

Research Article

Time and Travel Burden Associated with Hexapod-Assisted Correction of Lower Extremity Deformity

Sarah Bradley¹, Matthew A Dow¹, Sara Van Nortwick¹, Ryan McFadden¹, Robert F Murphy^{1*}

¹Associate Professor, College of Medicine, Department of Orthopaedics and Physical Medicine, USA

*Correspondence author: Robert F Murphy, Associate Professor, College of Medicine, Department of Orthopaedics and Physical Medicine, USA;

Email: murphyr@muscul.edu

Citation: Murphy RF, et al. Time and Travel Burden Associated with Hexapod-Assisted Correction of Lower Extremity Deformity. J Ortho Sci Res. 2023;4(2):1-6.

<https://doi.org/10.46889/JOSR.2023.4204>

Received Date: 11-05-2023

Accepted Date: 28-05-2023

Published Date: 06-06-2023



Copyright: © 2023 by the authors. Submitted for possible open access publication under the terms and conditions of the Creative Commons Attribution (CC BY) license

(<https://creativecommons.org/licenses/by/4.0/>).

Abstract

Background: Hexapod devices, colloquially referred to as frames, are powerful tools to correct lower extremity deformity. However, patients who undergo treatment with frames are followed closely to ensure that clinical and radiographic correction are satisfactory. Depending on the size of the state and the number of surgeons that offer frame treatment, patients may need to travel a long distance and frequently, to obtain care. We sought to characterize the number of clinical and surgical encounters, as well as the cumulative driving distance, for frame patients treated at a single academic health center.

Methods: All patients treated with a hexapod frame for any etiology by three pediatric orthopaedic surgeons at a single children's hospital over an 8-year period were investigated. Patients were queried for demographic data, number of non-surgical and surgical clinical encounters and number of days in the frame. Driving distance was calculated from the patients address to the academic health system address.

Results: Thirteen patients qualified for inclusion (10 male, 3 female). Mean age at frame application was 14.6 years (range 4-31). Mean time in the frame was 150.5 days (range 90-207). Throughout the course of their frame treatment, patients had a mean of 16 non-surgical (range 5-26) encounters and a mean of 3 (range 2-6) surgical encounters. Mean one-way driving distance between the treating institution and the patient's home was 77 miles (range 20-212 miles). When two way driving distance was multiplied by the total number of encounters for each patient, the mean distance driven was 2616 miles (range 862-7632 miles).

Conclusion: In this cohort of patients with a lower extremity frame, there were on mean 16 non-surgical and 3 surgical encounters, with a mean driving distance during the treatment program of 2600 miles. When agreeing to undertake a hexapod-assisted program for lower extremity pathology, patients should be counseled about the temporal and financial nature of this strategy, so they are aware of the large commitment needed.

Keywords: Deformity; Taylor Spatial Frame; Area Deprivation Index; Patients

Introduction

The Taylor Spatial Frame (TSF) is an external fixation device which permits the treatment of complex deformities by allowing correction in six-axes. The basic construct consists of two rings connected by six telescopic struts and uses computer software for a precise and simultaneous multiplanar adjustment [1-3]. This hexapod design addressed limitations to the use of earlier devices such as the lizarov external fixator [4].

TSF has utility in lower limb lengthening and correction of various congenital and acquired deformities [5-7]. Hexapods have been associated with lower complication rates and greater precision while achieving the same target correction compared to other fixation methods [8]. A drawback of TSF for complex deformity, however, is the necessity for several sequential follow up appointments to monitor and adjust correction parameters [9].

When compared to other fixation methods, hexapods have been shown to have increased times to removal, with fixation times reported from 2 to 12 month [10,11]. A main goal of this treatment is to reduce treatment time and return patients to “normal” activity sooner [3]. Longer treatment times leads to additional care encounters, increased expenses and more time required off from school and work.

With the aforementioned considerations, the temporal nature and financial demand of TSF creates a burden on patients and families. This study aimed to describe the burden of care for TSF patients treated at a single health center. We aimed to characterize the number of clinical and surgical encounters, as well as the cumulative driving distance and travel time to quantify the burden placed on families undergoing this treatment.

Methods

After Institutional Review Board approval was obtained, a retrospective chart review was performed to identify patients treated with a hexapod frame for any etiology by three pediatric orthopedic surgeons at a single children’s hospital over an 8-year period. The chart review of each subject included demographic data, address, number of non-surgical and surgical clinical encounters, number of days in the frame, number of radiographic images and insurance information. Driving distance from each subjects’ zip code to the institution was calculated using Google Maps. Neighborhood Atlas was used to assign an Area Deprivation Index (ADI) score to each subject based on their address. The ADI is based on a measure created by the Health Resources and Services Administration and refined to the Census Block Group neighborhood level. This measure includes factors for income, education, employment and housing quality (*1,2) IBM SPSS Statistics for Windows v27 was used to calculate univariate and bivariate statistical analysis.

* 1. Kind AJH, Buckingham W. Making Neighborhood Disadvantage Metrics Accessible: The Neighborhood Atlas. *New England Journal of Medicine*, 2018. 378: 2456-2458. DOI: 10.1056/NEJMp1802313. PMCID: PMC6051533.

2. University of Wisconsin School of Medicine and Public Health. 2023. Area Deprivation Index. <https://www.neighborhoodatlas.medicine.wisc.edu/>

Results

Thirteen patients from a single institution qualified for inclusion. There were 10 male and 3 female, with a mean age at index frame application was 14.6 years (range 4-31). Table 1 lists the demographic, clinical and surgical details of the 13 patients. Patients spent a mean of 150.5 days (range 90-207) in the frame. Over the course of that treatment, patients had a mean of 19 total encounters (range 7-32). This included a mean of 16 non-surgical (range 5-26) and mean of 3 surgical encounters (range 2-6). During frame treatment, from application to removal, patients had on average 12 radiographs (range 3-17). Complications were seen in 4 patients including revisions, infection and symptomatic screws (Fig. 1).

Patient	Age at frame Application	Diagnosis	Total Time in Frame (Days)	Clinical Encounters	Surgical Encounters	Number of Radiographs During Frame Treatment	Complications
1001	14	Blounts Disease, tibia vara	112	15	2	9	
1002	14	ewings sarcome, malunion of tibia	168	26	6	16	Revision, Infection
1003	17	pseudoachondroplasia	189	18	4	17	
1004	14	Blounts Disease, tibia vara	119	12	3	7	Revision
1005	4	scoliosis, leg length discrepancy	147	22	5	11	Infection
1006	14	blounts disease	169	9	2	17	
1007	15	multiple hereditary exostoses, valgus defrmity ankle	190	15	3	13	
1008	14	Olliers Disease, leg length discrepancy	207	21	2	15	
1009	13	tibia vara	189	16	2	13	
1010	7	fracture femur, osteomyelitis of femur	127	5	2	7	
1011	20	aquired deformity of lower extremity	145	15	3	14	Symptomatic Screw
1012	13	closed fracture of tibia secondary to GSW	120	15	3	12	
1013	31	flexion contracture of knee, crouched gait	90	13	2	3	

Table 1: Lists the demographic, clinical and surgical details of the 13 patients.

Patients drove on average 77 miles (range 20-212 miles) one-way from their home to the treating institution. When two way driving distance was multiplied by the total number of encounters for each patient, the mean distance driven was 2616 miles (range 862-7632 miles). The mean time traveled for care was 186.92 minutes (range 39-191 minutes). When the number of total encounters attended was considered for each patient, the mean total time spent traveling over the treatment period was 3314.46 minutes (range 1652- 6876 minutes).

ADI scores for the 13 patients are reported in Table 2. ADI scores based on national rankings are presented as percentiles, where ADIs were spilt into 100 equal sections. ADI scores based on individual states are presented as deciles, where scores were split into 10 equal sections. Individual block groups/neighborhoods are categorized, with those in the first percentile/decile being the least disadvantaged and those in the hundredth/tenth being the most.

Patient	Race	Insurance	State ADI Decile	National ADI Percentile	Distance Traveled to MUSC Health	Travel Time to Care
1001	Black	Public	3	47	92.4	184.8
1002	Non-Hispanic White	Public	2	36	20.3	40.6
1003	Non-Hispanic White	Public	2	31	30.9	61.8
1004	Black	Public	7	83	48.5	97
1005	Non-Hispanic White	Public	9	90	63.9	127.8
1006	Black	Public	9	93	67.9	135.8
1007	Non-Hispanic White	Private	2	35	30.9	61.8
1008	Non-Hispanic White	Private	3	53	91.5	183
1009	Black	Public	10	95	64.7	129.4
1010	Other	Public	4	59	98.6	197.2
1011	Non-Hispanic White	Private	2	37	212	424
1012	Black	Public	10	99	119	238
1013	Black	Public	10	97	61.6	123.2

Table 2: ADI scores for the 13 patients.

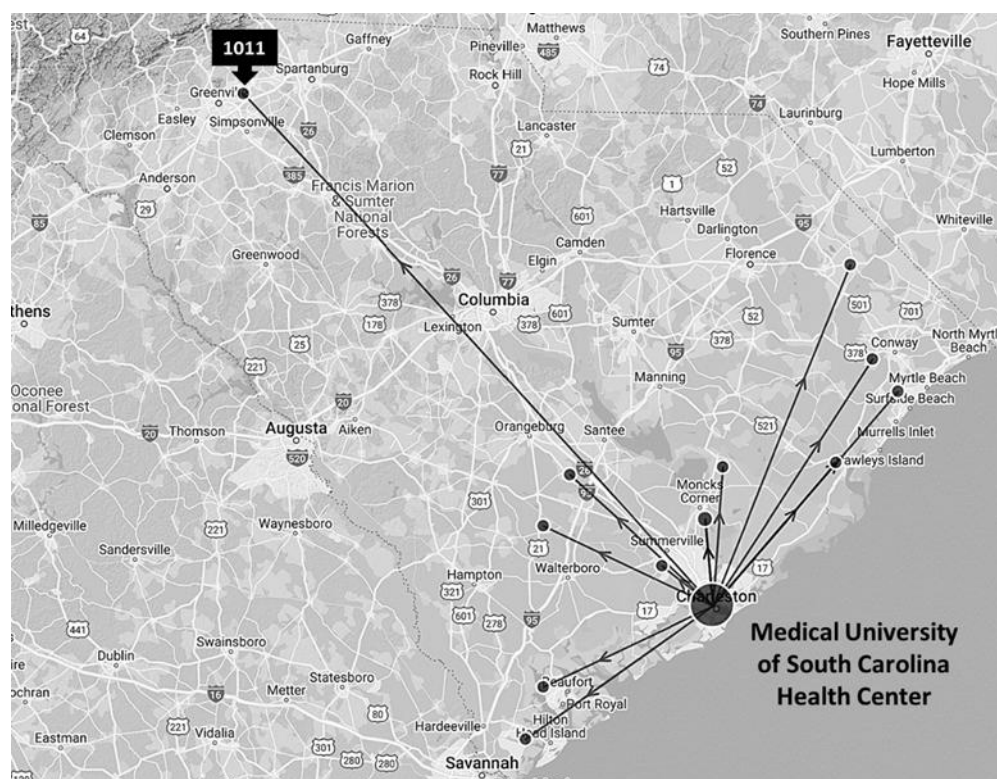


Figure 1: Map demonstrating location of frame patients relative to the medical center.

Discussion

Advancements in limb lengthening have aimed at reducing external fixation time and returning patients to normal function sooner [3]. With the frequent appointments required for sequential distractions, treatment with TSF still has limitations. Watts, et al., evaluated the time to frame removal in pediatric patients with tibia fractures [12]. When 3 different external fixation methods were compared, TSF was found to have the highest median time of 198 days from index to removal.

The economic burden of TSH as a treatment modality is a major concern. Hughes, et al., noted increased number of clinic visits, complications and readmission for removal, as some of the hidden cost associated with external fixation [13]. A 2022 analysis of the burden of care following index hexapod application showed an average \$35,986.88 (range \$27,363.52-\$52,546.37) spent in the 12-months following post-index surgery for those aged <17 with congenital deformity. Reid, et al., found this group of 168 patients, with an average duration of care similar to ours at 149.5 days, also had an average 22.26 outpatient physical therapy appointments and average 8.94 outpatient imaging procedure [14].

With frequent appointments required to achieve target correction, it is important to identify risk factors to successful treatment. Access to pediatric orthopedic surgeons can be a barrier to obtaining subspecialized care. In a review of pediatric surgical specialties, Mayer et al. reported that in 2009, in the United States, the average distance to the nearest pediatric orthopedist was 40.0 miles [15]. Greater travel times put a burden on families. The mean one-way driving distance for TSF patients treated at our health center was 77 miles, potentially making distance to care a greater barrier to treatment in the studied population. However, several studies in the last decade have explored specific social determinants of health that may more accurately predict adherence to follow-up in pediatric orthopedics patients [16].

Hubbard, et al., observed that while distance traveled was not a predictor of appointment adherence following operative treatment of pediatric supracondylar humerus fractures, race and estimated income were predictive [17]. Likewise, a 2022 retrospective cohort study of pediatric orthopedics patients saw increased odds of missed care opportunities in Black and Hispanic patients when compared to White patients and publicly insured when compared to private insurance holders. Tartarilla, et al., found that these disparities persisted between in-person visits and telemedicine visits, indicating that distance to care may not be the most reliable when predicting which patient's follow-up [18].

Our study aimed to capture social determinants of health by looking at ADI. In orthopedic patients, ADI has been a reliable predictor of socioeconomic status and a reliable measure of outcome [19,20]. In pediatric patients treated for fractures, Meza, et al., found those with a higher ADI were significantly more likely to miss follow-up appointments [21]. Our study found 6 of 13 patients treated with TSF to have national ADI scores over the 80th percentile. The relationship between social determinants of health and missed appointments in this patient population warrants further investigation.

External fixation devices also propose a psychological toll for children and families [22,23]. Ramaker, et al., investigated the psychological and social function of 26 patients throughout leg lengthening with the Ilizarov frame [24]. Questionnaires demonstrated poor school or work circumstances for 9 patients, sleeping problems for 12 patients and difficulty taking care of the affected leg for most patients during lengthening. When evaluating the mental health of children during leg lengthening, Niemelä, et al., also observed many patients having difficulties attending school full time during the treatment due to pain or practical problems [25]. Parents of 7 out of the 27 patients treated with the Ilizarov frames in this study also report the amount of time required for care during this period to be extensive. These studies emphasize the need for substantial education prior to index surgery regarding the intensity frame treatment.

Our study did have limitations due to the study design and estimated driving calculations. Our study had a small sample size of 13 patients. Given this is a retrospective study there is a possibility we failed to include qualified patients. Furthermore, the burden of care analysis is not all encompassing, with valuable confounding variables absent due to the nature of the data collection. Travel times and distances were calculated based on zip code rather than exact address, which is subject to inaccuracies. These distances also assumed that patients remained at the same address for the entirety of the study period.

In our cohort of 13 patients treated with TSF, there was on average >4.5 months between index application and frame removal. Patients had on average 16 non-surgical and 3 surgical encounters during this treatment period. The average total distance traveled was 2616 miles and the average total time spent traveling was 3314 minutes. When considering TSH for the treatment of lower limb deformity, additional counseling must take place to educate families on the temporal and financial commitment of the treatment modality.

Conflict of Interest

The authors have no conflict of interest to declare.

References

1. Eidelman M, Bialik V, Katzman A. Correction of deformities in children using the Taylor spatial frame. *J Pediatr Orthop B*. 2006;15(6):387-95.
2. Basha K, Alawadhi A, Alyammahi M. Comparison of three circular frames in lower limb deformity correction: a biomechanical study. *Cureus*. 2022;14(5):e25271.
3. Calder PR, Faimali M, Goodier WD. The role of external fixation in paediatric limb lengthening and deformity correction. *Injury*. 2019;50(1):S18-23.
4. Keshet D, Eidelman M. Clinical utility of the Taylor spatial frame for limb deformities. *Orthopedic Research and Reviews*. 2017;9:51-61.
5. Horn J, Steen H, Huhnstock S, Hvid I, Gunderson RB. Limb lengthening and deformity correction of congenital and acquired deformities in children using the Taylor spatial frame. *Acta Orthopaedica*. 2017;88(3):334-40.
6. Koren L, Keren Y, Eidelman M. Multiplanar deformities correction using Taylor spatial frame in skeletally immature patients. *The Open Orthopaedics J*. 2016;10(1):71-9.
7. Naqui SZ, Thiryayi W, Foster A, Tselentakis G, Evans M, Day JB. Correction of simple and complex pediatric deformities using the Taylor-Spatial Frame. *J Pediatr Orthop*. 2008;28(6):640-7.
8. Reitenbach E, Rödl R, Gosheger G, Vogt B, Schiedel F. Deformity correction and extremity lengthening in the lower leg: comparison of clinical outcomes with two external surgical procedures. *SpringerPlus*. 2016;5(1).
9. Ray V, Popkov D, Lascombes P, Barbier D, Journeau P. Simultaneous multisegmental and multifocal corrections of complex lower limb deformities with a hexapod external fixator. *Orthopaedics and Traumatology: Surgery and Research*. 2021:103042.
10. Marangoz S, Feldman DS, Sala DA, Hyman JE, Vitale MG. Femoral deformity correction in children and young adults using

- Taylor spatial frame. *Clinical Orthopaedics and Related Res.* 2008;466(12):3018-24.
11. Iobst C. Limb lengthening combined with deformity correction in children with the Taylor Spatial Frame. *J Pediatr Orthop B.* 2010;19(6):529-34.
 12. Watts A, Sadekar V, Moulder E. A comparative evaluation of the time to frame removal for tibia fractures treated with hexapod and Ilizarov circular frames. *Injury.* 2023;54(3):996-1003.
 13. Hughes A, Heidari N, Mitchell S. Computer hexapod-assisted orthopaedic surgery provides a predictable and safe method of femoral deformity correction. *The Bone and Joint J.* 2017;99-B(2):283-8.
 14. Reid JS, Vanderkarr M, Ray B, Chitnis A, Holy CE, Sparks C. Two-year clinical and economic burden, risk and outcomes following application of software-assisted hexapod ring fixation systems. *BMC Musculoskeletal Disorders.* 2022;23(1).
 15. Mayer ML, Beil HA, von Allmen D. Distance to care and relative supply among pediatric surgical subspecialties. *J Pediatr Surg.* 2009;44(3):483-95.
 16. Arant KR, Modest JM, Gil JA, Cruz AI Jr. What's new in pediatric orthopaedic health care disparities? *J Pediatr Orthop.* 2022;42(9):e954-9.
 17. Hubbard EW, Rathjen KE, Elliott M, Wimberly RL, Riccio AI. Predictors of appointment adherence following operative treatment of pediatric supracondylar humerus fractures: which patients are not following up? *J Pediatric Orthopaedics B.* 2022;31(1):25-30.
 18. Tartarilla AB, Tennermann N, Melvin P, Ward VL, Bauer AS. Sociodemographic Missed-care predictors for pediatric orthopaedic telemedicine during COVID-19. *J Pediatr Orthop.* 2022;42(6):e688-95.
 19. Cheng AL, McDuffie JV, Schuelke MJ, Calfee RP, Prather H, Colditz GA. How should we measure social deprivation in orthopaedic patients? *Clinical Orthopaedics and Related Research.* 2022;480(2):325-39.
 20. Evans S, Okoroafor UC, Calfee RP. Is Social deprivation associated with PROMIS outcomes after upper extremity fractures in children? *Clinical Orthopaedics and Related Research.* 2021;479(4):826-34.
 21. Meza BC, Iacone D, Talwar D, Sankar WN, Shah AS. Socioeconomic deprivation and its adverse association with adolescent fracture care compliance. *JB and JS Open Access.* 2020;5(2):e0064.
 22. Montpetit K, Hamdy RC, Dahan-Oliel N, Zhang X, Narayanan UG. Measurement of health-related quality of life in children undergoing external fixator treatment for lower limb deformities. *J Pediatr Orthop.* 2009;29(8):920-6.
 23. Martin L, Farrell M, Lambrenos K, Nayagam D. Living with the Ilizarov frame: adolescent perceptions. *J Advanced Nursing.* 2003;43(5):478-87.
 24. Ramaker RR, Lagro SWJ, Roermund PMV, Sinnema G. The psychological and social functioning of 14 children and 12 adolescents after Ilizarov leg lengthening. *Acta Orthopaedica Scandinavica.* 2000;71(1):55-9.
 25. Niemelä BJ, Tjernström B, Andersson G, Wahlsten VS. Does leg lengthening pose a threat to a child's mental health? An interim report one year after surgery. *J Pediatr Orthop.* 2007;27(6):611-7.

Journal of Orthopaedic Science and Research



Publish your work in this journal

Journal of Orthopaedic Science and Research is an international, peer-reviewed, open access journal publishing original research, reports, editorials, reviews and commentaries. All aspects of orthopaedic health maintenance, preventative measures and disease treatment interventions are addressed within the journal. Orthopaedicians and other researchers are invited to submit their work in the journal. The manuscript submission system is online and journal follows a fair peer-review practices.

Submit your manuscript here: <https://athenaeumpub.com/submit-manuscript/>