The Comparison between Computer-Assisted Hexapods and Ilizarov Apparatus in Gradual Tibial Deformity Correction: A Preliminary Study

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Background: *The Hexagonal external fixator (Hexapods) is known to have the ability to correct complex multi-planar deformities faster than the Ilizarov apparatus. However, the difficulty of achieving deformity correction by Hexapods seems to limit its popularity.*

Objective: *This study aims to compare the advantages and disadvantages of Hexapods and Ilizarov in the gradual correction of complex tibial deformities.*

Material and Method: *A retrospective review was performed in patients with complex tibial deformities treated with Hexapods or with Ilizarov apparatus from 2000 to 2014. Magnitude of deformity, length of time in Hexapods or Ilizarov apparatus, Lengthening Index, and complications were recorded. Statistical analysis was used to compare the two methods.*

Results: *Six patients were treated with Ilizarov apparatus and seven patients were treated with Hexapods. Patients in Hexapods group had more coronal plane angulation before surgery than in the Ilizarov group with statistical significance (p = 0.02). The differences of the sagittal and the axial plane angulations were not statistically significant. The difference of leg length was also not statistically significant. After completion of treatment, no statistical significance of residual deformities was found between the two methods. Lengthening Index had trends toward significance in Hexapods group (p = 0.051).*

Conclusion: *Computer-assisted Hexapods may reduce the Lengthening Index compared to the conventional Ilizarov method. The hexapods device could be beneficial for faster correction of complex deformity if the patients or family members understand how to manipulate the apparatus.*

Keywords: *Ilizarov method, External fixator, Apparatus, Computer-assisted hexapods, Ortho-SUV, Lengthening index, Complex tibial deformity*

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Complex deformities of the long bones could be congenital, a complication of fractures, physeal injuries, or fracture-dislocations. These deformities which defined as deformity in two or more planes lead to disability, abnormal gait, inability to participate in sporting activities, disfigures and miserable lives. Management of these deformities could be divided into acute correction and gradual correction[1]. Circular fixation is the most common method used for achieving gradual correction[2-5]. Most authors use circular fixator called Ilizarov apparatus (IA) to perform gradual correction[6-8]. Ilizarov could correct multiplane deformities (angulation, malrotation and shortening). However, most cases need multiple times of frame transformation in order to achieve correction of deformity of all planes. Hexapod, which has become popular recently, could provide multiplane correction without having to transform the frame. Deformities in all planes could be simultaneously corrected. These computer-assisted Hexapods (e.g. Taylor spatial frame, and Ortho-SUV frame[9]) could solve the problem of frame transformation and thus reduce the time needed in external fixator. Computer-assisted Hexapods, through its software, calculates how to correct the deformities and provides precise correction. The final alignment after correction could be anticipated from the computer-generated x-ray pictures. Besides that, the steps of correction could be regulated and the struts could be checked during the gradual correction at any time. These abilities are not available in the IA. The

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Hexapods is also much simpler to use than Ilizarov. At present, any complex deformity could be managed with Hexapods with the help of its software.

The present study is intended to compare the Computer-assisted Hexapods with the Ilizarov circular frame in the time needed for correction of complex tibial deformities.

Material and Method

The retrospective review of patients with complex tibial deformities treated with either Ortho-SUV frame (Ortho-SUV Ltd. and Vreden Russian Research Institute of Traumatology and Orthopedics, St. Petersburg, Russian Federation) or IA at Siriraj Hospital was performed. Patients treated between October 2008 and October 2015 were included in the study. Cases included complex deformities in late stage Blount disease, traumatic physeal arrest, and malunion of long bone. Data gathered included age, gender, site of the deformity, amount of angulation in each plane of deformity, length of time in Ilizarov circular frame and in Ortho SUV frame, Lengthening index (LI), and complications. Clinical examination was evaluated. Plain radiographs and standing tele-roentgenograms were used to evaluate magnitude of deformities and the limb length. Mechanical axis deviation (MAD) and alignments of the legs in all planes before and after correction were evaluated.

All operations were performed by the authors' team. Circular rings were placed perpendicular to the axis of the affected bone, parallel to the ankle or knee joints. Transverse osteotomy was made at the center of rotation and angulation (CORA) or as closed to it as possible. Deformity correction started 7 days after the osteotomy. In the Hexapods (Ortho-SUV group), planning of deformity correction was done by using Ortho-SUV software based on pre-operative deformity evaluation and postoperative radiographs.

Data analysis was performed using SPSS version 18.0. Data were presented as median (min-max) and number (percentage). Continuous variables were analyzed using the student's t-test or Mann-Whitney U test when appropriate. Categorical variables were analyzed using the Chi-squared test and Fisher's exact test. A *p*-value of less than 0.05 was considered statistically significant.

Results

Thirteen patients were included in the present study. Seven patients were treated with Ortho-SUV frame. Six patients were treated with Ilizarov circular frame. Demographic data was summarized in Table 1. Gender, age and side of deformity were not statistically different. Most patients in Ortho-SUV group underwent gradual lengthening and delayed plate fixation while most patients in Ilizarov group were managed by gradual lengthening until bone consolidation ($p = 0.029$). Case example in Ortho-SUV group is illustrated in Fig. 1.

Pre-operative and postoperative data were summarized in Table 2. Limb length discrepancy (LLD), Mechanical axis deviation (MAD), and lengthening index (LI) were appraised. LLD, MAD and sagittal angulation were not statistically different. However, Patients in Ortho-SUV group had significantly more angulation in coronal plane before surgery. After

Table 1. Demographic data

	Ortho-SUV (n = 7)	IA (n = 6)	*p*-value
Gender: female	5 (71%)	4 (67%)	1.00
Age (year)	13 (10 – 42)	11.5 (4 – 52)	0.37
Side: right	5 (71%)	3 (50%)	0.59
Diagnosis			
Blount disease	4 (57%)	1 (16%)	
Physeal arrest	2 (29%)	2 (33%)	0.27
Malunion or nonunion	1 (14%)	2 (33%)	
AVM	0	1 (16%)	
Surgical planning			
Gradual lengthening	6 (86%)	1 (17%)	0.029
Gradual lengthening and delayed plate fixation	1 (14%)	5 (83%)	

Values are number (percentage) and median (min-max)

treatment, no parameters had any statistically significant differences. Lengthening index were lower in Ortho-SUV group ($p = 0.051$). Two cases in Ortho-SUV group changed to Ilizarov after angulation and rotation were corrected because of strut usage difficulty. One case in IA group had nonunion and plate fixation was performed afterwards. Union was achieved after plate fixation in all cases.

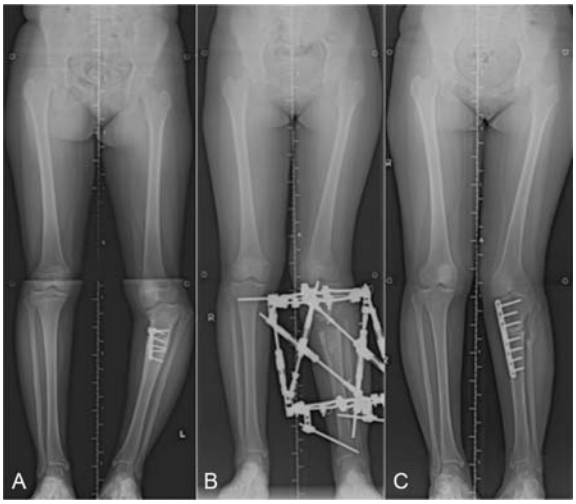

Fig. 1 Case example from Ortho-SUV group; demonstrated preoperative radiograph (A); showed radiograph during Ortho-SUV usage (B); demonstrated radiographs after delayed internal fixation (C).

Discussion

Complex long bone deformity is not uncommon but is very difficult-to-treat. These deformities may comprise of LLD, angular deformities or nonunion with or without infection. Severe deformities can lead to disabilities, abnormal gait and pain from early osteoarthritis. Restoration of joint line orientation and bone alignments will save this group of patients from having miserable lives. The treatment could be acute deformity correction or gradual correction. Circular fixator such as Ilizarov is most commonly used to provide gradual correction of the deformity[6,7]. However, gradual correction using Ilizarov is time consuming and requires a steep learning curve. Deformity is corrected one plane at a time which then requires frame transformation and fine adjustment. Hexapod doesn't require frame transformation and is easier to use. Solomin LN et al perform a comparative study in complex femoral deformity and found that Ortho-SUV frame could significantly reduce the time needed for correction by 2.3 times[9]. Ortho SUV has been used in our institute just recently. This Hexapods could decrease the LI in most cases and the correction is easier to achieve. Fine adjustment could be done at any step of correction. Most deformities in the present study were improved though some LLD and angular deformities still remained. This problem may be due to callus subsidence from not applying supplementary internal fixation. This callus subsidence was also found in some reports[10,11]. Immediate plate or intramedullary nail fixation and lengthening over internal fixation may

Table 2. Preoperative and postoperative data

	Ortho SUV (n = 7)	IA (n = 6)	*p*-value
LLD (tibia in mm)			
Preoperative	23 (4-54)	25 (20-117)	0.63
Postoperative	21.5 (3-36)	11.5 (3-36)	0.59
MAD (mm)			
Preoperative	60 (0-88)	7.5 (4-41)	0.30
Postoperative	12.5 (2-39)	18 (7-48)	0.66
Coronal angulation			
Preoperative	31 (2-38)	7.5 (0-11)	0.022
Postoperative	7 (1-13)	10.5 (5-12)	0.53
Sagittal angulation			
Preoperative	8 (0-16)	10.5 (7-14)	0.89
Postoperative	8 (1-24)	10 (6-26)	0.50
Overall lengthening (mm)	30 (20-64)	35.5 (5-98)	0.95
Lengthening index (LI)	1 (0.4-2.4)	1.74 (1.18-6)	0.051

Values are median (min-max)

prevent these residual deformities and reduce time in external fixator[12,13]. However, postoperative infection was found to be significant in some literature[14]. The present study found that LI trended toward significance in Ortho-SUV group (p = 0.051). It may not be a statistically significant difference because sample size was too small and one case in Ortho-SUV, who was in Ortho-SUV for two months, chose to convert to IA due to complexity of strut usage. If this patient were excluded from calculation, the Ortho-SUV group had LI of less than 1.3 which is significantly lower than the other group.

Conclusion

Computer-assisted Hexapods may reduce the Lengthening Index compared to the conventional Ilizarov method. This device could be beneficial for faster correction of complex deformity if the patients or family members understand how to manipulate the apparatus.

What is already known this topic?

Gradual correction of complex deformity is one of the recommended treatment options. Ilizarov apparatus is the popular method of gradual correction in these deformities. Computer-assisted hexapods could provide more precise correction planning and alleviate the need of frame transformation.

What this study adds?

Computer-assisted hexapods may include lengthening index. In most cases the correction is easier to achieve.

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Potential conflicts of interest

None.

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การศึกษาเบื้องต้นเปรียบเทียบระหว่างอิลิซารอฟกับการใช้คอมพิวเตอร์คำนวณแก้ไขความผิดรูปด้วยอุปกรณ์แบบหกเสาในการแก้ไขแบบค่อยเป็นค่อยไปในความผิดรูปของกระดูกหน้าแข้ง

ธเนศ อริยะวัตรกุล, จตุพร โชติกวณิชย์, กมลพร แก้วพรสวรรค์, พีระจิตร เอี่ยมโสภณา

ภูมิหลัง: อุปกรณ์แบบหกเสาที่ใช้คอมพิวเตอร์ช่วยคำนวณเป็นอุปกรณ์ที่ใช้แก้ไขความผิดรูปได้ในหลายมิติ อย่างไรก็ดีอุปกรณ์นี้มีความยากในการใช้งาน จึงทำให้มีความนิยมไม่มาก

วัตถุประสงค์: การศึกษานี้มุ่งศึกษาข้อดีและข้อเสียของอุปกรณ์แบบหกเสาที่ใช้คอมพิวเตอร์ช่วยคำนวณเปรียบเทียบกับอิลิซารอฟในการแก้ไขความผิดรูปแบบหลายมิติของกระดูกหน้าแข้ง

วัสดุและวิธีการ: ทำการศึกษาย้อนหลังในผู้ป่วยที่รักษาความผิดรูปซับซ้อนของกระดูกหน้าแข้งด้วยอุปกรณ์แบบหกเสาที่ใช้คอมพิวเตอร์ช่วยคำนวณและอิลิซารอฟตั้งแต่ พ.ศ. 2543 ถึง 2557 เก็บข้อมูลมุมความผิดรูป, ระยะเวลาที่ใส่อุปกรณ์แบบหกเสาที่ใช้คอมพิวเตอร์ช่วยคำนวณ, ระยะเวลาที่ใส่อิลิซารอฟ, จำนวนเดือนต่อระยะที่ยืดได้หนึ่งเซนติเมตร, ผลแทรกซ้อน และนำมาคำนวณทางสถิติ

ผลการศึกษา: ผู้ป่วยจำนวน 6 รายรักษาด้วยอิลิซารอฟ และจำนวน 7 รายรักษาด้วยอุปกรณ์แบบหกเสาที่ใช้คอมพิวเตอร์ช่วยคำนวณผู้ป่วยในกลุ่มที่ใช้อุปกรณ์แบบหกเสาที่ใช้คอมพิวเตอร์ช่วยคำนวณจะมีมุมเริ่มต้นของความโก่งในแนวหน้าข้างมากกว่าอย่างมีนัยสำคัญทางสถิติ ($p = 0.02$) หลังการรักษาความผิดรูปที่แก้ไขได้ในสองระบบไม่มีความแตกต่างอย่างมีนัยสำคัญทางสถิติ จำนวนเดือนที่ใช้ต่อระยะความยาวที่ได้หนึ่งเซนติเมตร มีแนวโน้มที่จะมีนัยสำคัญทางสถิติ ($p = 0.051$)

สรุป: อุปกรณ์แบบหกเสาที่ใช้คอมพิวเตอร์ช่วยคำนวณสามารถลดจำนวนเวลาและจำนวนเดือนที่ใช้ต่อระยะความยาวที่ได้หนึ่งเซนติเมตร อุปกรณ์นี้เหมาะกับผู้ป่วยที่มีความผิดรูปซับซ้อนหลายมิติ