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Outcomes of Idiopathic Flexible Flatfoot Deformity Reconstruction in the Young Patient

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Abstract

Background: Operative correction of flatfoot deformity has been well studied in the older population. There is a subset of younger patients without congenital foot deformity that also develop a collapsing flatfoot. However, assessment of outcomes across age groups is limited, especially in the young demographic. The purpose of our study was to compare operative outcomes of flatfoot reconstruction between these 2 age groups.

Methods: Seventy-six feet (41 left, 35 right) in 71 patients who underwent flexible flatfoot reconstruction were divided into 2 groups based on age: $\leq$30 years (n = 22) and >30 years (n = 54). Exclusion criteria included congenital causes of flatfoot (tarsal coalition, vertical talus, overcorrected clubfoot). Average age was 20.8 years (range, 14-30) and 55.4 years (range, 35-74) in the younger and older cohorts, respectively. Preoperative and minimum 2-year postoperative Patient-Reported Outcomes Measurement Information Systems (PROMIS) scores were compared. Five radiographic parameters were assessed pre- and postoperatively: talonavicular coverage angle, lateral talo–first metatarsal angle, lateral talocalcaneal angle, calcaneal pitch, and hindfoot moment arm. Procedures performed and incidence of minor (removal of symptomatic hardware) and major (revision) reoperations were compared.

Results: Younger patients were less likely to undergo flexor digitorum longus transfer, first tarsometatarsal fusion, spring ligament repair, and posterior tibial tendon repair (all P < .05). Both younger and older cohorts demonstrated significant improvement in multiple PROMIS domains at an average follow-up of 30.6 (range, 24-44) and 26.8 (range, 24-45) months, respectively (P = .07). Younger patients demonstrated significantly higher pre- and postoperative Physical Function (mean difference postoperatively, 4.6; 95% confidence interval, 1.5-7.8; P = .03). There were no differences in radiographic parameters postoperatively. There were 8 (36.4%) reoperations (all minor) in the younger group, and 21 (38.9%) reoperations (6 major, 15 minor) in the older group (P = .84).

Conclusion: Our data suggest that age may play a role in clinical outcomes, procedures indicated, and subsequent corrective reoperations. Younger patients maintained greater physical function with comparable radiographic correction, with less frequent indication for tendon transfers, arthrodesis, and additional corrective surgeries.

Level of Evidence: Level III, retrospective comparative study.

Keywords: flexible flatfoot deformity, AAFD, young patient, outcomes, tendon transfer

Introduction

Collapsing flatfoot deformity, previously referred to as adult acquired flatfoot deformity, is a progressive disease characterized by a combination of multiple deformities, including collapse of the medial longitudinal arch, forefoot abduction, and heel valgus. Although it is thought to be caused by a combination of dysfunction in ligaments and the posterior

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tibial tendon that support the medial longitudinal arch of the foot, the precise etiology is not clear and may differ between young adolescents and older patients.

In the operative treatment of flatfoot deformity, multiple bony and soft tissue procedures are often required to obtain a plantigrade foot.[12,14,15] For example, a medializing calcaneal osteotomy (MCO) is often indicated to correct valgus hindfoot alignment, lateral column lengthening (LCL) to correct abduction deformity, and/or flexor digitorum longus (FDL) transfer to address posterior tibial tendon degeneration.[5,6,23] In patients with severe flatfoot deformity or advanced osteoarthritis, arthrodesis may be warranted. The pathology in younger and older patients is separate from congenital causes of flatfoot such as coalition, congenital vertical talus, or overcorrected clubfoot. In the absence of these congenital causes of flatfoot, the senior authors approach these with the same operative algorithm as our older patients, and in a small case series, they seem to do very well clinically.[30]

Previous studies in the literature have generally demonstrated excellent improvement in pain relief, functional outcomes, and radiographic correction as a result of flatfoot reconstruction.[9,10] However, many of the studies in the literature that have assessed outcomes of operative correction of the collapsing flatfoot deformity have been in older adult patients, with the average patient being a woman in her 50s.[12,22] Thus, the outcomes of flatfoot reconstruction in the younger, active patient is limited in the literature. A previous study found an excellent rate of return to sports and significant decrease in pain in a cohort of 16 pediatric flatfeet (10 patients, mean age 15.6 years) who underwent operative correction for symptomatic flexible flatfoot.[21]

Therefore, the purpose of this study was to compare the clinical and radiographic outcomes in patients 30 years old or younger with idiopathic flexible flatfoot deformity undergoing reconstructive procedures with that of older patients. In addition, the procedures performed for reconstruction and the incidence of subsequent reoperations were compared between the 2 groups.

Methods

All patients were identified through an institutional review board–approved registry of prospectively collected data at the authors' institution. Consecutive patients who underwent a flatfoot reconstruction for symptomatic flexible flatfoot deformity between January 2016 and November 2017 were identified for inclusion. Two foot and ankle fellowship–trained orthopedic surgeons performed all reconstructions. The registry data included patient demographic information, radiographs, clinical outcome scores including Patient-Reported Outcomes Measurement Information Systems (PROMIS), and operative reports with operative procedures performed at the authors' institution. The study protocol was approved by the registry's research steering committee.

Study Cohort

Patients were eligible to be included in the study if they had a diagnosis of flexible flatfoot deformity at the time of reconstruction and had a minimum of 2 years' follow-up. Patients were excluded if they had either a history of a congenital cause of flatfoot deformity (including tarsal coalition, congenital vertical talus, or overcorrected clubfoot) (n = 8), underwent a subtalar or talonavicular fusion (n = 18), or had an open physis on preoperative weightbearing radiographs (n = 0). Congenital causes of flatfoot were excluded as this was felt to be due to a different underlying pathology. In order to compare 2 more homogenous cohorts, patients who underwent subtalar fusion were excluded. Subtalar arthrodesis was thought to be a confounding factor as it may be more commonly performed in older patients and affect postoperative functional outcomes. This left a total of 76 feet (41 left, 35 right) in 71 patients who underwent reconstruction for flexible collapsing flatfoot deformity who constituted our study cohort.

Patients were categorized into 2 different cohorts based on age. A younger cohort consisted of patients aged ≤30 years (n = 22 feet, 19 patients), and an older cohort consisted of patients aged >30 years (n = 54 feet, 52 patients). A cut-off of 30 years of age was chosen by the senior authors based on clinical experience that suggests a different pathologic process than typical patients who are often in their 50s.[17,30,33,43] In addition, previous studies in the literature have used an age of 30 as a meaningful cut-off for comparison in young patients following orthopedic surgery.[1,21,31] The average age was 20.8 years (range, 14-30 years) and 55.4 years (range, 35-74 years) in the younger and older cohorts, respectively ($P < .01$). Average BMI was 26.8 (range, 18-38) and 29.0 (range, 18-41) in the younger and older cohorts, respectively ($P = .12$). The younger cohort consisted of 6 women (30%), whereas the older cohort consisted of 33 women (61%) ($P = .03$). Patient demographics and comorbidities are recorded in Table 1. Operative reports were reviewed and concurrent procedures as part of the flatfoot reconstruction by age group were also tabulated (Table 2).

Clinical Outcome Evaluation

Clinical outcomes were evaluated preoperatively and at minimum 2 years postoperatively using PROMIS, which has been validated in numerous foot and ankle conditions including flatfoot deformity.[2,18,20] PROMIS is a computerized adaptive test (CAT) used to assess functional outcomes in multiple domains. The following PROMIS domains were evaluated: Physical Function, Pain Interference, Pain Intensity, Global Physical Health, Global Mental Health and Depression. Scores have a mean of 50, with a higher value indicating greater physical function, severity of pain, global health, and depression. Based on previous studies, a minimal clinically important difference of 4.5 was used to determine the clinical significance of pre- to postoperative improvement.[20,29] The average time to follow-up was 30.6 months (range, 24-44) in the younger cohort and 26.8 months (range, 24-45) in the older cohort ($P = .07$). Preoperative, postoperative, and change in PROMIS patient-reported outcomes were compared between the 2 cohorts.

In addition to patient-reported outcomes scores, hospital records were reviewed and subsequent procedures following the index flatfoot reconstruction were recorded. These were classified as major reoperations (revision surgery or arthrodesis) or minor reoperations (removal of symptomatic hardware). Incidence of postoperative complications, including poor wound healing, infection, and deep vein thrombosis, were also recorded.

Table 1. Patient Demographics and Comorbidities.

Characteristic	Age ≤30 y (n = 19)	Age >30 y (n = 52)	*P* Value
Age, y, mean (SD)	20.8 (5.8)	55.4 (9.2)	**<.01***
BMI, mean (SD)	26.8 (5.3)	29.0 (5.6)	.12
Gender, n (%)			**.03***
Females	6 (30)	33 (61)	
Males	13 (70)	19 (39)	
Ethnicity, n (%)			
White	14 (74)	46 (88)	.15
African American	1 (5)	5 (10)	>.99
Asian	4 (21)	1 (2)	**.02***
Comorbidities, n (%)			
HTN	1 (5)	17 (33)	**.02***
HLD	1 (5)	15 (29)	.05
History of smoking	4 (21)	20 (28)	.26
History of cancer	1 (5)	4 (8)	>.99
History of DVT/clotting disorder	3 (16)	4 (8)	.38
Diabetes	0 (0)	3 (6)	.56

Abbreviations: BMI, body mass index; DVT, deep vein thrombosis; HLD, hyperlipidemia; HTN, hypertension.

Radiographic Outcome Evaluation

Previously validated radiographic measurements were measured on anteroposterior and lateral weightbearing plain radiographs and hindfoot alignment view (Saltzman view). These measurements included talonavicular coverage angle on the anteroposterior view, talo–first metatarsal (Meary angle), talocalcaneal angle, and calcaneal pitch on the lateral view, and the hindfoot moment arm (HMA) on the Saltzman view.[4,34,35]

All parameters were digitally measured using a metric software system (IDS7, Sectra, Sweden). Deformity correction was assessed by comparing preoperative with latest postoperative radiographs at a minimum of 6 months following operative treatment. A minimum of 6 was chosen because patients were typically fully weightbearing at this time, and a previous study did not demonstrate any statistically significant changes in radiographic measurements in patients with collapsing foot deformity after 3 months postoperatively.[28] Mean radiographic follow-up was 12.8 months (range, 6-28 months) and 13.5 months (range, 6-31 months) in the younger and older cohorts, respectively ($P = .44$). Differences in radiographic and clinical follow-up times reflect the fact that not all patients required radiographs at their latest clinical follow-up.

Operative Techniques

All flatfoot reconstructive surgeries were performed by the 2 senior authors (SJE, JTD), who are both foot and ankle fellowship–trained orthopedic surgeons. Depending on the deformity, flatfoot reconstructions consisted of a combination of the following procedures: FDL transfer, MCO, LCL, medial dorsal opening wedge (Cotton) osteotomy, first

Table 2. Results of Chi-square Tests for the Association Between Age Group and Procedures Performed.[a]

Procedure	Proportion (n) Age ≤30 y (n = 22)	Proportion (n) Age >30 y (n = 54)	PD	95% CI	P^b
LCL	0.77 (17)	0.65 (35)	0.12	–0.09, 0.34	.36
Cotton	0.55 (12)	0.30 (36)	0.25	0.01, 0.49	.07
Achilles lengthening	0.36 (8)	0.50 (27)	–0.14	–0.38, 0.10	.36
Gastrocnemius lengthening	0.41 (9)	0.39 (21)	0.02	–0.22, 0.26	0.87
FDL transfer	0.50 (11)	0.96 (52)	–0.46	–0.68, –0.25	**<.01***
First TMT fusion	0.18 (4)	0.48 (26)	–0.30	–0.51, –0.09	**.04***
Spring ligament repair	0.09 (2)	0.57 (31)	–0.48	–0.66, –0.30	**<.01***
PTT repair	0.18 (4)	0.59 (32)	–0.41	–0.62, –0.20	**<.01***

Abbreviations: FDL, flexor digitorum longus; LCL, lateral column lengthening; PD, prevalence difference; PTT, posterior tibial tendon; TMT, tarsometatarsal.
[a]Proportion (and number, n) of patients who underwent each procedure in each age group are reported, with the probability of procedures performed in each age group expressed using PD with a 95% CI.
[b]*P* values were adjusted for multiple comparisons using the Benjamini & Hochberg method.
*$P < .05$.

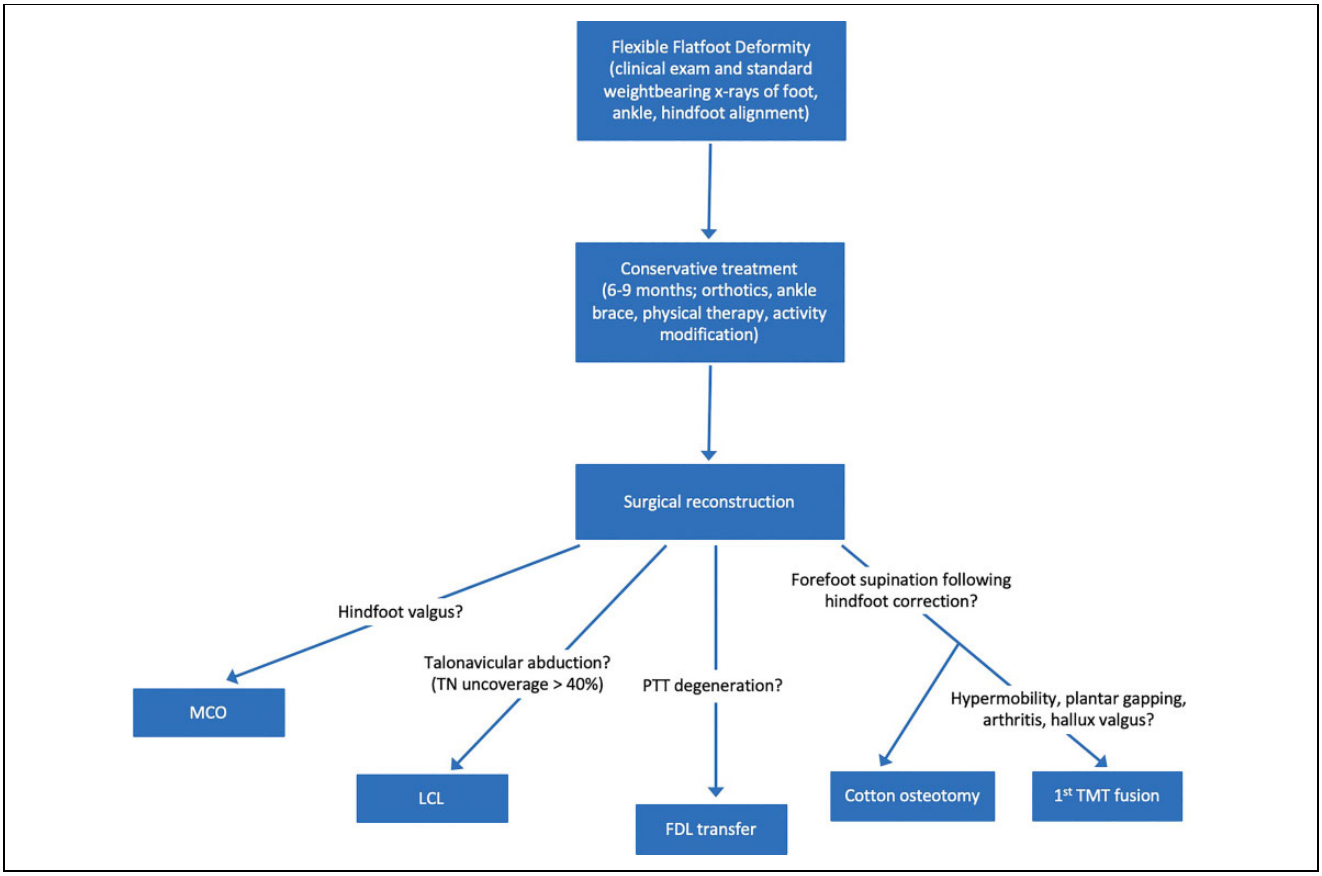

Figure 1. Treatment algorithm for flexible flatfoot deformity.

tarsometatarsal fusion, posterior tibial tendon repair, spring ligament repair, Achilles lengthening, or gastrocnemius recession. The same operative algorithm was used to correct deformity in each group (Figure 1). MCO was indicated to correct hindfoot valgus, and the amount of translation was titrated according to the amount of preoperative moment arm deformity as determined on the preoperative hindfoot alignment view.[8] LCL was indicated to correct severe talonavicular abduction as determined by the preoperative talonavicular coverage angle and incongruency angle.[7] FDL transfer was generally performed when the posterior tibial tendon was substantially degenerated. Medial column procedures were used to correct residual forefoot supination after the hindfoot was corrected. A first tarsometatarsal (TMT) fusion was performed in cases of first TMT hypermobility, plantar gapping based on weight-bearing preoperative images, arthritis, or hallux valgus; a Cotton osteotomy was indicated in the absence of one of the reasons to perform a TMT fusion and was titrated to correct deformity as determined by the preoperative cuneiform articular angle.[31]

All feet underwent either MCO alone (n = 24) or combined MCO with LCL (n = 54). The MCO was performed through a lateral incision, and this transverse osteotomy was fixed with two 4.5-, 6.5-, or 7.3-mm cannulated screws. LCL was achieved through a lateral incision over the anterior calcaneus using the step-cut lengthening osteotomy (n = 41) or Evans-type osteotomy technique (n = 13).[13,42] Autograft and iliac crest bone marrow aspirate were packed in the osteotomy site and secured with 2 fully-threaded cortical screws or a compression locking plate. Step-cut lengthening osteotomy and Evans-type osteotomy techniques have been shown to have similar functional outcomes.[36]

Following correction of heel alignment, subsequent procedures to obtain a plantigrade foot were performed. Cotton osteotomies were employed through a dorsal approach, packed with bone graft, and fixed with a plate and screws. First tarsometatarsal fusions were performed through a dorsal longitudinal approach. The joint surfaces were meticulously debrided of cartilage and prepared with flat cuts. Subchondral bone was fenestrated using a small drill or Kirschner wire. Two fully threaded cortical crossing screws were used for fixation.

Postoperatively, patients remained nonweightbearing for 6-8 weeks before progressing to full weightbearing by 10-12 weeks.

Statistical Analysis

The association between patient age group and preoperative PROMIS, postoperative PROMIS, and radiographic

Table 3. Results of Linear Regression for Differences in PROMIS Patient-reported Outcome Scores Between Age Groups Pre- and Postoperatively.[a]

	Preoperative			Postoperative		
PROMIS Domain	Estimate	95% CI	*P*[a]	Estimate	95% CI	*P*[b]
Physical function	5.56	1.95, 9.18	**.03***	4.62	1.50, 7.75	**.03***
Pain interference	–3.87	–7.07, –0.68	.05	–0.75	–4.86, 3.37	.86
Pain intensity	–3.47	–6.92, –0.02	.12	–1.48	–5.09, 2.13	.56
Global physical health	5.22	1.10, 9.33	.05	0.40	–3.44, 4.24	.89
Global mental health	2.10	–2.59, 6.80	.56	–2.89	–7.47, 1.69	.42
Depression	0.29	–3.93, 4.52	.89	2.65	–1.94, 7.24	.43

Abbreviation: PROMIS, Patient-Reported Outcomes Measurement Information Systems.
[a]Each estimate reflects the difference in average score of the younger cohort compared to the older cohort (a positive value reflects a higher score in the younger cohort). *P* values refer to comparisons between the 2 age groups.
[b]*P* values were adjusted for multiple comparisons using Benjamini & Hochberg method.
**P* < .05.

Table 4. Results of Linear Regression for Change in PROMIS Patient-Reported Outcome Scores Pre- and Postoperatively Within Age Groups.[a]

	Age ≤30 y			Age >30 y			Between Groups
PROMIS Domain	Estimate	95% CI	*P*[b]	Estimate	95% CI	*P*[b]	*P*[b]
Physical function	6.54	1.44, 11.64	**.02***	7.57	5.66, 9.48	**<.01***	.69
Pain interference	–7.29	–11.49, –3.09	**<.01***	–10.07	–12.49, –7.64	**<.01***	.17
Pain intensity	–6.79	–11.01, –2.56	**<.01***	–9.61	–12.24, –6.99	**<.01***	.29
Global physical health	4.51	–0.47, 9.50	.10	8.39	6.06, 10.72	**<.01***	.09
Global mental health	–0.92	–7.51, 5.68	.84	3.26	0.94, 5.58	**.01***	.14
Depression	0.49	–5.51, 6.49	.86	–1.07	–3.18, 1.04	.38	.38

Abbreviation: PROMIS, Patient-Reported Outcomes Measurement Information Systems.
[a]Estimates and *P* values refer to pre- to postoperative change in the respective cohort; *P* value for "between groups" refers to comparison of change between the 2 cohorts.
[b]*P* values were adjusted for multiple comparisons using Benjamini & Hochberg method.
**P* < .05.

measures was evaluated using multivariate linear regression. Multivariable adjustment was not performed as all measured covariates were likely mediators on the pathway between age and measures of interest. The association between age group and whether a certain procedure was performed was assessed using separate chi-square tests; the prevalence difference (PD) is reported. All measures of effect are presented with 95% confidence intervals. All *P* values were 2-sided, and statistical significance was evaluated with an alpha of .05. Analyses were performed in R, version 3.6.2.

Results

Flatfoot Reconstruction Procedures

The number of concurrent corrective procedures at the time of index surgery was similar between the 2 age cohorts, with younger patients requiring an average of 4 (range, 2-5) corrective procedures and older patients requiring an average of 5 (range, 3-6) corrective procedures. The type of operative procedures differed between the age groups (Table 2). Patients in the younger cohort were statistically less likely to undergo FDL transfer (PD, –0.46; 95% CI, –0.68 to –0.25; $P < .01$), first tarsometatarsal fusion (PD, –0.3; 95% CI, -0.51 to 0.09; $P = .04$), spring ligament repair (PD, –0.48; 95% CI, –0.66 to –0.3; $P < .01$), and posterior tibial tendon repair (PD, –0.41; 95% CI, –0.62 to –0.2; $P \leq .01$) compared with the older cohort.

Clinical Outcomes

Preoperatively, younger patients had significantly greater PROMIS Physical Function (mean difference, 5.6; 95% CI, 2.0-8.0; $P = .03$) compared to older patients (Table 3). Postoperatively, younger patients continued to have significantly greater Physical Function (mean difference, 4.6; 95% CI, 1.5-7.8; $P = .03$) compared with older patients.

Within the younger cohort, there was significant improvement postoperatively in Physical Function (mean improvement, 6.5; 95% CI, 1.4-11.6; $P = .02$), Pain Interference (mean improvement, –7.3; 95% CI, –11.5 to –3.1; $P < .01$), and Pain Intensity (mean improvement, –6.8; 95% CI, –11.0 to –2.6; $P < .01$) compared to preoperatively (Table 4). Within the older group, there was significant

Table 5. Preoperative and Postoperative Radiographic Parameters Compared Between Patients in the Younger Cohort (≤30 Years Old) With Patients in the Older Cohort (>30 Years Old).[a]

	Younger	Older	*P* Value
TN coverage angle mean (SD)			
Preoperative	30.8 (12.6)	27.2 (10.3)	.6
Postoperative	15.4 (11.0)	17.0 (10.7)	.4
HMA, mean (SD)			
Preoperative	16.3 (6.8)	10.9 (6.3)	<.01*
Postoperative	0.2 (4.2)	0.4 (2.6)	.6
Meary angle, mean (SD)			
Preoperative	–19.4 (10.1)	–19.3 (9.5)	.9
Postoperative	–9.4 (6.0)	–9.8 (7.6)	.8
Lateral talocalcaneal angle, mean (SD)			
Preoperative	51.5 (9.6)	50.3 (8.6)	.6
Postoperative	49.2 (7.9)	49.6 (7.6)	.4
Calcaneal pitch, mean (SD)			
Preoperative	15.3 (5.5)	15.2 (5.5)	.9
Postoperative	19.5 (5.8)	18.5 (6.4)	.2

Abbreviations: HMA, hindfoot moment arm; TN, talonavicular.
[a]*P* values refer to comparisons between the 2 age groups.
**P* < .05.

improvement postoperatively in Physical Function (mean improvement, 7.6; 95% CI, 5.7-9.5; $P < .01$), Pain Interference (mean improvement, –10.1; 95% CI, –12.5 to –7.6; $P < .01$), Pain Intensity (mean improvement, –9.6; 95% CI, –12.2 to –7.0; $P < .01$), Global Physical Health (mean improvement, 8.4; 95% CI, 6.1-10.7; $P < .01$), and Global Mental Health (mean improvement, 3.3; 95% CI, 0.9-5.6; $P = .01$) compared with preoperatively. There were no significant differences in the change in PROMIS domains between the 2 cohorts (all $P > .05$).

Radiographic Outcomes

Preoperatively, all radiographic measurements were comparable between the 2 age groups except for HMA, which was significantly higher in the younger cohort (16.3 vs 10.9 mm), $P < .01$) (Table 5). There was no statistically significant difference in any of the radiographic parameters between the age groups postoperatively.

Reoperations

There were a total of 8 reoperations (36.4%) in the younger cohort at a mean of 8.3 months following the index surgery. All reoperations were minor and consisted of removal of hardware due to pain and/or discomfort (7 due to MCO, 1 due to first TMT fusion), which resolved after removal. In comparison, there were a total of 21 reoperations (38.9%) in the older cohort at a mean of 10.7 months following the index surgery. There were 6 major reoperations: 1 patient underwent conversion to triple arthrodesis for recurrence of flatfoot deformity, 1 patient underwent subtalar arthrodesis with MCO for sinus tarsi impingement and recurrent valgus hindfoot alignment, and 4 patients underwent a repeat MCO alone for recurrent valgus hindfoot alignment. There were 15 minor reoperations consisting of removal of symptomatic hardware. There was no significant difference in the overall reoperation rate between the 2 cohorts ($P = .84$).

In terms of complications, 1 patient in the older cohort had a wound abscess requiring incision and drainage, followed by a course of antibiotics. There were otherwise no other incidences of infection or deep vein thrombosis in the postoperative period.

Discussion

The current study suggests that operative correction of symptomatic flexible collapsing foot deformity in younger patients maintains higher physical function clinical outcome scores postoperatively as seen preoperatively in this cohort when compared with older patients. Additionally, reconstruction could be performed in this younger cohort with comparable radiographic correction, fewer tendon transfer and arthrodesis procedures, and no incidence of revision or realignment surgeries.

In the operative treatment of symptomatic flatfoot deformity, there has not been a clear consensus on the optimal time of surgery or the optimal operative procedures indicated. Flatfoot reconstructive procedures were first introduced and developed for the treatment of pediatric flatfoot and later applied to adults. In the literature, studies have demonstrated outcomes of operative correction in the older adult population, as well as in pediatric patients whose etiology was often caused by a congenital deformity.[11,16,19,40] Operative outcomes in a more selective, young population have not been well studied, nor has an association between age and outcomes been determined.[30] We used an age cutoff of 30 years old as this age would reflect outcomes of a younger cohort with perhaps more physical demand from the average older flatfoot patient described in the literature. It has been the authors' experience that these patients develop ligamentous stretching at an early age most likely because of an underlying pathologic bone anatomy morphology and alignment but that they do quite well in terms of function after surgery.[17,30,33,43] A previous study by Conti et al reported clinical outcomes in patients aged <45 years as a "younger" cohort, and they found no significant differences in clinical outcomes or subsequent surgeries between their older and younger cohorts.[10] However, we looked at young adults aged ≤30 years.

Outcomes of flatfoot reconstruction in the young patient have been previously reported in a study of pediatric symptomatic flatfoot deformity. Oh et al reported successful return to participation of sports activity in a cohort of 16 pediatric patients with mean age 15.6 years.[30] The authors observed that at an average of 5.2 years' follow-up, this adolescent cohort demonstrated significant improvement in patient-reported outcomes (American Orthopaedic Foot & Ankle Society [AOFAS] ankle-hindfoot scores, 36-Item Short Form Health Survey [SF-36], Foot and Ankle Outcome Score [FAOS]) as well as return to sports activity with reduction in pain. It is important to note that half of these pediatric patients still had an open physis at the time of the study, which we excluded in our series. Previous studies have demonstrated that arch parameters of the foot are dynamically changing with age when the physis is open in pediatric patients.[3,24,39] Therefore, it is possible that operative outcomes in this population may not solely be due to the corrective procedures themselves. We excluded patients with an open physes in order to better assess outcomes of flatfoot reconstruction in the younger adult.

In our study, an age of 30 years old or younger was associated with a significantly higher pre- and postoperative PROMIS Physical Function. Postoperatively, the younger cohort maintained a higher Physical Function score, 4.6 (95% CI, 1.5-7.8; $P = .03$) points higher than older patients. To determine if this held clinical significance, we compared this difference in improvement with previously published minimal clinically important difference values for PROMIS Physical Function in foot and ankle surgery. Two separate studies using the distribution-and-one-half SD method to calculate the minimal clinically important difference cited threshold values of 4.2 to 4.7,[20,29] suggesting that the difference observed in our study has clinical significance. Physical Function is defined by the ability to carry out various activities reflecting physical capability, ranging from self-care (basic activities of daily living) to more vigorous activities that require increased range of mobility, strength, and/or endurance.[20] This suggests that when adequately corrected, younger patients may be more likely to return to their more physically demanding lifestyle.

In our study cohort, preoperative radiographic parameters were similar except for HMA, which reflected greater valgus deformity in the younger cohort. It is possible that patients had a worse valgus inclination of the posterior facet of the hindfoot joint, and therefore, developed problems earlier compared to older patients.[32] Despite having more severe heel valgus deformity preoperatively, the younger cohort demonstrated a greater degree of improvement in HMA, and postoperatively there were no differences in any of the radiographic parameters between age groups.

Importantly, we observed that younger patients were significantly less likely to require corrective procedures of the posterior tibial tendon (posterior tibial tendon repair and FDL tendon transfer) and spring ligament compared with older patients. This finding corroborates previous findings in the literature in which the posterior tibial tendon and ligaments are found to be more degenerated in older patients.[10,30] In addition, younger patients were less likely to undergo fusion of the first TMT joint. We hypothesize that this may be related to the accumulation of medial arch overload, which leads to degeneration of the TMT joint, including arthritis, plantar gapping, and hallux valgus over time in the older patients. Tendon harvest may put patients at more risk of nerve damage,[26,27] and TMT fusion introduces a risk of nonunion and are noteworthy to mention when counseling patients on flatfoot reconstruction.[41]

In terms of reoperations, we observed major reoperations only in the older cohort. In the younger cohort, the only indication for reoperation was removal of painful hardware (36.4%). Of the 8 cases, 7 included removal of calcaneal screws following MCO (31.8%). Generally, the removal rate of calcaneal screws after MCO is reported to be 15% to 45%.[25,37,38] Therefore, our finding is consistent with previous studies and unlikely attributed to age. There were no incidences of major reoperations such as revision surgery or arthrodesis in the young cohort at short-term 2-year follow-up. This observation is consistent with previous findings in which patients less than 45 years old had a lower incidence of revision surgery when compared to patients older than 45 years.[10] The authors hypothesize that this may be attributed to the general ability for these younger patients to adapt and compensate more than older patients in the setting of under- or overcorrection. Younger patients with better bone quality also likely heal better than their older counterparts.

Demographically, we observed a difference in gender distribution within the age groups. Although the older cohort consisted of 33 (61%) females, which reflects findings in the literature of a higher prevalence of flatfoot deformity in the female population,[12,22] we observed that only 6 (30%) of the younger patients were female ($P = .03$). It is worth considering that the trend observed in older patients may not necessarily exist in younger patients although this observation is limited by our relatively small sample size.

Strengths of this study include that this is a large cohort of patients with flexible collapsing foot deformity who were 30 years old or younger with pre- and postoperative radiographic and clinical outcomes follow-up. Other strengths of this study include the ability to compare the change in preoperative and postoperative clinical outcomes using a patient-reported outcomes instrument that is validated for flatfoot deformity and follow-up at a minimum of 2 years postoperatively. In addition, all patients were treated by the 2 senior authors using the same technique and indications.

Our study is not without limitations. A significant limitation of this study is that sample sizes were based on a sample of convenience in consecutive patients, and a power analysis was not performed. Differences in clinical outcomes and radiographic measurements that did not meet statistical significance were at risk of a type II error. However, we believe that even if these differences did exist, they would likely not reach clinical significance. Additionally, we did not match the cohorts based on the severity of their presenting deformity, clinical findings, or radiographic measurements, and therefore, we acknowledge the potential for confounding that each variable introduces. However, our stringent inclusion and exclusion criteria allowed for comparison of the 2 groups, and we were able to demonstrate similar preoperative deformity and postoperative correction through radiographic analysis. The results of this study were also limited by inherent differences in the healing rates and participation in physical activity between younger and older patients. This may explain why patient-reported physical function remained significantly higher in the younger cohort postoperatively. Nevertheless, our study suggests that younger patients may be able to return to more physically active lifestyles compared with older patients. This information can be used when surgeons counsel patients preoperatively.

In conclusion, our study found promising outcomes in older and younger patients following idiopathic flexible flatfoot reconstruction, with patients 30 years and younger demonstrating significantly higher physical function outcome scores both pre- and postoperatively compared to older patients. In addition, younger patients were less likely to require soft tissue procedures of the posterior tibial tendon and spring ligament at the time of surgery, without incidence of subsequent corrective reoperations in the short term. These results suggest that age may play a role in operative outcomes of flatfoot reconstruction, and earlier reconstruction of the symptomatic flexible collapsing foot deformity may be considered in select patients.

Ethics Approval

Ethical approval for this study was obtained from **Hospital for Special Surgery Foot and Ankle Steering Committee.**

Declaration of Conflicting Interests

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