

**Limb length discrepancy after
limb salvage procedures in
skeletally immature
patients**

Essay

*submitted for partial fulfillment of master degree in orthopaedic
surgery*

**Presented by
Baher Atef Kaissar
M.B.B.CH**

**Under supervision of
Dr. Atef Abd El-Aziz Hanna**
*Professor of orthopaedic surgery
Faculty of medicine
Cairo University*

Dr. Walid Atef Ebeid
*Professor of orthopaedic surgery
Faculty of medicine
Cairo University*

2009

Abstract

This would obviate the need for surgery on the uninvolved extremity as well as revision surgery to the affected limb. Modular expandable prostheses have been in use as early as 1976. Recently, a non-invasive expandable prosthesis has been developed. Lengthening procedures are done as outpatient procedures in the radiology department.

Segmental limb resection is becoming a practical alternative to limb ablation in tumor surgery. The addition of van Nes rotationplasty to provide a pseudo knee joint has been found to be a practical, functional addition facilitating prosthesis use. The modified van Nes rotationplasty in tumor surgery is not a truly limb-saving procedure but rather a limb-sparing procedure: it does save the limb but spares some parts of it for functional benefit.

Key words

Limb length discrepancy after
limb salvage procedures in

Acknowledgement

First and above all, I want to thank God whom without his help and blessings I wouldn't have finished this work.

I would like to express my deepest gratitude, appreciation and sincere thanks to **Professor Dr. Atef Abd ElAziz Zaki Hanna**, professor of orthopaedic surgery, Cairo University for his supervision, generous support and sincere encouragement not only during the course of this study but through out my career in general.

No words also can express my deepest gratitude, appreciation and sincere thanks **Professor Dr. Walid Atef Ebeid**, professor of orthopaedic surgery, Cairo University for his kind supervision, valuable guidance and useful remarks that made this work accomplished.

Last but not least, I would like to express my deep respect, appreciation and gratitude to my wife and my parents for their love, understanding and assistance.

List of figures

Fig 1:	Zonal structure of the growth plate.	3
Fig 2:	Greulich – Pyle Atlas	12
Fig 3:	Position of patient in bed	14
Fig 4:	Heel level and length discrepancy	14
Fig 5:	Determining if the shortening is due to pathology above or below trochanters	15
Fig 6:	Segment responsible for shortening	15
Fig 7:	measure from the anterior superior iliac spine to the tip of the medial malleolus	16
Fig 8:	the other limb must be put in the same position	16
Fig 9:	Measuring the tibial length	16
Fig 10:	Measuring femoral shaft shortening.	16
Fig 11:	measuring the distance from the xiphisternum and each medial malleolus	17
Fig 12:	Examine the patient while standing.	17
Fig 13:	Patient stand on graduated blocks	18
Fig 14:	Graduated blocks used to level the pelvis for estimating leg length discrepancy.	20
Fig 15:	Technique of teleoroentgenography.	21
Fig 16:	Technique of orthoroentgenography.	22
Fig 17:	Technique of X-ray scanography.	22
Fig 18:	Average total length of the femur and tibia with 1 and 2 SD range for girls and boys	3
Fig 19:	Moseley's Straight line graph	3

Fig 20: Phemister technique of open Epiphysiodesis (cubes are rotated 90)	5
Fig 21: Phemister technique of open Epiphysiodesis(cubes are rotated 180)	5
Fig 22: Proper technique of staple insertion.	5
Fig 23: Percutaneous epiphysiodesis of the knee joint.	6
Fig 24: Scheme of insertion of cannulated percutaneous screws epiphysiodesis (PETS)	6
Fig 25: The Orthofix limb lengthener for callotasis of the femur.	6
Fig 26: The technique of corticotomy in callotasis.	6
Fig 27: Roentgenographic sequence of bony callus formation during lengthening process.	6
Fig 28: (A) Roentgenographic appearance on the day of fixator removal compared with (B) remodeling of the newly formed bone segment.	7
Fig 29: Tibial lengthening with the Ilizarov device.	7
Fig 30: The Ilizarov frame	7
Fig 31: The monolateral external fixators	7
Fig 32: The EBI external fixators	7
Fig 33: Taylor Spatial Frame fixators	7
Fig 34: The universal joints are passive and do not require clamping.	7
Fig 35: Changing strut lengths only, the Taylor Spatial Frame fixator can adjusted to mimic or mirror skeletal deformities.	7
Fig 36: The internal design of the ISKD	8
Fig 37: The device will lengthen with rotational displacement as small as and up to 9° of rotational oscillation.	8
Fig 38: Intramedullary Skeletal Kinetic Distractor (ISKD)	8
Fig 39: Radiographs are obtained at each visit to confirm the amount lengthening and to monitor the progression of bone consolidation.	8
Fig 40: The Albizzia nail	8

Fig 41: Patient with the internal nail albezzia the x-ray is taken approx.10 d after the surgery.	9
Fig 42: The x-ray is taken approx. 6 months after the surgery.	9
Fig 43: The Fitbone motorized lengthening device.	9
Fig 44: Modular segmental expandable prosthesis (unassembled)	9
Fig 45: Modular segmental expandable prosthesis (assembled)	9
Fig 46: Modular segmental expandable prosthesis inserted in the knee.	9
Fig 47: Expandable prosthesis with automatic elongation mechanism: ratc mechanism	10
Fig 48: Intra-operative fluoroscopic view of the knee	10
Fig 49: Schematic drawing of Howmedica device.	10
Fig 50: The non-invasive distal femoral expandable endoprosthesis	10
Fig 51: Section through the femoral component of the non-invasive di: femoral expandable endoprosthesis.	10
Fig 52: A representation of the endoprosthesis in an external drive unit.	10
Fig 53: An 11 years old Patient activating an electromagnetic devi radiographs showing the prosthesis immediate postoperative and follow up 30 months	106
Fig 54: Phenix expandable prosthesis inserted in the knee.	10
Fig 55: A lateral rendering shows a custom Phenix femoral prosthesis.	10
Fig 56: Postoperative view shows the hinge and expansion mechanism of Phenix prosthesis.	11
Fig 57: An AP radiograph shows the expandable portion of the Phe prosthesis.	11
Fig 58: Patient activating an electromagnetic device to correct leg-len discrepancy.	11
Fig 59: Schematic view of the expandable prosthesis Mutars Xpand.	11

منسَّق: إلى اليسار، بعد: ٠ سم،
تعداد رقمي + المستوى: ١ + نمط
الترقيم: ١، ٢، ٣ ... بدء الترقيم
ب: ١ + محاذة: أسير + محاذة
عند: ٠,٦٣ سم + علامة جدولة
بعد: ١,٢٧ سم + مسافة بادئة:
١,٢٧ سم

محذوف:

Fig 60: Photograph shows a retrieved specimen with a fracture through nonexpendable portion of the device.	11
Fig 61: Subluxation of the hip joint in young children who have proximal femur endoprostheses.	12
Fig 62: Rotationplasty type AI for lesion in distal femur.	12
Fig 63: Rotationplasty type AII for lesion in proximal tibia	12
Fig 64: Rotationplasty type BI for lesion in proximal femur	12
Fig 65: Rotationplasty type BII for lesion in proximal femur with involvement of hip joint and contiguous soft tissue.	12
Fig 66: Rotationplasty type BIII for lesion in midfemur.	12
Fig 67: A rhomboid skin incision	12
Fig 68: preparation of main vessels and nerves	12
Fig 69: Condition after resection of the distal femur and the knee joint	12
Fig 70: Plate osteosynthesis of tibia and femur	13
Fig 71: Early mobilization with a Whitman's plaster and below-knee prosthesis- preparation of main vessels and nerves.	13
Fig 72: Final prosthesis with thigh socket and side hinges b Prosthesis with thigh socket for swimming and exercising	13
Fig 73: The performances obtained are every bit as good as those of patients with below-knee amputations	13

List of tables

Table 1 : Leg Length Data for a 9 years and 3 months old girl	32
Table 2 : The Arithmetic method	33
Table 3 : The growth remaining method	34
Table 4 : Lower limb multiplier for boys	43
Table 5 : Lower limb multiplier for girls	43
Table 6 : Steps for the Multiplier method	44
Table 7 : Error in predicting bone length discrepancy of untreated femur and tibia at maturity using the multiplier method	47
Table 8 : Comparison of error between multiplier and Moseley methods in predicting limb length discrepancy at maturity after Epiphysiodesis	4
Table 9 : Treatment options for lower limb length discrepancy	4

Contents

1. Introduction
2. Chapter 1: anatomy and physiology of bone growth. 1
 - The structure of the growth plate
 - Maturation of the growth plate
3. Chapter 2: assessment and prediction of lower limb length discrepancy 13
 - Clinical assessment
 - Radiological assessment
 - Phases of analysis
 - Data collection
 - Assessment of past growth
 - Prediction of future growth
 - Prediction of the effect of surgery
 - The arithmetic method
 - The growth remaining method
 - Moseley straight line graph
 - The multiplier method
4. Chapter 3: treatment and prevention of lower limb length discrepancy 48
 - Epiphysiodesis
 - Distraction osteogenesis

External fixators

Intramedullary lengthening

- Expandable prosthesis
- Rotationplasty

5. Summary	133
6. References	136
7. Arabic summary	145

Introduction

Limb length discrepancy is a recognized complication of tumors in skeletal immature patients.

Some tumors cause limb length discrepancy merely by its presence as multiple exostosis and Ollier's disease which is characterized by severe deformity of extremities and retarded growth because of multiple enchondromas.

The most common malignant bone tumors, osteosarcoma and Ewing sarcoma cause limb length discrepancy as sequelae of their management. They commonly occur in the skeletally immature patients. Sacrifice of major growth plates during resection is usually done.

Fixed length reconstruction of the limb in a skeletally immature child will result in significant limb length inequality as growth progresses.

In the lower extremity, tumors about the knee, including the distal femur and proximal tibia, usually present the dilemma of whether limb salvage by arthrodesis, osteoarticular allograft, or endoprosthetic replacement would result in a significant limb length inequality and hence amputation of the extremity would be a preferable procedure.

However, children with lower limb inequality have been managed by bone lengthening using callus distraction according to growth predicting curves.

The techniques of rotationplasty and an expandable endoprosthesis have been successfully used for treating skeletally immature patients with osteosarcoma of distal femur.

With regard to survival and function, the results obtained with these innovative methods are favorable compared with those of a high above knee amputation.

The **aim of the work** is to analyze the different methods of prevention and overcoming lower limb discrepancies in skeletally immature patients after limb salvage surgery.

CHAPTER 1

ANATOMY AND PHYSIOLOGY OF BONE GROWTH.

Contents

8. Introduction

9. Chapter 1: anatomy and physiology of bone growth. 1
- The structure of the growth plate
 - Maturation of the growth plate

10. Chapter 2: assessment and prediction of lower limb length discrepancy 13

- Clinical assessment
- Radiological assessment
- Phases of analysis
- Data collection
 - Assessment of past growth
 - Prediction of future growth
 - Prediction of the effect of surgery
- The arithmetic method
- The growth remaining method
- Moseley straight line graph