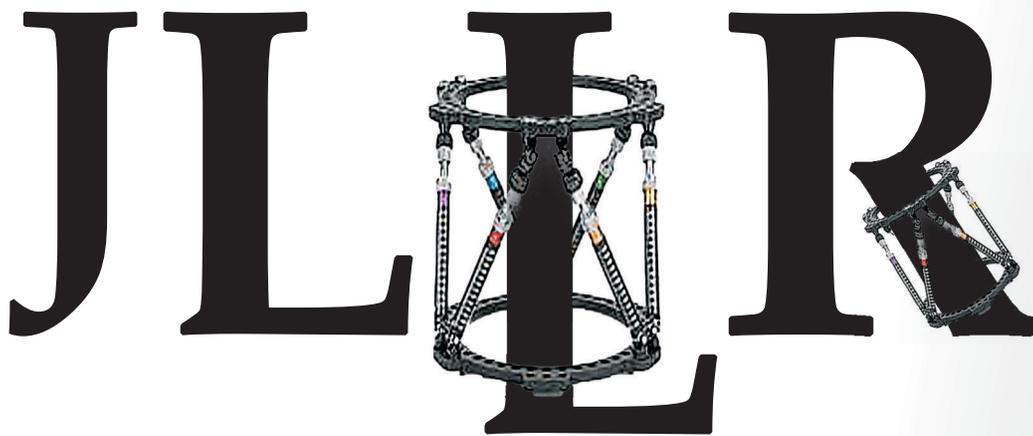


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Patient Perspectives in the Choice of Management of Leg Length Discrepancy

Abstract

Background: The traditional limb length discrepancy management algorithm dictates that patients with less than 5 centimeters (cm) of leg length discrepancy should not be offered lengthening surgery as a treatment option. With the development of intramedullary lengthening nails, the procedure for limb lengthening has become more patient friendly and reliable. This study investigated current patient preferences for management when faced with a projected final length discrepancy of less than 5 cm. **Materials and Methods:** Following IRB approval, a retrospective chart review of a single surgeon's experience with patients presenting with clinical and radiological evidence of limb length discrepancy between 2017 and 2020 was performed. Patients were excluded from the study if the final discrepancy or projected discrepancy was more than 5 cm. The same management options for the LLD were presented to each patient and their family: 1) Observation, 2) Shoe lift, 3) Epiphysiodesis/Acute shortening of the longer limb, 4) Limb lengthening of the shorter limb. **Results:** Sixty-two (62) patients met the inclusion criteria. This was comprised of 45 skeletally immature patients and 17 skeletally mature patients. Forty-four (44) patients (71% of the entire group) preferred to have the shorter limb lengthened. This represents 27 (60%) of the skeletally immature patients and all 17 (100%) of the skeletally mature patients. No patients chose acute shortening or a shoe lift as definitive management. **Conclusion:** With 71% of patients opting for a lengthening procedure, this study demonstrates that patients prefer limb lengthening over limb shortening for discrepancies less than 5 cm. With improvements in the knowledge and techniques of limb lengthening as well as better patient experience particularly with the intramedullary lengthening nails, surgeons should not feel obligated to only offer lengthening to patients with LLD > 5 cm.

Keywords: Bone lengthening, epiphysiodesis, limb length discrepancy

Introduction

Limb length discrepancy (LLD) is a common occurrence with some surveys reporting that as much as 70% of the general population may have different leg lengths.^[1-3] Three-dimensional motion analysis studies have shown that length discrepancies in the lower limb measuring as little as 5–10 mm can cause biomechanical changes during gait.^[4] Harvey *et al.* suggested that there was an increased risk of knee osteoarthritis in patients with a leg length discrepancy as little as 5 mm.^[5] Other studies have suggested a relationship between length discrepancy of the lower limbs and low back pain.^[6-8]

While there are differing recommendations for the exact management of leg length discrepancy in the literature, the consensus

opinion dictates that for discrepancies <2–2.5 cm, no treatment is necessary. For discrepancies between 2 cm and 5 cm, several management strategies have been proposed including shoe lifts, epiphysiodesis, or acute shortening.^[9-13] For leg length discrepancies >5 cm, limb lengthening has been recommended as the preferred method of management.^[14]

The origin of declaring this arbitrary amount of leg length discrepancy as the threshold between lengthening and shortening is unclear. In the past, it appears limb lengthening was reserved for only the larger discrepancies at least partly because the method of achieving length was so arduous. At the time, the management paradigm was being developed (1980s); lengthening was primarily performed by the Wagner technique, and the Ilizarov circular external fixator experience was still in its infancy in the western world. Each method had

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a high complication rate, and the patient experience with the external devices was less than ideal.^[15,16] However, with the advent of the intramedullary lengthening nails, the limb lengthening experience has become much more patient friendly and reliable.^[17] As the ability to lengthen has become more comfortable for the patient, it is conceivable that this option may become more desirable as a management option for discrepancies <5 cm.

The purpose of this study was to review the current patient preferences regarding the pattern of management of LLD measuring <5 cm.

Methods

This was a retrospective chart review of a single surgeon's experience. Following IRB approval, all patients who were seen in the Center for Limb Lengthening and Reconstruction with clinical evidence of length discrepancy of the lower limbs between December 2016 and August 2020 were eligible for inclusion in the review. Limb length discrepancy was confirmed and quantified by radiological measurements made from full-length standing X-rays of patients taken according to the method described by Paley.^[18] They were excluded from the study if the discrepancy or projected discrepancy was >5 cm. Patients were grouped according to the management method chosen and age (16 years or younger vs. older than 16 years).

Surgical options for management of LLD were either lengthening of the shortened bone, acute shortening of the longer bone, or epiphysiodesis of the longer bone. All patients were evaluated by the senior author and were presented the same four options for the management of the LLD as follows:

1. No treatment
2. Shoe lift
3. Limb shortening procedure (epiphysiodesis for skeletally immature and acute shortening for skeletally mature patients)
4. Limb lengthening using an intramedullary lengthening nail or circular external fixator.

The advantages and disadvantages of each option were explained, and each patient was allowed to choose his/her own preference of treatment.

As a part of our standard informed consent process, the details of the various options of treatment as well as the potential complications were discussed with each patient/parent before a choice of treatment was made. Lengthening was achieved using an intramedullary lengthening nail or a circular external fixator, while permanent epiphysiodesis was performed using the percutaneous drill/ curette technique.

Statistical analysis was done using GraphPad Prism version 8.2.0. Continuous variables were expressed as means with variance represented by standard deviation.

Categorical variables were expressed as percentages. The *t*-test with Welch's correction was used for comparison of means. For multiple comparison of means, one-way analysis of variance with Tukey's *post hoc* test was used. A $P < 0.05$ was determined to be significant for all statistical tests.

Results

A total of 91 participants were reviewed during the study period. This included 73 patients who had lengthening and 18 patients who had epiphysiodesis. Twenty-nine patients had >5 cm of LLD and were thus excluded from the final analysis. Sixty-two patients met the inclusion criteria with a mean LLD of 3.1 ± 0.9 cm (range 1.7–5 cm). Of the 62 patients, 44 (71%) patients chose the lengthening surgery and 18 (29%) patients chose epiphysiodesis. No patients chose acute shortening or shoe lift as the definitive treatment option. The mean age at surgery was 16.1 ± 6 years (9–45 years). There were 33 male and 29 female patients. The etiology of the discrepancy was congenital in 32 cases, developmental in four, posttraumatic in nine (including one post radiation growth arrest), metabolic in one, neurologic in eight, postinfective in four, and neoplastic in four cases.

There was a statistically significant difference ($P = 0.0139$) in the mean LLD for the lengthening group (3.28 ± 0.9 cm, range 2–5 cm) and for the epiphysiodesis group (2.71 ± 0.7 cm, range 1.7–4 cm) [Figure 1]. Discrepancy was localized to the femur in 47 cases, to the tibia in 13 cases, and was a combination of both bones in two cases.

The mean age for the lengthening group was 17.4 ± 6.6 years (9–45 years). There were 22 males and 22 females in this group. Length discrepancy was present in the femur in 38 cases and in the tibia in six cases. The mean age for the epiphysiodesis group was 12.9 ± 1.6 years (10–15 years). There were 11 male and

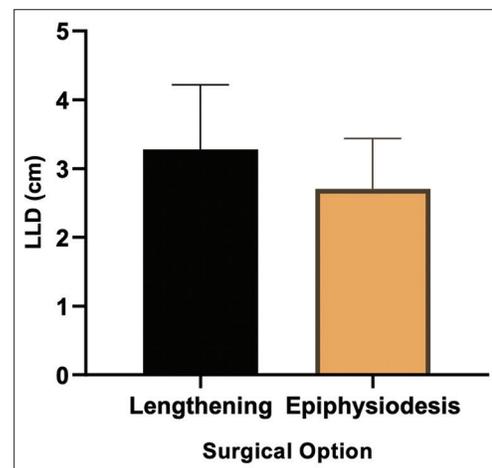


Figure 1: Bar chart showing mean limb length discrepancy in both groups of patients

seven female patients. This group included seven patients who had proximal tibial epiphysiodesis, nine patients who had distal femoral epiphysiodesis, and two patients who had combined (proximal tibia and distal femur) epiphysiodesis. All but five patients in the lengthening group had this achieved with an intramedullary PRECICE nail. These five patients all had tibial lengthening using a circular fixator: three required simultaneous multiplanar deformity correction, one patient was skeletally immature precluding the insertion of the intramedullary lengthening nail, and one patient chose the external fixator to avoid the restricted weight-bearing necessary with the use of the intramedullary lengthening nail.

Patients were further subdivided into groups based on the age and surgical option for achieving limb length equalization [Table 1].

For patients aged 16 years or younger, there was a statistically significant difference between the mean LLD in the lengthening group of patients and those patients who underwent epiphysiodesis ($P = 0.0026$) [Figure 2a]. We also noted a significant difference ($P = 0.0085$) in the mean LLD between both lengthening group of patients (16 years or younger vs. older than 16 years) [Figure 2b]. We did not have any patients over the age of 16 opting for acute shortening of the longer limb as a treatment option.

Discussion

In this study, the pattern of patient preference for the management of LLD <5 cm was evaluated. The findings

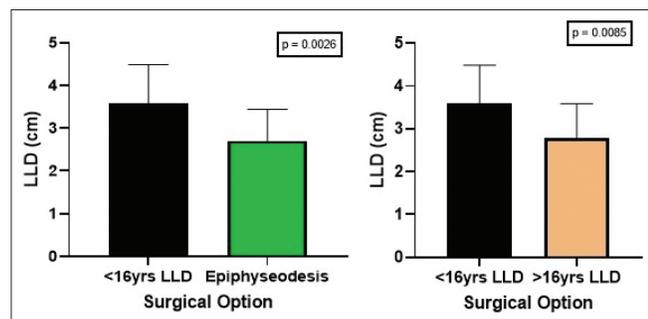


Figure 2: Bar charts showing mean limb length discrepancy (LLD) comparisons between different subgroups of patients. A. Comparison between patients aged 16 years or younger who had lengthening surgery and patients 16 years or younger who had epiphysiodesis. B. Comparison between patients aged 16 years and younger who had lengthening, and patients aged 16 years and older who had lengthening

revealed that 60% of skeletally immature patients prefer lengthening to epiphysiodesis. Among the skeletally mature patients, 100% opted to have lengthening rather than acute shortening.

The current LLD management paradigm has been in place for more than 30 years. Moseley suggested that LLD of <2 cm requires no treatment while recommending epiphysiodesis or a shoe lift for discrepancies of 2–6 cm. For larger discrepancies, he advocated lengthening surgery if the discrepancy was between 6 and 15 cm and amputation with prosthetic fitting for LLD larger than 15 cm.^[9] Menelaus recommended observation for discrepancies <2.5 cm, a shoe lift for discrepancies of 2.5–4 cm, epiphysiodesis or acute shortening osteotomies for discrepancies of 2.5–10 cm, lengthening for discrepancies >7.5 cm, and a combination of shortening of the longer side and lengthening of the shorter side for discrepancies >15 cm.^[10] Reid and Smith classified LLD on the basis of increasing magnitude into mild, moderate, and severe types.^[19] They suggested that mild LLD (<3 cm) required no treatment or nonsurgical management, while severe LLD (>6 cm) should be managed surgically. The choice of management of moderate LLD (3–6 cm) was thought best decision based on the specific needs of the patient.

Depending on the size of the discrepancy and the age of the patient, there are several methods available to manage LLD. These include shoe lifts, acute shortening of the longer contralateral limb,^[20–22] prematurely stopping growth in the longer limb, or lengthening the shortened limb.^[13,23] While the traditional management paradigm only recommends limb lengthening for discrepancies >5 cm, 71% of our patients preferred lengthening rather than a shortening procedure for discrepancies <5 cm. When the results were further subdivided by skeletal maturity, 60% of skeletally immature patients chose lengthening over epiphysiodesis and 100% of the skeletally mature patients chose lengthening over acute shortening. These results may reflect several considerations. While epiphysiodesis is an outpatient surgery with a shorter recovery time than lengthening, the relative inaccuracy of the final result and the need to operate on the “good” limb are deterrents to patients and their families. With the advent of intramedullary lengthening nails, the improved patient comfort combined with the accurate and reliable results

Table 1: Summary statistics for the subgroups

	<16 years (n=45)		>16 years (n=17)	P
	LL (n=27)	Epiphysodesis (n=18)**	LL (n=17)	
Age (years)	14±1.8	12.9±1.6	22.7±8	
Age range	9-16	10-15	17-45	
LLD (cm)	3.6±0.9	2.71±0.7	2.8±0.8	0.0010
LLD (range)	2.3-5	1.7-4	2-5	

**All patients who had epiphysiodesis were <16 years old. LL: Limb lengthening, LLD: Limb length discrepancy

has caused more patients to choose this option despite the longer healing time. Many patients prefer to preserve their maximum height which may have potential psychological and financial effects. The fact that none of the skeletally mature patients chose acute shortening seems to validate this assumption. In addition, epiphysiodesis can only be performed in skeletally immature individuals and only at a certain time period. Limb lengthening allows the patient to schedule the surgery at their convenience without any time pressure to make a decision. For the patients that did choose epiphysiodesis, however, the decreased cost and the shorter recovery time for return to sport may have been the prevalent reasons for this choice.

For patients younger than 16 years old, those who chose epiphysiodesis were noted to have a significantly smaller amount of LLD in comparison to those who chose lengthening ($P = 0.0026$). We also noted a significantly smaller amount of LLD in patients older than 16 years who chose lengthening in comparison to those younger than 16 years who chose lengthening ($P = 0.0085$). While the reasons for these observations are not immediately obvious, we speculate that patients may be more willing to accept the option of epiphysiodesis if the projected discrepancy is not deemed “too much.” Furthermore, we believe that the observed difference in mean LLD between both groups of patients who underwent lengthening surgery (<16 years old vs. older than 16 years old) is a reflection of the absence of epiphysiodesis as a treatment option in skeletally mature patients. This is reflected by the fact that no skeletally mature patients chose acute shortening as a management option. We believe that a determination of the reasons for these observations would be best addressed by a prospectively designed study looking at factors that determine choice of treatment from a patient perspective.

There are multiple limitations of this study. First, it is a retrospective study from a single institution with a relatively small sample size. A prospective, multicenter study will need to be conducted to corroborate these findings. Second, since every preoperative discussion was conducted by the same surgeon, a concerted effort was made to present a consistent explanation of the management options to each of the patients and their families. However, it was impossible to eliminate all potential unconscious bias for the patient and surgeon regarding the ultimate choice of management. Third, this retrospective review was designed to highlight patient choices regarding surgical options for managing LLD. It did not necessarily evaluate the basis for the choice patients made. We believe that this is best accomplished by a follow-up, prospectively designed study focusing on the specific factors that influence the patient decision-making process. Finally, this study did not look at treatment outcomes as well as patient satisfaction studies to determine if there was any difference between lengthening and epiphysiodesis. Since this may inform the choice of treatment from both a physician and a patient

perspective, we believe it will be a valuable addition to future prospectively designed studies on this topic.

Conclusions

The results of this study demonstrate that, among both skeletally mature and immature patients, lengthening of the shorter limb rather than procedures that shorten or arrest growth of the longer limb is the preferred treatment option for patients with LLD <5 cm.

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Conflicts of interest

There are no conflicts of interest.

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