

## Article

# Lateral Column Lengthening Effect on Total Subtalar Joint Range of Motion: A Pilot Study

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## Abstract

Lateral column lengthening (LCL) calcaneal osteotomy is a well-established surgical procedure used in flexible flatfoot reconstructive surgery. The effects of LCL on subtalar joint (STJ) range of motion (ROM) have not been thoroughly explored in the literature. Our study aimed to objectively measure the average decrease in the total ROM of the STJ following LCL. A retrospective cohort study was conducted on 15 patients (20 feet) who underwent LCL for various indications. Data for STJ ROM was collected from both the preoperative and postoperative periods. Mean follow-up for the cohort was 12 weeks postoperatively. The mean total preoperative STJ ROM was  $39.65 \pm 2.52$  degrees, while the mean total postoperative STJ ROM was  $19.17 \pm 2.62$  degrees ( $p < 0.001$ ). This represents a statistically significant reduction of 20.48 degrees (48% decrease) in STJ ROM from preoperative to postoperative measurements. This study provides the first objective measurement of the STJ ROM decrease following LCL calcaneal osteotomy on patients in vivo. The findings highlight the substantial impact of the procedure on the ROM in the STJ. These results have important implications for patient management and should be considered when evaluating the outcomes of LCL procedures. Further research is warranted to explore the functional consequences and long-term effects of the reduced STJ ROM and to develop strategies for optimizing foot function in patients undergoing this procedure.

**Keywords:** lateral column lengthening; Evans osteotomy; calcaneal osteotomy; equinus; pes planovalgus; flatfoot deformity; subtalar joint



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## 1. Introduction

LCL calcaneal osteotomy, commonly referred to as an Evans osteotomy, is a surgical procedure commonly employed in treating various foot and ankle pathologies, including pediatric and flexible flatfoot deformities, tarsal coalition, and posterior tibial tendon dysfunction. Dr. Dillwyn Evans described the LCL calcaneal osteotomy in 1975 to revise the iatrogenic over-corrected clubfoot [1]. The procedure involves making an osteotomy at the lateral aspect of the calcaneal neck by inserting an allograft bone wedge or synthetic materials. The effects of LCL have been well assessed regarding changes in hindfoot alignment. LCL corrects the hindfoot alignment in all three planes, as evidenced by multiplanar radiographic measurements [2,3]. The LCL calcaneal osteotomy and other indicated procedures can correct some of the most severe deformities without joint arthrodesis or extraarticular implants [4]. While LCL has been widely studied for its effectiveness in addressing these

conditions, the impact of this procedure on the motion of the STJ remains a topic of interest and clinical relevance.

The STJ is a unique joint complex comprising the talocalcaneal (TC) and talocalcaneonavicular (TCN) joints. The STJ has an obliquely oriented joint axis that functions in a 3-dimensional or tri-planar manner. The function of the STJ is determined by its spatial relationship with joints distal to their articulation with the navicular and cuboid. The configuration of these joint surfaces forms the two primary columns of the foot: medial (talar) and lateral (calcaneal) [5]. Much of the motion of the STJ occurs in the frontal plane, which is commonly defined as having a total of 30 to 40 degrees of motion in inversion and eversion (25° to 30° in inversion and 5° to 10° in eversion, respectively) [6,7]. The STJ contributes to the overall stability and mobility of the foot during weightbearing activities. Any alteration in the motion of the STJ can significantly impact patients' gait patterns, foot mechanics, and functional outcomes. Concerns have been raised regarding the effect of LCL on STJ ROM, as well as impingement of the STJ after LCL [8]. Recently, one team of investigators measured STJ ROM in 14 cadaver feet, reporting no statistically significant difference before and after LCL [9]. Despite this initial cadaveric finding, to our knowledge, no study to date has measured this effect both before and after LCL in vivo.

Our principal investigator (PAD) has observed a clinical decrease in the total ROM of the STJ after LCL. To date, there are no reports in the literature of the effect of LCL on the STJ ROM, nor have any studies quantified the decrease in the STJ ROM after an LCL. The purpose of this study was to give a preliminary objective measurement for the average decrease in the total ROM of the STJ after LCL.

## 2. Materials and Methods

### 2.1. Study Design

A retrospective cohort study was performed to analyze the total STJ ROM of patients that had undergone LCL performed by the primary investigator in a private practice setting.

### 2.2. Participants and Selection

Patients included in the study were patients undergoing an LCL calcaneal osteotomy (CPT 28300) for any reason. All patients were surgically treated between 2020 and 2023 by a single surgeon (Patrick A DeHeer, DPM). Exclusion criteria included any patient with a previous calcaneal osteotomy, calcaneal coalition, or fusion of associated joint complexes. A total of 20 feet in 15 patients met the criteria for inclusion.

### 2.3. Data Collection and Variable Definitions

Measurements of patients' STJ ROM were collected retrospectively. These measurements had been performed three times pre-operatively and three times at 12 weeks ( $\pm 1$  week) postoperatively with a manual goniometer and documented by the principal investigator. The method of measurement involved the patient lying flat on the clinical examination table in a prone position, with their feet dangling off the edge of the bed. The total reduction in STJ ROM was reported and percent reduction was calculated. Data collected from patients included sex, age, side of the operation, graft size, preoperative STJ total ROM, and 12-week ( $\pm 1$  week) postoperative STJ total ROM.

### 2.4. Quality Control

A repeated measures ANOVA ( $p = 0.47$ ) was used to test whether there was significant variation in the measurements themselves to ensure measurement consistency and reliability.

### 2.5. Follow-Up

Mean follow-up was 12 weeks postoperatively. Postoperative protocol consisted of 4 weeks of non-weight-bearing and 4 weeks of assisted weight-bearing in a CAM boot, followed by transition into full weight-bearing in regular shoe gear.

### 2.6. Ethics Approval and Informed Consent

IRB approval was obtained for data collection (RIN20250084). The IRB waived the requirement for obtaining informed consent given the retrospective nature of the study.

### 2.7. Statistical Analysis

Demographic variables, including age, sex, and side of the operation, were described with counts, rates, and measures of central tendency. Measurements were compared within each patient with paired *t*-tests. A ratio of preoperative to postoperative total ROM was also calculated for each patient. The values were found to be normally distributed. Covariates considered included days between measurements, size of allograft, age, and side of the foot. These were evaluated with exploratory regression analyses to assess for association with changes in ROM. A *p*-value of less than 0.05 was considered statistically significant for inferential tests. SPSS 24.0 (IBM Corp., Armonk, NY, USA) was used for statistical analyses.

## 3. Results

A total of 20 LCL calcaneal osteotomy procedures were performed in 15 patients, including 8 females (53%) and 7 males (47%). Among these patients, 5 underwent bilateral procedures. The left foot was involved in 14 cases (70%), while the right foot was involved in 6 cases (30%). The median age of patients at the time of surgery was 16 years, ranging from 10 to 65 years. The mean duration between pre-operative and post-operative measurements was 96.65 days. Calcaneal allografts of sizes 8 mm and 10 mm were used, with 6 grafts (30%) and 14 grafts (70%) respectively (Table 1).

**Table 1.** Descriptive statistics of patient cohort.

| Descriptive Statistics                       |           |               |           |
|----------------------------------------------|-----------|---------------|-----------|
|                                              | n         | Mean (SD)     | 90% CI    |
| Time Between Pre-Op and Post-Op Measurements | 20 (100%) | 96.65 (21.28) | 69–135.95 |
|                                              | n         | Median (IQR)  | Min–Max   |
| Patient Age                                  | 20 (100%) | 16 (17)       | 10–65     |
|                                              |           |               |           |
| Graft Size (mm)                              |           |               |           |
|                                              | n         | %             |           |
| 8 mm                                         | 6         | 30.0          |           |
| 10 mm                                        | 14        | 70.0          |           |
| Total                                        | 20        | 100.0         |           |
|                                              |           |               |           |
| Patient Sex                                  |           |               |           |
|                                              | n         | %             |           |
| Female                                       | 11        | 55.0          |           |
| Male                                         | 9         | 45.0          |           |
| Total                                        | 20        | 100.0         |           |

The mean total preoperative STJ ROM was  $39.65 \pm 2.52$  degrees, while the mean total postoperative STJ ROM was  $19.17 \pm 2.62$  degrees ( $p < 0.001$ ) (Table 2). This indicates a statistically significant 48% reduction in STJ ROM following LCL calcaneal osteotomy. It is worth noting that the difference among measurements of preoperative and postoperative STJ ROM did not show a significant difference ( $p = 0.47$ ), suggesting consistency and intra-rater reliability in the measurement technique (Table 3).

**Table 2.** Change in subtalar joint range of motion Pre-Op vs. Post-Op.

| Change in STJ ROM Measurement |    |              | Paired <i>t</i> Test |             |
|-------------------------------|----|--------------|----------------------|-------------|
|                               | n  | Mean (SD)    | <i>t</i>             | <i>p</i>    |
| Pre-Op                        | 20 | 39.65 (2.52) | 24.05                | <0.001      |
| Post-Op                       | 20 | 19.17 (2.62) |                      |             |
| Change in ROM (Delta)         | 20 | 20.48 (3.81) | 95% CI               | 18.70–22.27 |

**Table 3.** Comparison of variability between Pre-Op and Post-Op repeat measurements.

| Repeated STJ ROM Measurements |         |    |              | Repeated Measures ANOVA |          |
|-------------------------------|---------|----|--------------|-------------------------|----------|
|                               | Measure | n  | Mean (SD)    | <i>F</i>                | <i>p</i> |
| Pre-Op                        | 1       | 20 | 39.70 (3.10) | 0.55                    | 0.47     |
|                               | 2       | 20 | 39.25 (2.69) |                         |          |
|                               | 3       | 20 | 40.00 (2.34) |                         |          |
| Post-Op                       | 1       | 20 | 19.45 (2.59) | 2.86                    | 0.12     |
|                               | 2       | 20 | 19.05 (3.22) |                         |          |
|                               | 3       | 20 | 19.00 (2.41) |                         |          |

The time interval between measurements, the sidedness of the foot, the age of the patient, and the size of the graft used were not statistically significant factors in relation to the observed changes in STJ ROM. These findings suggest that the decrease in ROM was consistent regardless of the time between measurements, the side of the foot affected, or the size of the calcaneal allograft used in the procedure.

#### 4. Discussion

LCL calcaneal osteotomy is an important procedure used in the treatment of pediatric and flexible flatfoot deformities. As with any operative procedure, the surgeon must understand the cause and effect of the chosen treatments. LCL improves the triplanar positioning of the flexible flatfoot, as evidenced by the reduction in talar head uncoverage (Figure 1), as well as the correction of several radiographic parameters, including calcaneal inclination angle and Meary's angle (Figure 2). The present study aimed to establish an objective measurement for the previously unexplored average decrease in the total ROM of the STJ after LCL. The results of this study demonstrate that LCL may be associated with a significant decrease in STJ ROM. This finding has several implications for both clinical practice and future research.

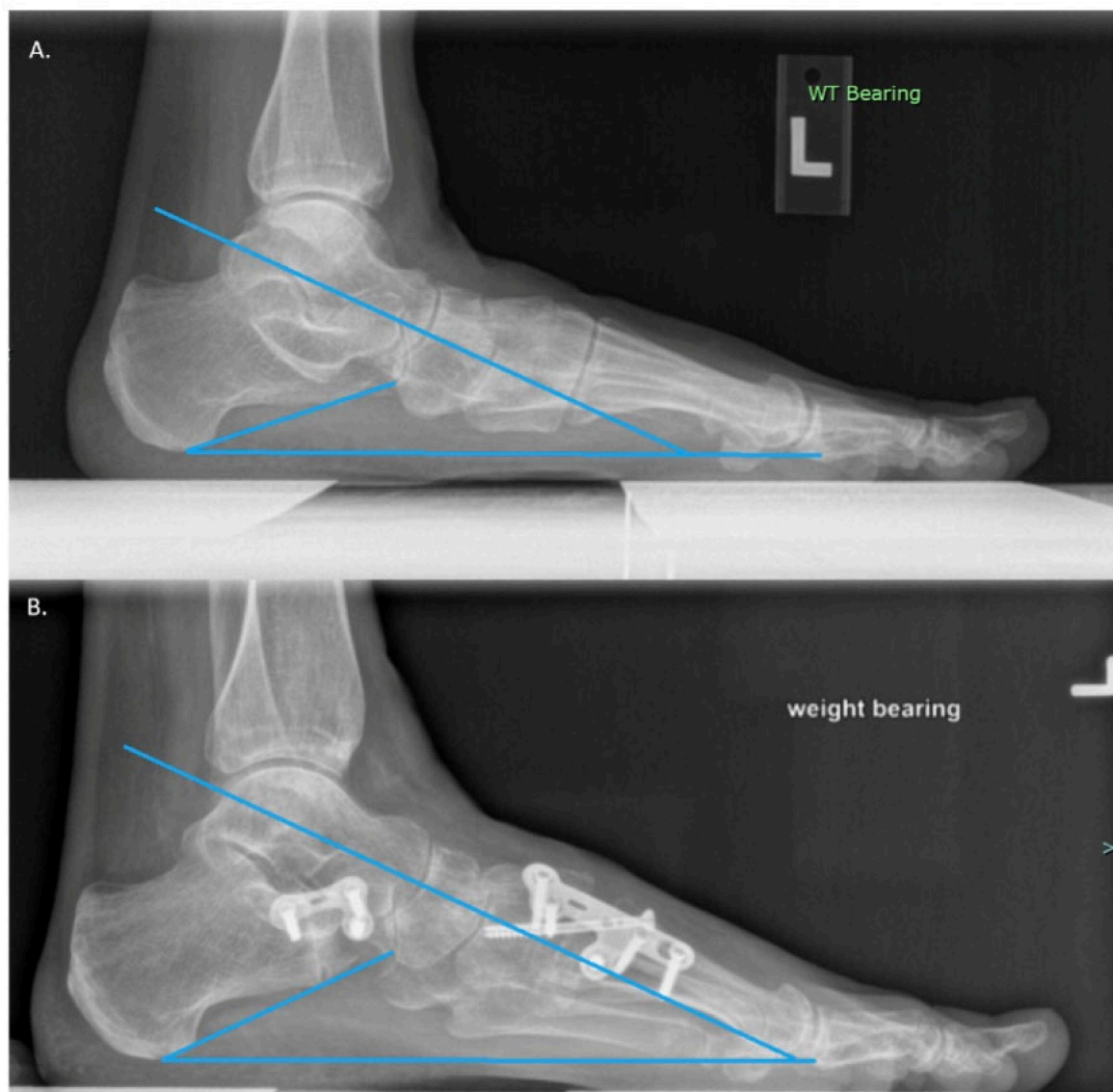


**Figure 1.** Preoperative (A) and postoperative (B) AP radiographs of the left foot comparing alignment. The blue lines outline and bisect the talar head. Note the improvement in talar head uncoverage.

The most well-described long-term sequela observed after LCL procedures is increased pressure at the calcaneocuboid joint [10–12]. The effect of LCL on the mechanics of the STJ has not been solidly established, although reduced eversion post-LCL has been proposed as a mechanism accounting for increased lateral column pressures [13]. Choi et al. described a 7.3% increase in the dorsiflexion of the talus as well as a 0.85 mm anterior shift in the talar body as observed on lateral radiograph after LCL [14]. This change may affect both the ankle and the STJ. Based on the results of the current study, we suggest that LCL may affect the mechanics of the STJ in a manner not previously reported in the literature.

Decreased STJ ROM may have functional consequences for patients undergoing LCL. The STJ is crucial for normal foot and ankle motion, particularly in inversion and eversion movements. In theory, limitations in STJ ROM could lead to altered gait patterns and reduced functional activities, although several studies have shown significant improvement in functional scores after LCL [15,16]. Regardless, patients who undergo LCL should be aware of the potential impact on their foot and ankle function that may necessitate further

monitoring or additional interventions such as physical therapy or orthotic devices to compensate for the restricted ROM.



**Figure 2.** Preoperative (A) and postoperative (B) lateral radiographs of the left foot comparing alignment. The blue lines assist in visualizing the improvements in calcaneal inclination angle and talar declination angle.

The size of graft used for the LCL is an important component of deformity correction. Chan et al. reported that each millimeter of graft used in LCL correlates to  $6.8^{\circ}$  of correction of the lateral incongruency angle [17]. One recent study used weightbearing CT scans to measure the change in several radiographic parameters with varying sizes of allografts used in LCL on 8 cadaver feet. It was found that 6 mm allografts were often adequate to reduce the flatfoot deformity radiographically, and 10 mm may trend towards overcorrection in cadaveric models [18]. However, expert consensus from 2020 determined that a length of 5–10 mm is appropriate for the amount of lengthening required to correct deformity intra-operatively on patients in vivo [19]. In this patient cohort, either an 8 mm or 10 mm size allograft wedge was used depending on intra-operative decision making concerning the amount of deformity correction required. The size of graft used in LCL should always be determined intra-operatively through direct observation of deformity correction.

Another consideration regarding the reduction in STJ ROM is the association of forefoot supinatus deformity with hindfoot valgus, as we clinically observed, which has a basis in twisted plate theory [20]. Forefoot supinatus is compensated by STJ eversion. The LCL osteotomy is often performed along with posterior muscle lengthening (gastrocnemius recession or Tendo-Achilles lengthening) and a medial column procedure (cotton osteotomy or first metatarsal cuneiform arthrodesis). Uncorrected or under-corrected forefoot supinatus may result in deltoid insufficiency and, ultimately, ankle valgus in cases where STJ ROM is limited (talonavicular arthrodesis) or eliminated (STJ arthrodesis) [21]. The limitation of STJ ROM caused by LCL in patients with untreated or under-corrected forefoot supinatus may result in uncompensated or partially (lateral foot pain) or fully compensated (deltoid insufficiency/ankle valgus) deformities.

Surgeons should consider decreased STJ ROM as an important factor when evaluating the outcomes of patients having undergone LCL. Traditionally, the success of the procedure has been assessed based on radiographic measurements, clinical pain relief evaluation, and improvements in foot alignment. However, the findings of this study emphasize the need to incorporate assessments of STJ ROM as a critical outcome measure. Future studies including this parameter in outcome evaluations will provide a more comprehensive understanding of the procedure's functional consequences and overall success.

The limitations of this study should also be acknowledged along with calls to action for further study into this topic in the future. The sample size was relatively small, and the follow-up duration was limited. A larger-scale study with a more extended follow-up period would enhance the generalizability of the results and would help distinguish between limited STJ ROM truly caused by sequela of the lengthening of the lateral column versus expected postoperative edema. Recent studies have described residual swelling, redness and pain during periods of transition from immobilization devices into regular shoe gear after foot surgery, typically lasting 1–3 months after the transition to full weight-bearing [22]. The postoperative STJ ROM of the patients in this study was measured at 12 weeks ( $\pm 1$  week), which was, on average, 4 weeks after the transition to full weight-bearing in normal shoe gear. This lies at the latter end of what Santini et al. described as the “three-month adaptation phase” [21]. We posit that given the specific postoperative protocol used by the primary investigator (4 weeks non-weightbearing, 4 weeks assisted weightbearing in CAM boot, followed by full weightbearing in a regular shoe gear), as well as the frequent use of ace compression bandaging during the transition periods, that postoperative edema cannot account for the significant reduction observed in STJ ROM in this patient cohort. Nevertheless, we acknowledge the influence of postoperative edema at the 12-week mark as a potential confounding factor. Methodological improvement for future studies should include measurements of STJ ROM at the 6- and 12-month marks to account for this limitation.

Measurement bias is also a limitation of our methodology as the goniometer measurements were performed by a single investigator. Future studies expanding upon our findings may consider using multiple investigators, including a score of intra-rater reliability. This would be more feasible with a prospectively designed study. Another consideration is the lack of data concerning relative pronation to supination STJ ROM in these patients. This data was collected retrospectively, with only the total STJ ROM value having been documented. Future prospective studies could investigate the relative decreases in STJ pronation versus supination, which may further elucidate the downstream effects of LCL osteotomies on STJ biomechanical function. This study did not evaluate the pre- and postoperative forefoot to rearfoot relationship. We also could not evaluate the percentage change in STJ ROM compared to the contralateral foot as only the values for the operative

foot had been recorded. Similar studies would benefit from comparing any reduction in STJ motion to an unaffected contralateral limb and excluding bilateral cases.

Various ancillary procedures were also performed in the setting of the LCL osteotomy and were not accounted for statistically, though none of these should affect the isolated open chain biomechanics of the STJ. This study did not compare the STJ ROM after other procedures that commonly cause postoperative edema. More data on STJ ROM after procedures such as ankle fusion and ankle ORIF would elucidate whether the decrease in STJ ROM observed in this study is caused by postoperative edema or due to the biomechanical mechanism discussed in this paper. Another area for future study could focus on the correlation between the amount of deformity correction and the amount of reduction in STJ ROM.

In summary, future studies should consider a more comprehensive, prospective study design to assess the overall impact of LCL on patient outcomes. Exploring the long-term effects of decreased STJ ROM after LCL is a valuable and promising avenue for future research. Longitudinal studies that assess patients' functional outcomes, gait analyses, and patient-reported measures over an extended period will provide insight into the durability of the ROM limitations and their impact on daily activities. Additionally, investigating the efficacy of interventions such as physical therapy or specific exercises in mitigating the decreased ROM and optimizing foot function would be beneficial.

## 5. Conclusions

In this cohort of 20 feet in 15 patients, a significant decrease in STJ ROM was observed after undergoing the LCL calcaneal osteotomy procedure. Surgeons should consider this impact when evaluating the procedure's outcomes and managing patient expectations. Further research is warranted to explore the long-term effects of reduced STJ motion and to investigate interventions aimed at optimizing foot function and minimizing functional limitations for patients undergoing LCL osteotomies.

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**Informed Consent Statement:** Patient consent was waived due to retrospective nature of the study.

**Data Availability Statement:** Datasets are available upon request by emailing co-author Peter Sorensen at peter.sorensen@ascension.org.

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