Effectiveness of different minimally invasive epiphysiodesis techniques in the management of pediatric leg length discrepancies: a systematic review protocol

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Review question/objective: The objective of this review is to synthesize the best available evidence on the use of percutaneous epiphysiodesis for the management of pediatric leg length discrepancies (LLDs). The effectiveness of four different percutaneous epiphysiodesis techniques will be compared, including transphyseal screws (percutaneous epiphysiodesis using transphyseal screws), physeal drilling and curettage, physeal stapling and guided growth with eight-Plates.

Specific review questions to be addressed include:

- What method of percutaneous epiphysiodesis is most effective at achieving growth arrest and correcting a LLD in terms of:
  - Percentage of correction
  - Rate of correction
- Are the postoperative complication profiles different for each method of percutaneous epiphysiodesis in terms of:
  - Angular deformity
  - Failure of growth arrest
  - Infection
  - Re-operation/intervention
- How do children respond to each technique, specifically:
  - How quickly are they able to leave hospital?
  - How quickly do they return to activities of daily living such as schooling?

Keywords: Epiphysiodesis; leg length discrepancy; leg length inequality; minimally invasive; pediatric

Background

Leg length discrepancies (LLDs) are a common phenomenon in the general community with 23% of the population having a discrepancy of 1 cm or more.1,2 The causes of LLDs can be subdivided into congenital disorders or acquired physeal disruption. Congenital LLDs include disorders such as hemihypertrophy/hemihyperplasia, skeletal dysplasia, developmental dysplasia of the hip, unilateral club foot and paralytic disorders, whereas acquired physeal disruption is commonly secondary to infection, trauma or tumors.2,3

Little functional impact is appreciated in LLDs of less than 2 cm.4 Gait asymmetry or altered gait kinetics develops with an inequality of 2 cm or more,5,7 the larger the inequality the greater the mechanical disadvantage.7 If a LLD of greater than 2 cm is not addressed, the individuals have a greater propensity to develop back pain, structural scoliosis, equinus contracture of the ankle, osteoarthritis of the hip or knee and generally reduced quality of life.2,8,9

A number of different methods have been developed in an attempt to accurately predict the extent of LLDs at skeletal maturity. This is important for determining the most appropriate timing of an intervention as well as identifying the treatment best suited to the child. A discrepancy of less than 2 cm will rarely require treatment and, if it does,
Epiphysiodesis is the process of surgically halting the growth of a long bone prematurely through manipulating its physis. It is a concept that was first described in 1933 by Phemister.\(^2\)\(^3\) It can be used to restrict the growth of part of a physis, which is of benefit in the management of angular deformities, or inhibit the growth of an entire physis when managing pure LLDs (shortening the longer limb). Some epiphysiodesis techniques permanently cease the growth of the physis, whereas other more recently developed techniques are able to transiently modulate the growth of that bone, which hypothetically results in greater control and flexibility for correcting LLDs.

The Phemister technique involves the excision of a 1-cm rectangular bone block of cortical bone containing the peripheral physis and adjacent metaphyseal and epiphyseal bone from the medial and lateral aspects of the physis. The physis is then curetted and the bone blocks reinserted after being rotated 180°, thus creating a bone bridge bypassing the growth plate.\(^2\)\(^2\) This technique is open and results in permanent cessation of physisal growth. Since 1933, there have been multiple new techniques of epiphysiodesis proposed, most of which are percutaneous or minimally invasive.\(^2\)\(^3\) Compared with the Phemister technique, these percutaneous approaches have been shown to have similar efficacies with similar complication rates and shorter hospital stays and for these reasons the Phemister technique has become obsolete.\(^1\)\(^4\)\(^2\)\(^4\)\(^2\)\(^6\) Therefore, this systematic review will focus on the effectiveness of percutaneous techniques, which are described below.

Canale and Christian,\(^2\)\(^7\) Ogilvie and King,\(^2\)\(^8\) and Timperlake et al.\(^2\)\(^9\) have focused on permanent percutaneous methods of epiphysiodesis, using image intensification, under which the physis is ablated or destroyed with drills and curettes through small medial and lateral incisions. In 1998, Metaizeau et al.\(^2\)\(^1\) described a further permanent method of epiphysiodesis using two transphyseal screws obliquely placed across the physis forming a cross in both the coronal and sagittal planes.\(^3\)\(^0\) This concept is thought to work by applying compressive forces through the physis.

Blount and Clarke\(^3\)\(^1\) proposed the first reversible method of epiphysiodesis using three staples on each side of the physis. One staple spike would be placed in the metaphysis and the other in the epiphysis.
There have been a number of reported complications with this form of reversible epiphysiodesis, including an unpredictable pattern of growth following the removal of staples, and the development of angular deformities. In 2007, Stevens introduced an alternative reversible technique, which relied on a tension band construct using eight-Plates. This concept was initially used for the correction of angular deformities but has since been modified to treat moderate LLDs. The use of eight-Plates for the correction of LLDs to date is quite controversial with Stewart et al claiming they are not effective for epiphysiodesis about the knee. Their study found that the eight-Plates achieved suboptimal correction when compared with physeal ablation. However, following the publication of their study commentaries including that by Kaymaz and Komurcu have questioned the study’s methodology.

The primary goal of all epiphysiodesis procedures is to reduce the disability associated with LLDs by reducing the discrepancy to less than 2 cm, thus eliminating or at least minimizing significant gait abnormalities and abnormal loading on joints. Unfortunately, like all surgical procedures, epiphysiodesis is not complication free. Recognized complications include articular effusions, postoperative hematomas, superficial wound infections, postoperative exostosis, iatrogenic fractures and failure to achieve growth arrest. A handful of studies have shown that the complication rates between open and percutaneous techniques are similar. However, comparative efficacy of different percutaneous methods of epiphysiodesis such as transphyseal screws (percutaneous epiphysiodesis using transphyseal screws), drilling with curettage, physeal stapling and guided growth with eight-Plates have been less well established. Independently, all four of these techniques of epiphysiodesis have been reported to yield low rates of complications and obtain satisfactory growth arrest.

The aim of this review is to assess whether one form of percutaneous epiphysiodesis is more effective than another in correcting moderate LLDs. The review will aim to compare the four listed interventions. Studies that have evaluated two or more of the interventions and studies that have investigated only a single intervention will be considered for inclusion.

**Inclusion criteria**

**Types of participants**

This review will consider studies that include:

- Individuals, both men and women, with open physes. (It is likely only patients under the age of 16 will be included, though because of the variability in growing and physeal closure timing no participants will be excluded based on age.)
- Predicted LLD at skeletal maturity of between 2 cm and 5 cm.

**Exclusion criteria:**

- Predicted LLDs at skeletal maturity of greater than 5 cm as percutaneous epiphysiodesis should not be first-line treatment option.

**Types of intervention(s)**

This review will consider studies that evaluate the use of different techniques for percutaneous epiphysiodesis. The specific techniques of interest include:

- Transphyseal screws (percutaneous epiphysiodesis using transphyseal screws)
- Physeal drilling and curettage
- Physeal stapling
- Guided growth with eight-Plates.

The review will aim to compare the four listed interventions. Studies that have evaluated two or more of the interventions and studies that have investigated only a single intervention will be considered for inclusion.

**Outcomes**

This review will consider studies that include the following outcome measures:

**Primary outcomes**

- Absolute LLD (measured in centimeters) at skeletal maturity (measurements to be taken from the anterior superior iliac spine to the medial malleolus)
- Rate of correction
- Percentage of correction relative to desired correction
- Incidence of long-term complications such as:
  - Failure of growth plate arrest
  - Failure to achieve adequate reduction in LLD (≤2 cm LLDs)
  - Incidence of angular deformities
- Hardware failure – such as breakage of physeal staples.

Secondary outcomes
- Incidence of acute complications such as:
  - Postoperative infection
  - Unplanned return to theatre
  - Hematomas/effusions large enough to impact of postoperative recovery
- Patient’s ability to return to preoperative function, including:
  - Length of time taken for patient to return to school
  - Length of time taken for patient to return to sport
  - Knee range of motion
- Length of hospital stay.

Types of studies
Priority will be given to higher evidence-level study designs, first considering randomized controlled trials. However, in the absence of randomized controlled trials, this review will consider both experimental and epidemiological study designs, including non-randomized controlled trials, quasi-experimental studies, before and after studies, prospective and retrospective cohort studies, case control studies and analytical cross-sectional studies for inclusion. This review will also consider descriptive epidemiological study designs, including case series and descriptive cross-sectional studies for inclusion. Individual case reports will be excluded.

Search strategy
The search strategy aims to find both published and unpublished studies. A three-step search strategy will be utilized in this review. An initial limited search of PubMed will be undertaken followed by analysis of the text words contained in the title and abstract, and the index terms used to describe articles. A second search using all identified keywords and index terms will then be undertaken across all included databases. Third, the reference list of all identified reports and articles will be searched for additional studies. All studies published in English, even those translated from a different primary language, will be considered for inclusion in this review. Articles published from 1949 onward will be considered for inclusion as this is when percutaneous epiphysiodesis was first used clinically.

The databases to be searched include:
- PubMed
- Embase
- The Cochrane Central Register of Controlled Trials
- Web of Knowledge
- Scopus.

Grey literature will be searched through the following sources:
- Scirus
- Mednar
- ProQuest Theses and Dissertations
- Grey Source
- Index to Theses
- Libraries Australia.

Articles presented at conferences or meetings hosted by State or National Orthopedic Associations, available through the relevant association website or on request, will also be considered for inclusion.

Initial keywords to be used will be:
“leg length inequality” [MH] OR “leg length discrepancy” [tw]
AND
Child [MH] OR pediatric [tw] OR paediatric [tw]
AND

Assessment of methodological quality
Articles selected for retrieval will be assessed by two independent reviewers for methodological validity prior to inclusion in the review using standardized critical appraisal instruments from the Joanna Briggs Institute Meta-Analysis of Statistics Assessment and Review Instrument (JBI-MAStARI) (Appendix I). Any disagreements that arise between the reviewers will be resolved through discussion or with a third reviewer.

Data extraction
Data will be extracted from articles included in the review using the standardized data extraction tool from JBI-MAStARI (Appendix II). The data
extracted will include specific details about the interventions, populations, study methods and outcomes of significance to the review question and specific objectives. The authors of the included studies will be contacted if important data that is relevant to the review is missing in the published articles.

Data synthesis
Quantitative data will, wherever possible, be pooled in statistical meta-analysis using JBI-MAStARI. All results will be subject to double data entry. Effect sizes expressed as odds ratio (for categorical data) and weighted mean differences (for continuous data) and their 95% confidence intervals will be calculated for analysis. Heterogeneity will be statistically assessed using the standard $\chi^2$ and also explored using subgroup analyses based on the different study designs included in this review. Where statistical pooling is not possible the findings will be presented in narrative form, including tables and figures to aid in data presentation, wherever appropriate.

Acknowledgements
This systematic review forms partial submission for the degree award of Master of Clinical Science for the first author.

References
### Appendix I: Appraisal instruments

**MASTARI appraisal instrument**

**JBI Critical Appraisal Checklist for Randomised Control / Pseudo-randomised Trial**

<table>
<thead>
<tr>
<th>Question</th>
<th>Yes</th>
<th>No</th>
<th>Unclear</th>
<th>Not Applicable</th>
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<tr>
<td>1. Was the assignment to treatment groups truly random?</td>
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<td>2. Were participants blinded to treatment allocation?</td>
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<td>3. Was allocation to treatment groups concealed from the allocator?</td>
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<td>4. Were the outcomes of people who withdrew described and included in the analysis?</td>
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<td>5. Were those assessing outcomes blind to the treatment allocation?</td>
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<td>6. Were the control and treatment groups comparable at entry?</td>
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<td>7. Were groups treated identically other than for the named interventions</td>
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<td>8. Were outcomes measured in the same way for all groups?</td>
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<td>9. Were outcomes measured in a reliable way?</td>
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<td>10. Was appropriate statistical analysis used?</td>
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Overall appraisal: Include □ Exclude □ Seek further info. □

Comments (Including reason for exclusion)
JBI Critical Appraisal Checklist for Descriptive / Case Series

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<tr>
<th>Question</th>
<th>Yes</th>
<th>No</th>
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<tbody>
<tr>
<td>1. Was study based on a random or pseudo-random sample?</td>
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<td>2. Were the criteria for inclusion in the sample clearly defined?</td>
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<td>3. Were confounding factors identified and strategies to deal with them stated?</td>
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<td>4. Were outcomes assessed using objective criteria?</td>
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<td>5. If comparisons are being made, was there sufficient descriptions of the groups?</td>
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<td>6. Was follow up carried out over a sufficient time period?</td>
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<td>7. Were the outcomes of people who withdrew described and included in the analysis?</td>
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Overall appraisal: Include □ Exclude □ Seek further info □

Comments (Including reason for exclusion)
**JBI Critical Appraisal Checklist for Comparable Cohort/ Case Control**

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<tr>
<th>1. Is sample representative of patients in the population as a whole?</th>
<th>Yes</th>
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<td>2. Are the patients at a similar point in the course of their condition/illness?</td>
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<td>3. Has bias been minimised in relation to selection of cases and of controls?</td>
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<td>4. Are confounding factors identified and strategies to deal with them stated?</td>
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Overall appraisal: Include □ Exclude □ Seek further info. □

Comments (Including reason for exclusion)

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Appendix II: Data extraction instruments

MAStARI data extraction instrument

**JBI Data Extraction Form for Experimental / Observational Studies**

Reviewer ___________________________ Date ___________________________

Author ___________________________ Year ___________________________

Journal ___________________________ Record Number __________________

**Study Method**

- [ ] RCT
- [ ] Quasi-RCT
- [ ] Longitudinal
- [ ] Retrospective
- [ ] Observational
- [ ] Other

**Participants**

Setting

Population

**Sample size**

- Group A ________________
- Group B ________________

**Interventions**

- Intervention A

- Intervention B

**Authors Conclusions:**

**Reviewers Conclusions:**
**Study results**

**Dichotomous data**

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<tr>
<th>Outcome</th>
<th>Intervention 1 ( ) number / total number</th>
<th>Intervention 2 ( ) number / total number</th>
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**Continuous data**

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<th>Outcome</th>
<th>Intervention 1 ( ) number / total number</th>
<th>Intervention 2 ( ) number / total number</th>
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