have read the CARE Checklist (2016), and the manuscript was prepared and revised according to the CARE Checklist (2016).

Country/Territory of origin: Poland

ORCID number: Rafał Stanisław Domagalski 0009-0000-7770-4338; Bogdan Dugiełło 0000-0001-8119-0245; Sonia Rokicka 0009-0000-1083-201X; Szymon Czech 0000-0003-1180-7726; Rafał Skowroński 0000-0003-4068-7022; Dominika Rokicka 0000-0002-9974-1778; Marta Patrycja Wróbel 0000-0002-6091-4168; Krzysztof Strojek 0000-0002-6260-8674; Tomasz Stołtny 0000-0002-5189-1064.

S-Editor: Zhang H
L-Editor: A
P-Editor: Che XX

REFERENCES

1 **Kurtz S**, Ong K, Lau E, Mowat F, Halpern M. Projections of primary and revision hip and knee arthroplasty in the United States from 2005 to 2030. *J Bone Joint Surg Am* 2007; **89**: 780-785 [PMID: 17403800 DOI: 10.2106/JBJS.F.00222]

2 **Schwartz BE**, Piponov HI, Helder CW, Mayers WF, Gonzalez MH. Revision total hip arthroplasty in the United States: national trends and in-hospital outcomes. *Int Orthop* 2016; **40**: 1793-1802 [PMID: 26830782 DOI: 10.1007/s00264-016-3121-7]

3 **Tarazi JM**, Chen Z, Scuderi GR, Mont MA. The Epidemiology of Revision Total Knee Arthroplasty. *J Knee Surg* 2021; **34**: 1396-1401 [PMID: 34507367 DOI: 10.1055/s-0041-1735282]

4 **Dargel J**, Oppermann J, Brüggemann GP, Eysel P. Dislocation following total hip replacement. *Dtsch Arztebl Int* 2014; **111**: 884-890 [PMID: 25597367 DOI: 10.3238/arztebl.2014.0884]

5 **Karachalios T**, Komnos G, Koutalos A. Total hip arthroplasty: Survival and modes of failure. *EFORT Open Rev* 2018; **3**: 232-239 [PMID: 29951261 DOI: 10.1302/2058-5241.3.170068]

6 **Savio D**, Bagno A. When the Total Hip Replacement Fails: A Review on the Stress-Shielding Effect. *Processes* 2022; **10**: 612 [DOI: 10.3390/pr10030612]

7 **Gómez-Vallejo J**, Roces-García J, Moreta J, Donaire-Hoyas D, Gayoso Ó, Marqués-López F, Albareda J. Biomechanical Behavior of an Hydroxyapatite-Coated Traditional Hip Stem and a Short One of Similar Design: Comparative Study Using Finite Element Analysis. *Arthroplast Today* 2021; **7**: 167-176 [PMID: 33553545 DOI: 10.1016/j.artd.2020.11.022]

8 **Arabnejad S**, Johnston B, Tanzer M, Pasini D. Fully porous 3D printed titanium femoral stem to reduce stress-shielding following total hip arthroplasty. *J Orthop Res* 2017; **35**: 1774-1783 [PMID: 27664796 DOI: 10.1002/jor.23445]

9 **Lee YK**, Yoon BH, Choi YS, Jo WL, Ha YC, Koo KH. Metal on Metal or Ceramic on Ceramic for Cementless Total Hip Arthroplasty: A Meta-Analysis. *J Arthroplasty* 2016; **31**: 2637-2645.e1 [PMID: 27215192 DOI: 10.1016/j.arth.2016.04.014]

10 **Augustyn A**, Stołtny T, Rokicka D, Wróbel M, Pająk J, Werner K, Ochocki K, Strojek K, Koczy B. Revision arthroplasty using a custom-made implant in the course of acetabular loosening of the J&J DePuy ASR replacement system - case report. *Medicine (Baltimore)* 2022; **101**: e28475 [PMID: 35089189 DOI: 10.1097/MD.0000000000028475]

11 **Higgins JE**, Conn KS, Britton JM, Pesola M, Manninen M, Stranks GJ. Early Results of Our International, Multicenter, Multisurgeon, Double-Blinded, Prospective, Randomized, Controlled Trial Comparing Metal-on-Metal With Ceramic-on-Metal in Total Hip Arthroplasty. *J Arthroplasty* 2020; **35**: 193-197.e2 [PMID: 31540737 DOI: 10.1016/j.arth.2019.08.002]

12 **Vendittoli PA**, Shahin M, Rivière C, Barry J, Lavoie P, Duval N. Ceramic-on-ceramic total hip arthroplasty is superior to metal-on-conventional polyethylene at 20-year follow-up: A randomised clinical trial. *Orthop Traumatol Surg Res* 2021; **107**: 102744 [PMID: 33316444 DOI: 10.1016/j.otsr.2020.102744]

13 **Crawford DA**, Adams JB, Morris MJ, Berend KR, Lombardi AV Jr. Revision of Failed Metal-on-Metal Total Hip Arthroplasty: Midterm Outcomes of 203 Consecutive Cases. *J Arthroplasty* 2019; **34**: 1755-1760 [PMID: 31053470 DOI: 10.1016/j.arth.2019.04.019]

14 **Kelmer G**, Stone AH, Turcotte J, King PJ. Reasons for Revision: Primary Total Hip Arthroplasty Mechanisms of Failure. *J Am Acad Orthop Surg* 2021; **29**: 78-87 [PMID: 32404682 DOI: 10.5435/JAAOS-D-19-00860]

15 **Stryker LS**, Odum SM, Fehring TK, Springer BD. Revisions of monoblock metal-on-metal THAs have high early complication rates. *Clin Orthop Relat Res* 2015; **473**: 469-474 [PMID: 25028106 DOI: 10.1007/s11999-014-3791-7]

16 **Abu-Zeid MY**, Habib ME, Marei SM, Elbarbary AN, Ebied AA, Mesregah MK. Impaction bone grafting for contained acetabular defects in total hip arthroplasty. *J Orthop Surg Res* 2023; **18**: 671 [PMID: 37697375 DOI: 10.1186/s13018-023-04154-0]

17 **Hu CY**, Yoon TR. Recent updates for biomaterials used in total hip arthroplasty. *Biomater Res* 2018; **22**: 33 [PMID: 30534414 DOI: 10.1186/s40824-018-0144-8]

18 **Miettinen SSA**, Mäkinen TJ, Laaksonen I, Mäkelä K, Huhtala H, Kettunen JS, Remes V. Dislocation of large-diameter head metal-on-metal total hip arthroplasty and hip resurfacing arthroplasty. *Hip Int* 2019; **29**: 253-261 [PMID: 30209970 DOI: 10.1177/1120700018798302]

WJO World Journal of Orthopedics

Submit a Manuscript: https://www.f6publishing.com

World J Orthop 2024 July 18; 15(7): 675-682

DOI: 10.5312/wjo.v15.i7.675

ISSN 2218-5836 (online)

CASE REPORT

Gouty destruction of a patellar tendon reconstruction and novel revision reconstruction technique: A case report

Carl C Edge, Jonathan Widmeyer, Omar Protzuk, Maya Johnson, Robert O'Connell

Specialty type: Orthopedics

Provenance and peer review: Unsolicited article; Externally peer reviewed.

Peer-review model: Single blind

Peer-review report's classification

Scientific Quality: Grade C

Novelty: Grade B

Creativity or Innovation: Grade B

Scientific Significance: Grade B

P-Reviewer: Moldovan CA, Romania

Received: April 3, 2024

Revised: May 7, 2024

Accepted: June 3, 2024

Published online: July 18, 2024

Processing time: 100 Days and 1.3 Hours

Carl C Edge, Jonathan Widmeyer, Omar Protzuk, Maya Johnson, Department of Orthopaedic Surgery, Division of Sports Medicine, Virginia Commonwealth University Health System, Richmond, VA 23298-0153, United States

Robert O'Connell, Division of Sports Medicine, Orthowest, Carrolton, GA 30117, United States

Corresponding author: Carl C Edge, MD, Researcher, Department of Orthopaedic Surgery, Virginia Commonwealth University Health System, 1200 E. Broad Street 9th FloorBox 980153, Richmond, VA 23298-0153, United States. carl.edge@vcuhealth.org

Abstract

BACKGROUND

Gout is a disease characterized by hyperuricemia, and resultant deposition of uric acid crystals in tissues. While typically manifested as intraarticular crystals or tophi, gout can also cause pathology at entheses. Gouty deposition within tendinous structures put them at risk for traumatic and degenerative rupture. Furthermore, allografts can also be at risk of rupture in the setting of severe gout. We present the case of a 56-year-old female with severe gouty disease who sustained a re-rupture of a patellar tendon allograft reconstruction.

CASE SUMMARY

A 56-year-old female presented to clinic after feeling her left knee pop and collapse beneath her while descending stairs. She had a history of tophaceous gout and left patellar tendon rupture with reconstruction and multiple revisions over the course of 19 years. This patient presented with pain and extensor lag. A magnetic resonance image demonstrated a ruptured patellar tendon allograft reconstruction and avulsion fracture at the tibial tubercle. The patient was treated with a novel intervention of Achilles allograft with bone block in a unique configuration with a dermal allograft incorporated into the reconstruction. She was made non-weight bearing in the operative extremity in extension for the first four weeks postoperatively and was then progressed to active flexion over the course of eight weeks. At twelve weeks, she was able to fully extend her operative knee and at five months she was resuming her normal activities and exercises.

CONCLUSION

Failed patellar tendon reconstruction due to gouty infiltration is treated with dermal allograft augmented Achilles tendon reconstruction with bone block.

Key Words: Gout; Patella; Reconstruction; Dermal allograft; Revision; Case report

Core Tip: We present a case of a 56-year-old female with severe systemic tophaceous gout who presented with a rupture of her revision patellar tendon reconstruction due to severe gouty infiltration. The major takeaway from this case is that with multiple failed reconstructions of the patellar tendon, both structural and biologic reinforcement were sought to provide this patient the best chance for recovery and a substantial reconstruction. We provided a robust structural construct as well as biologic reinforcement with the use of an Achilles tendon allograft with a wedge-shaped bone block and a dermal allograft incorporated into the reconstruction.

Citation: Edge CC, Widmeyer J, Protzuk O, Johnson M, O'Connell R. Gouty destruction of a patellar tendon reconstruction and novel revision reconstruction technique: A case report. *World J Orthop* 2024; 15(7): 675-682
URL: https://www.wjgnet.com/2218-5836/full/v15/i7/675.htm
DOI: https://dx.doi.org/10.5312/wjo.v15.i7.675

INTRODUCTION

Patellar tendon rupture is a relatively rare phenomenon. These injuries are often secondary to trauma, however, chronic inflammatory states, such as gout, have been shown to increase risk of patellar tendon rupture[1-4].

Gout is a disease characterized by hyperuricemia, and resultant deposition of uric acid crystals in tissues. While typically manifested as intraarticular crystals or tophi, gout can also cause pathology at entheses[5,6]. Gouty deposition within tendinous structures put them at risk for traumatic and degenerative rupture. Furthermore, allografts can also be at risk of rupture in the setting of severe gout, as described following Anterior Cruciate Ligament reconstruction[7]. We present the case of a 56-year-old female with severe gouty disease who sustained a re-rupture of a patellar tendon allograft reconstruction.

The literature review was performed using PubMed with the search items: "Patellar tendon reconstruction; gout tendinopathy; biologics in tendon reconstruction". Descriptive literature from the years 1995-2023 were reviewed including case reports, case series, clinical studies, and book chapters were selected. Eighty-seven articles were initially reviewed with criteria to exclude articles regarding veterinary research, articles not published in English, articles regarding arthroplasty, and basic science research.

CASE PRESENTATION

Chief complaints

A 56-year-old female who presents with inability to bear weight in her left leg or extend her left knee.

History of present illness

She presented to clinic in December of 2022 after feeling her left knee pop and collapse beneath her while descending stairs. She had immediate pain and inability to bear weight or extend her left knee.

History of past illness

She has a history of severe tophaceous gout and left patellar tendon rupture and primary repair with transosseous suture at age 37 in January, 2004. This repair failed nearly two years later and was revised with a patellar tendon advancement with cerclage wire reinforcement in December, 2005. This revision repair failed, requiring reconstruction in November 2006 with Achilles tendon allograft with bone block fixation (Table 1). Each time, it was felt that gouty depositions led to failure. She was followed closely by rheumatology and treated with multiple medications including allopurinol, febuxostat, and pegloticase (Krystexxa), an intravenously infused recombinant porcine-like uricase that metabolizes uric acid to allantoin which increases its solubility. She experienced moderate improvement of uric acid serum concentrations with her medical treatments. Her additional comorbidities included body mass index of 47, Sjogren's Syndrome, Chronic Kidney Disease, and progression of gout to multiorgan involvement since her previous patellar tendon reconstruction twelve years prior. Her gouty disease had contributed to severe arthritis in bilateral hands and feet, bilateral carpal tunnel syndrome (post bilateral carpal tunnel releases), and lumbar stenosis secondary to synovial gouty tophus (post lumbar decompression and fusion).

Physical examination

At presentation, she had a palpable defect in her left patellar tendon, ecchymosis into the calf with tenderness and

Table 1 Timeline of the history of left patellar tendon ruptures and interventions

Date	Event
January, 2004	Injury: Initial left patellar tendon rupture
	Intervention: Primary repair
December, 2005	Injury: Rupture of patellar tendon repair
	Intervention: Patellar tendon advancement with cerclage wire reinforcement
November, 2006	Injury: Re-rupture of patellar tendon
	Intervention: Reconstruction of patellar tendon with Achilles tendon allograft
December, 2022	Injury: Re-rupture of patellar tendon reconstruction

swelling. She had a 40-degree extensor lag. On exam, she was neurovascularly intact without any ligamentous instability of the knee.

Imaging examinations

A left knee magnetic resonance imaging (Figure 1) demonstrated ruptured patellar tendon allograft reconstruction and avulsion fracture at the tibial tubercle. Contralateral knee radiographs were obtained to determine patellar height (Figure 2). The patient was placed into a knee immobilizer with plans for revision reconstruction with allograft augmentation.

FINAL DIAGNOSIS

Combined with the mechanism of injury, preoperative physical exam and imaging, the intraoperative findings of tophaceous gout within the patellar tendon, and the lab results showing uric acid crystals, the final diagnosis was patellar tendon reconstruction re-rupture secondary to gouty infiltration.

TREATMENT

An anterior approach to knee was made using prior incision. Extensive gouty material was found within the allograft tendon and the surrounding tissues. This was debrided and sent to rule out infection and confirm the diagnosis of gout. Consistent with preoperative imaging, the allograft was ruptured at the tibial tubercle with loose tibial hardware. The tibial hardware was removed and gouty material within the previous graft insertion site was debrided. The graft was excised off the distal pole of the patella. Extensive gouty deposition was visualized within the joint (Figure 3). Synovial samples were sent which returned as uric acid crystals.

An Achilles tendon allograft (Lifenet, Virginia Beach, VA, United States) with a bone plug was prepared for the revision procedure. The bone plug was shaped into a trapezoid with the wider limb distally to act as a wedge and prevent superior migration [approximately 3 cm (Length) × 2 cm (Depth) × 2 cm (Width)] (Figure 4). A corresponding site was prepared at the tibial tubercle. The bone block was then secured with two 4.0mm partially threaded cannulated screws with washers (DePuy Synthes, West Chester, PA) (Figure 5). Two #5 FiberWire sutures (Arthrex, Naples, FL) were placed as locking Kraków stitch through the tendon portion of the allograft. These were pulled through three longitudinal trans-osseous tunnels drilled through the patella. These were provisionally tensioned and clamped with the knee in full extension.

Two knotless fiber tack anchors (Arthrex, Naples FL) were then placed on the medial and lateral borders of the inferior pole of the patella. A 3 mm thick dermal allograft (Arthrex, Naples, FL) was then secured to the inferior pole of the patella with the previously placed knotless fiber tack anchors. A transverse slit in the graft was created and the excess proximal Achilles tendon allograft was passed from posterior to anterior through this opening. The distal portion of the dermal allograft was secured to the tibial tubercle in the speed bridge fashion with four swivel lock anchors (Arthrex, Naples, FL) and fiber tape overlying the bone block. The graft was tensioned and the transosseous sutures through the patella were tied, completing the patellar tendon reconstruction. Appropriate patellar height was confirmed with fluoroscopy of the contralateral knee. Accessory sutures from the anchors in the tibial tubercle were utilized to reinforce the graft medially and laterally. FiberWire suture was used to repair the medial and lateral retinaculum to incorporate the graft into the repair. The remaining allograft tendon was brought superiorly and reinforced into the quadriceps tendon with #2 FiberWire in a figure-of-eight pattern. Prior to closure, the knee was brought to 60 degrees of flexion without excessive tension on the construct or gapping.

Figure 1 Preoperative sagittal magnetic resonance imaging. (Proton Density weighted image fat saturation)-demonstrates avulsion fracture of the tibial tuberosity with patellar tendon rupture and patella alta.

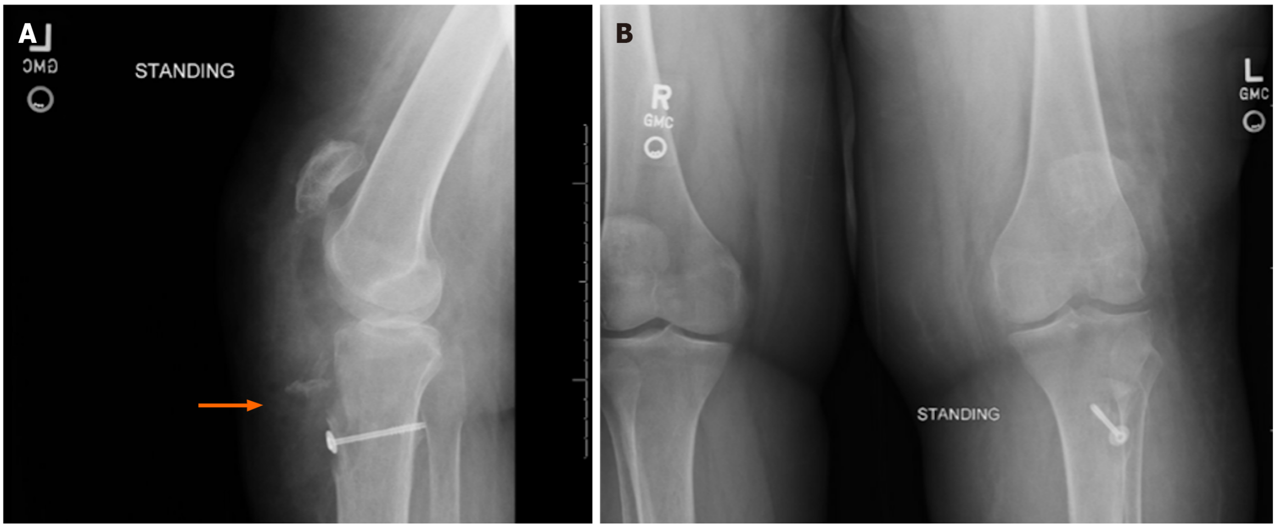

Figure 2 Preoperative plain radiographs. A: Left knee lateral radiograph demonstrating patella alta and tibial tubercle avulsion fracture; B: Standing Anterior-Posterior radiograph bilateral knees. Note patella alta of left knee with normal patellar height of right side.

OUTCOME AND FOLLOW-UP

Postoperatively, the patient was made non-weightbearing in the left lower extremity. Due to habitus and recurrent ruptures, we did not feel a knee immobilizer would provide adequate initial immobilization. Thus, she was placed into a long leg cast for two weeks. She was then transitioned to a custom fitted Total Range of Motion brace locked in extension and was allowed to bear weight. Isometric quad exercises were started. At one month, she began passive flexion exercises with a progression of 15 degrees per week. At nine weeks, she had full passive extension and seventy degrees of flexion in the left knee. She was still limited to weightbearing with the brace in extension until her quad strength improved. At three months, she had full active extension to resistance without extensor lag, as well as 90 degrees of active flexion. At five months, patient was riding a stationary bicycle and was ascending and descending stairs. Her active range of motion was from 10-115 degrees with full passive extension. At twelve months, she had no pain and felt she had improved function. Her extensor lag improved from 10 to 5 degrees (Figure 6). She returned to work and her usual daily and recreational activities.

International Knee Documentation Committee (IKDC) Subjective Knee Evaluation[8], Lower Extremity Functional Scale[9], and Lysholm Knee Scoring Scale[10] outcome measures were collected at follow ups (Table 2). All scores improved at all time points between 2 and 12 months.

Table 2 Patient reported outcome scores at 2, 3, 5, and 12 months post-operatively

Months post-op	Lower extremity functional scale	IKDC subjective knee form	Lysholm knee scale
2 months post-op	26	-	-
3 months post-opp	42.5	55%	52
5 months post-op	53	-	-
12 months post-op	59	69%	82

IKDC: International Knee Documentation Committee.

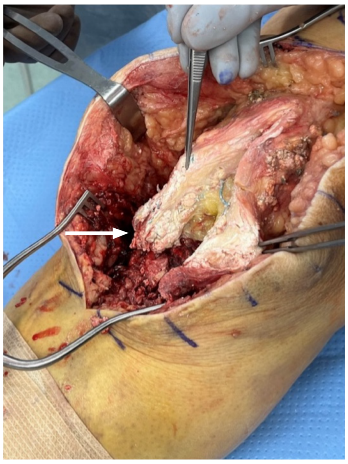

Figure 3 Intraoperative visualization of gouty infiltration of patellar tendon from prior allograft reconstruction. Gouty tophus noted within surrounding soft tissues with bony destruction of tibial tubercle.

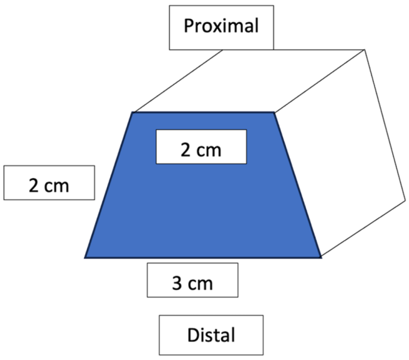

Figure 4 Three-dimensional representation of bone block after contouring. A corresponding notch in the tibial tubercle was made to create a dovetail joint for bone block placement. This was done to prevent proximal migration a reinforce stability of the reconstruction.

DISCUSSION

Although gouty destruction of tendons has been described, there are no current reports of complete destruction of a patellar tendon allograft leading to failure; as in this patient[7,11]. Due to extensive destruction of surrounding tissues including tibial tubercle bone, augmentation of both soft tissue and bone were necessary for adequate healing.

Dermal allografts provide biologic and noninflammatory properties as well as time-zero structural integrity[12]. Tendon allografts must undergo multiple stages of healing and maturation in order to achieve long term structural integrity. In this process, the graft must undergo revascularization to support subsequent cellular repopulation and matrix remodeling[13,14]. The decellularized human dermal matrix functions as a collagen scaffold that facilitates host tissue integration and thus can assist in tendon allograft maturation.

Other forms of bioaugmentation, such as platelet rich plasma, bone marrow aspirate concentrate, and bio-inductive patches, have been gaining popularity as adjuncts in the treatment of tendon injuries. Like dermal allograft, bio-inductive patches provide porous animal collagen scaffold that promotes tissue formation. While they do not enhance strength of the repair directly, once incorporated, increased tendon thickness and tissue healing has been implicated in improved

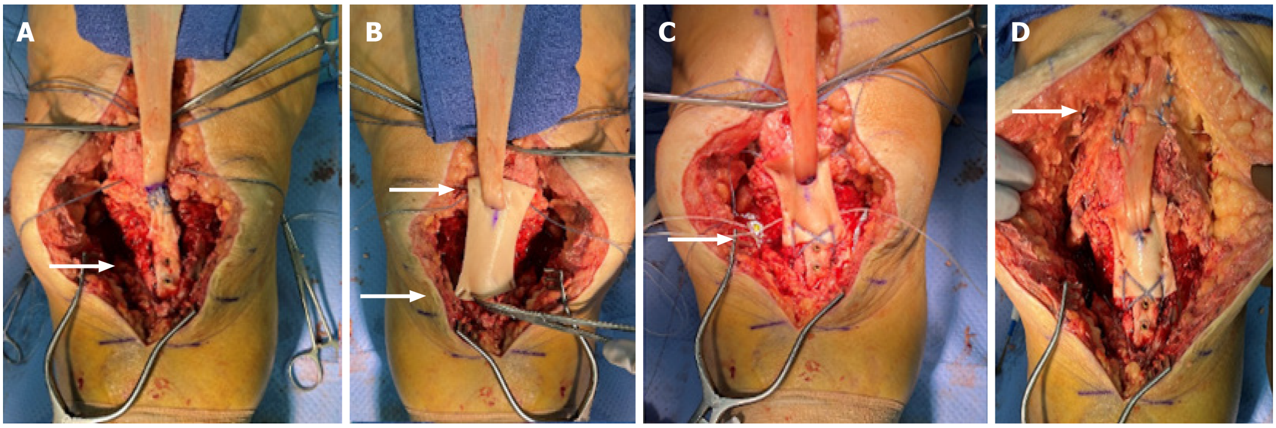

Figure 5 Intraoperative images of reconstructive technique. A: Achilles bone block secured with screws with tensioning of graft proximally by transosseous tunnel technique; B: Dermal allograft placed overlying Achilles allograft using transverse slit to pass excess proximal tendon graft. Dermal allograft secured proximal to inferior pole patella with knotless fiber tack anchors; C: Dermal allograft secured distally with four swivel lock anchors with speed bridge technique and fiber tape; D: Extra proximal Achilles allograft reinforced to quadriceps tendon.

Figure 6 Active knee range of motion from 5 to 115 degrees at 1 year follow up.

pain and functional outcomes[15,16]. One must consider that these adjuncts can be costly, do not provide any structural enhancement to the repair, and have only been used in patellar tendon reconstruction in limited cases[17-20]. While few reports exist regarding the application of bio-inductive patches to patellar tendon repair/reconstruction, there are promising short and mid-term results[19-21]. Due to the low incidence of patellar tendon reconstruction and varied reconstructive options, there have been no large scale comparative studies to determine optimal technique, however, gracilis and semitendinosus are often used[22,23]. The addition of bioaugmentation to the well-established outcomes of tendinous allografts yields a promising solution for the problem of patellar tendon tears necessitating reconstruction in poor healing environments.

Our patient’s self-reported outcome scores correspond to fair functionality and some difficultly performing moderate to high-strain activities[8-10]. Furthermore, this patient progressed to 115 degrees of flexion, with regression to 5 degrees of extensor lag. It is possible that as she began ambulating, the micro-elasticity of the allograft allowed for a small amount of lengthening, which resulted in a slight lag. Most importantly, the patient has progressed to independence with the ability to exercise and work without pain.

CONCLUSION

Our report suggests that while multi-revision patellar tendon reconstructions are debilitating with a difficult recovery, that a dermal allograft augmented Achilles allograft reconstruction with bone block is affective for treatment of recurrent patellar tendon rupture in the setting of gouty destruction with return to a functional level. This multi-graft technique could be considered for cases of graft revision or other complex patellar tendon reconstruction.

FOOTNOTES

Author contributions: Edge CC and Widmeyer J wrote the original manuscript; Edge CC, Protzuk O, Johnson M and O'Connell R conceptualised, wrote the review and edited; All authors have read and approved the final manuscript.

Informed consent statement: The patient provided informed written consent for collection and publication of information and imaging pertaining to this case.

Conflict-of-interest statement: The authors declare that they have no conflict of interest to disclose.

CARE Checklist (2016) statement: The authors have read the CARE Checklist (2016), and the manuscript was prepared and revised according to the CARE Checklist (2016).

Country of origin: United States

ORCID number: Carl C Edge 0009-0004-1509-6292.

S-Editor: Bai Y
L-Editor: A
P-Editor: Zhao YQ

REFERENCES

1 **Rosso F**, Bonasia DE, Cottino U, Dettoni F, Bruzzone M, Rossi R. Patellar tendon: From tendinopathy to rupture. *Asia Pac J Sports Med Arthrosc Rehabil Technol* 2015; **2**: 99-107 [PMID: 29264248 DOI: 10.1016/j.asmart.2015.07.001]

2 **Clark SC**, Jones MW, Choudhury RR, Smith E. Bilateral patellar tendon rupture secondary to repeated local steroid injections. *J Accid Emerg Med* 1995; **12**: 300-301 [PMID: 8775966 DOI: 10.1136/emj.12.4.300]

3 **Lu M**, Johar S, Veenema K, Goldblatt J. Patellar tendon rupture with underlying systemic lupus erythematosus: a case report. *J Emerg Med* 2012; **43**: e35-e38 [PMID: 19959318 DOI: 10.1016/j.jemermed.2009.08.054]

4 **Kartus J**, Movin T, Karlsson J. Donor-site morbidity and anterior knee problems after anterior cruciate ligament reconstruction using autografts. *Arthroscopy* 2001; **17**: 971-980 [PMID: 11694930 DOI: 10.1053/jars.2001.28979]

5 **Pineda C**, Amezcua-Guerra LM, Solano C, Rodriguez-Henríquez P, Hernández-Díaz C, Vargas A, Hofmann F, Gutiérrez M. Joint and tendon subclinical involvement suggestive of gouty arthritis in asymptomatic hyperuricemia: an ultrasound controlled study. *Arthritis Res Ther* 2011; **13**: R4 [PMID: 21241475 DOI: 10.1186/ar3223]

6 **Xu G**, Lin J, Liang J, Yang Y, Ye Z, Zhu G, Cao H. Entheseal involvement of the lower extremities in gout: an ultrasonographic descriptive observational study. *Clin Rheumatol* 2021; **40**: 4649-4657 [PMID: 34156566 DOI: 10.1007/s10067-021-05826-0]

7 **Rodas G**, Pedret C, Català J, Soler R, Orozco L, Cusi M. Intratendinous gouty tophus mimics patellar tendonitis in an athlete. *J Clin Ultrasound* 2013; **41**: 178-182 [PMID: 22457228 DOI: 10.1002/jcu.21910]

8 **Irrgang JJ**, Anderson AF, Boland AL, Harner CD, Kurosaka M, Neyret P, Richmond JC, Shelborne KD. Development and validation of the international knee documentation committee subjective knee form. *Am J Sports Med* 2001; **29**: 600-613 [PMID: 11573919 DOI: 10.1177/03635465010290051301]

9 **Binkley JM**, North American Orthopaedic Rehabilitation Research Network, Stratford PW, Lott SA, Riddle DL. Lower Extremity Functional Scale. *PsycTESTS Dataset* 2018 [DOI: 10.1037/t35109-000]

10 **E Albuquerque RP**, Giordano V, Calixto A, Malzac F, Aguiar C, do Amaral NP, Carvalho AC. Analysis on the modified lysholm functional protocol among patients with normal knees. *Rev Bras Ortop* 2011; **46**: 668-674 [PMID: 27027071 DOI: 10.1016/S2255-4971(15)30323-2]

11 **Lubis AMT**, Reksoprodjo AY, Kuncoro MW, Ifran NN. Post-ACL Reconstruction Graft Failure in Severe Gout Arthritis Patient. *Int Med Case Rep J* 2021; **14**: 725-730 [PMID: 34675691 DOI: 10.2147/IMCRJ.S325642]

12 **Acevedo DC**, Shore B, Mirzayan R. Orthopedic applications of acellular human dermal allograft for shoulder and elbow surgery. *Orthop Clin North Am* 2015; **46**: 377-388, x [PMID: 26043051 DOI: 10.1016/j.ocl.2015.02.006]

13 **Yao S**, Fu BS, Yung PS. Graft healing after anterior cruciate ligament reconstruction (ACLR). *Asia Pac J Sports Med Arthrosc Rehabil Technol* 2021; **25**: 8-15 [PMID: 34094881 DOI: 10.1016/j.asmart.2021.03.003]

14 **Yang C**, Teng Y, Geng B, Xiao H, Chen C, Chen R, Yang F, Xia Y. Strategies for promoting tendon-bone healing: Current status and prospects. *Front Bioeng Biotechnol* 2023; **11**: 1118468 [PMID: 36777256 DOI: 10.3389/fbioe.2023.1118468]

15 **Bragg JT**, Shields MV, Salzler MJ. Intrasubstance Patellar Tendon Repair with the Addition of a Bio-inductive Implant. *Arthrosc Tech* 2023; **12**: e11-e15 [PMID: 36814985 DOI: 10.1016/j.eats.2022.08.051]

16 **Mc Millan S**, Faoao DO, Ford E. Treatment of an Insertional High Grade Partial Patellar Tendon Tear Utilizing a Bio-Inductive Implant. *Arch*

Bone Jt Surg 2019; **7**: 203-208 [PMID: 31211200]

17 **Hung CY**, Lin SJ, Yeh CY, Yeh WL. Effect of Platelet-Rich Plasma Augmentation on Endoscopy-Assisted Percutaneous Achilles Tendon Repair. *J Clin Med* 2022; **11** [PMID: 36143034 DOI: 10.3390/jcm11185389]

18 **Thomas JR**. "The healthy tan": a modern misnomer. *Mo Med* 1989; **86**: 327-328 [PMID: 2755452]

19 **Aridici R**, Yetisgin A, Boyaci A, Tutoglu A, Bozdogan E, Sen Dokumaci D, Kilicaslan N, Boyaci N. Comparison of the Efficacy of Dry Needling and High-Power Pain Threshold Ultrasound Therapy with Clinical Status and Sonoelastography in Myofascial Pain Syndrome. *Am J Phys Med Rehabil* 2016; **95**: e149-e158 [PMID: 27552352 DOI: 10.1097/PHM.0000000000000600]

20 **Imam MA**, Holton J, Horriat S, Negida AS, Grubhofer F, Gupta R, Narvani A, Snow M. A systematic review of the concept and clinical applications of bone marrow aspirate concentrate in tendon pathology. *SICOT J* 2017; **3**: 58 [PMID: 28990575 DOI: 10.1051/sicotj/2017039]

21 **Geers BA**, Bishai SK. Chronic Midsubstance Patellar Tendon and Retinacular Rupture: Primary Repair Enhancement Using Bioinductive Implant Augmentation. *Arthrosc Tech* 2023; **12**: e1595-e1600 [PMID: 37780659 DOI: 10.1016/j.eats.2023.05.009]

22 **Gilmore JH**, Clayton-Smith ZJ, Aguilar M, Pneumaticos SG, Giannoudis PV. Reconstruction techniques and clinical results of patellar tendon ruptures: Evidence today. *Knee* 2015; **22**: 148-155 [PMID: 25819155 DOI: 10.1016/j.knee.2014.10.007]

23 **Kim WT**, Kao D, O'Connell R, Patel NK, Vap A. Clinical Outcomes are Similar Between Graft Types Used in Chronic Patellar Tendon Reconstruction: A Systematic Review. *Arthrosc Sports Med Rehabil* 2022; **4**: e1861-e1872 [PMID: 36312722 DOI: 10.1016/j.asmr.2022.06.007]

Published by **Baishideng Publishing Group Inc**
7041 Koll Center Parkway, Suite 160, Pleasanton, CA 94566, USA
Telephone: +1-925-3991568
E-mail: office@baishideng.com
Help Desk: https://www.f6publishing.com/helpdesk
https://www.wjgnet.com