J Child Orthop (2010) 4:267–271
DOI 10.1007/s11832-010-0247-9

TECHNICAL NOTE

A more patient-friendly use of circular fixators in deformity correction

Ralph J. Sakkers · A. J. van der Wal · P. T. Dijkstra · J. E. N. Jaspers

Received: 27 November 2009 / Accepted: 19 February 2010 / Published online: 19 March 2010

Abstract
Purpose The evaluation of a construction that allows the exchange of circular and unilateral external fixators on the same fixation pins to the bone in outpatient circumstances during bone lengthening and alignment procedures.
Methods Nine children were treated with this concept. After bone lengthening and alignment, the circular fixators were exchanged for unilateral fixators in the outpatient clinic to hold the position of the bony parts during the consolidation phase.
Results The decrease of time needed to use the circular fixator during the treatment was considered to be an improvement in comfort.
Conclusions The concept of using both a circular and a unilateral external fixator in a construction that allows the exchange of the external fixators in outpatient circumstances combines the advantages of both systems, and creates more options in the different stages of bone deformity correction. Patient comfort is increased by the decrease of time needed to use the circular fixator.

Keywords External fixator · Deformity correction · Limb lengthening

R. J. Sakkers (✉) · A. J. van der Wal
Department of Orthopaedic Surgery, University Medical Center Utrecht, P.O. Box 85500, 3508 AB Utrecht, The Netherlands
e-mail: r.sakkers@umcutrecht.nl

P. T. Dijkstra · J. E. N. Jaspers
Department of Medical Technology and Clinical Physics, University Medical Center Utrecht, P.O. Box 85500, 3508 GA Utrecht, The Netherlands

Background

Nowadays, external fixators for deformity corrections range from a simple tube, fixed to steel half-pins, to a hexapod circular system, in which both hydroxylapatite-coated half-pins and tension wires can be used. All systems have their advantages and disadvantages. Circular fixators are more commonly used in complex deformities that need correction and lengthening in all dimensions. Especially, the circular fixators with a hexapod system show a growing popularity because of their versatility and accuracy [1–3]. The disadvantage of the circular fixators is the volume they cover, and the fact that there is always a piece of metal between one's legs.

A decrease in time needed for a circular fixator in the treatment of limb deformities will mean an improvement in patient comfort. With this in mind, we developed a prototype construction in which a circular and a unilateral fixator can be mounted simultaneously on the same fixation pins to the bone, as well as separately [4]. Thus, any desired type of fixation can be mounted or exchanged in the outpatient clinic in the different stages of deformity correction and consolidation. In this technical note, we report our first experiences with this new concept.

Description of the procedure

Only existing and approved fixators on the market were used (Ilizarov fixator and Taylor Spatial Frame [TSF] as circular fixators; Orthofix ProCallus 90000 series, Orthofix Small D.A.F. 31000 series, and Orthofix LRS rail lengthener as unilateral fixators). For the fixation of the fixators to the bone of the patient, hydroxylapatite-coated pins (Orthofix) with a diameter of 6 mm each were used per fixation clamp. To be able to use a circular fixator and a unilateral fixator separately or simultaneously (the Utrecht concept), a new type of connector was developed to rigidly connect the circular fixator simultaneously on the same half-pins as the unilateral fixator. The new type of connector consists of parts which can be fixated with screws to each other, with the half-pins in between. One part of the connector can be fixated to a circular fixator ring with a screw through one of the holes of the ring or in between two rings with two screws. A larger and oval-shaped hole gives the connector a certain freedom of rotation about the holes in the fixator ring, in order to align the half-pins to the circular fixator. By firmly tightening all screws and bolts, a rigid and stiff connection between the half-pins and the circular fixator can be realized, and the unilateral fixator can be removed or mounted back on. After firmly connecting the unilateral fixator to the half-pins, the circular fixator can be removed or mounted back on (Figs. 1, 2).

In the operating room, the unilateral fixator is mounted on the bone with the half-pins. After fixation of the hinges between the body and the clamps, the unilateral fixator is removed and a percutaneous osteotomy is performed at the scheduled location with only the half-pins in situ. After the osteotomy, the unilateral fixator is mounted back on

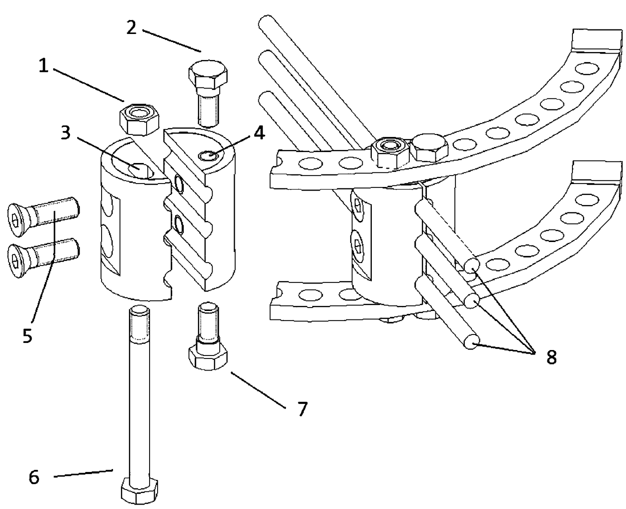

Fig. 1 Diagram of the designed connectors. The connector consists of two half-cylindrical-shaped parts, which can be fixated with screws (*5*) to each other with the half-pins (*8*) in between. The clamping distance of these pins (*8*) in the designed connector are equal to the clamping distance of the unilateral fixator. One part of the connector can be fixated to a ring-frame with a screw (*2*) through one of the holes of the ring or in between two rings with two screws (*2* and *7*). The larger and oval-shaped hole (*3*) gives the connector a certain freedom of rotation about hole *4* and the corresponding hole in the fixator ring, in order to align the half-pins (*8*) to the ring-frame. By firmly tightening bolt *1* and screw *6*, and all other screws (*2*, *5*, and, potentially, *7*) a rigid and stiff connection between the half-pins and the ring-frame is realized

the half-pins in the same position as before the osteotomy. Subsequently, the connector blocks are mounted on the half-pins parallel to the unilateral fixator clamps and the circular fixator is connected to the connector blocks. After firm fixation of the circular fixator, the half-pins are cut just lateral of the most outer placed blocks and the unilateral fixator is removed. Lengthening and correction of the bony deformity is started after 5–7 days. The circular fixator is exchanged for the unilateral fixator in the outpatient clinic 1 week after the completion of the scheduled lengthening and alignment. The body of the unilateral fixator is dynamized in the last phase of the consolidation period.

Patients

Nine children (aged 6–15 years) were treated with the Utrecht concept (Table 1). Lengthenings varied between 2 and 5 cm per bone, angular corrections were done for deformities between 20° varus and 20° valgus, and rotational corrections were done up to 15°. The first patient was treated with a combination of an Ilizarov circular fixator and an Orthofix unilateral fixator. All other patients were treated with the combination of a TSF circular fixator and an Orthofix unilateral fixator (Figs. 3, 4). One patient had the Utrecht concept on both the femur and the lower leg, three patients had the Utrecht concept for correction of the femur combined with lengthening of the lower leg with an Orthofix LRS rail lengthener, two patients had only the Utrecht concept for correction of the femur, and two patients had the Utrecht concept for correction of only the lower leg. The ninth patient started with the TSF on the femur and the Orthofix LRS rail lengthener on the tibia. After the scheduled lengthening of the lower leg of 3 cm, the Orthofix rail was exchanged for the TSF and a rotation of 15° external rotation of the distal part was done in 1 week. Afterwards, the TSF was exchanged for the Orthofix Small D.A.F. 31000 series with multiaxial hinges between the clamps and the body to allow mounting of the unilateral fixator on half-pins in a changed position. Two patients had temporary bridging of the knee by coupling the distal ring of the upper leg system with the proximal ring of the lower system. In one patient, these rings were connected to the unilateral fixator by the same clamp that was used to link the circular fixator to the fixation pins to the bone.

Outcomes

All of the patients were very happy to have the circular fixator exchanged for the unilateral fixator during the

Table 1 Results of the study cohort

Age/gender	Diagnosis	Femur objective/result	Tibia objective/result
9/F	Bar growth plate after osteomyelitis		U, 4 cm + 20° varus
13/F	Congenital limb deficiency	U, 3.5 cm/1.5 cm	R, 2 cm/3 cm
13/F	Congenital limb deformity		U, 2 cm + 20° valgus
14.5/M	Skeletal dysplasia	U, 3 cm + 6° valgus	R, 3 cm
14.5/M	Congenital limb deficiency	U, 3.5 cm + 7° valgus	R, 2 cm
8.5/F	Congenital limb deficiency + absent cruciate ligaments, frequent patella luxations	U, 4.5 cm + 5° valgus + 7° exo	U, 3 cm + 5° valgus
6.5/F	Enchondromatosis	U, 3 cm	
15/F	Skeletal dysplasia + posttraumatic deformity	U, 4 cm + 5 cm shift	
7/F	Congenital limb deficiency + absent cruciate ligaments	U, 4 cm + 4.5° valgus	R + U, 3 cm + 15° endo

In the second, patient there was loss of correction. In this patient, the complete upper and lower leg lengthening construction was connected with a fixed bridging of the knee and acted on a single ball hinge. In this case, it was not clear if we made a mistake in securing the ball hinge or if the lever arm force was too strong. This loss of correction was treated by mounting the circular fixator (TSF) on the half-pins again and gradually realigning the bone parts. Some length was lost in this correction procedure. The loss of length was partly compensated by extra lengthening of the tibia. All other lengthenings and alignments with the circular fixator (Ilizarov or TSF) had no loss of lengthening and alignment after exchange of the circular fixator for the unilateral fixator

U Utrecht concept, *R* Orthofix LRS rail lengthener

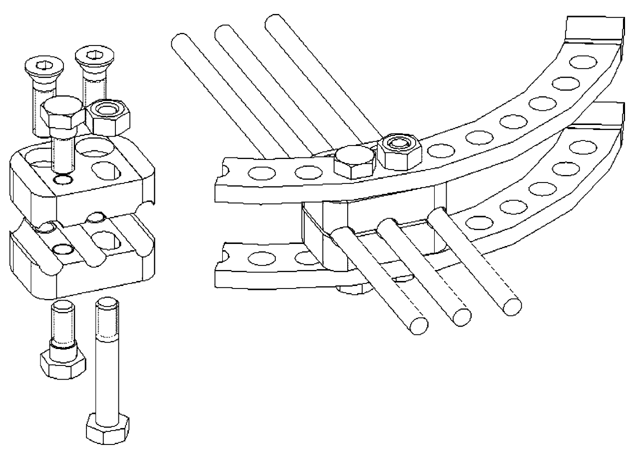

Fig. 2 An example of a connector that is designed for a transverse clamp

course of the treatment. In one patient, there was loss of correction. In this patient, the complete upper and lower leg lengthening construction was connected with a fixed bridging of the knee and acted on a single ball hinge. In this case, it was not clear if we made a mistake in securing the ball hinge or if the lever arm force was too strong. This loss of correction was treated by mounting the circular fixator (TSF) on the half-pins again and gradually realigning the bone parts. Some length was lost in this correction procedure. The loss of length was partly compensated by extra lengthening of the tibia (Table 1). All other lengthenings and alignments with the circular fixator (Ilizarov or TSF) had no loss of lengthening and alignment after exchange of the circular fixator for the unilateral fixator.

Discussion

In this report, we published our first experience with a concept that allows the exchange of circular and unilateral external fixators on the same fixation pins to the bone in outpatient circumstances. To further increase the patient comfort and to avoid non-central mounting of the circular ring fixator, we started using smaller rings by inversing the construction. In the operating room, the smallest rings possible are mounted as centrally as possible on the pins and the unilateral fixator is mounted lateral to the circular fixator (Fig. 4). After cutting of the half-pins at the necessary length for simultaneous fixation of the circular and the unilateral fixator, the unilateral fixator is removed. Several weeks later in the outpatient clinic, after the lengthening and alignment procedure with the circular fixator, a temporary unilateral fixator can again be mounted on the half-pins lateral to the circular fixator. After firm fixation of this temporary unilateral fixator, the circular fixator can be removed, and a second unilateral fixator can be mounted on the position of the circular fixator, parallel to the more laterally mounted unilateral fixator. After firm fixation of the unilateral fixator closest to the bone, the more lateral unilateral fixator can be removed.

In most of the patients in this first series, we used the Orthofix unilateral fixator with clamps with longitudinal pin configuration. However, as shown in Fig. 2, any configuration of half-pins of any type of clamp of unilateral fixators can be copied in the connector clamp. The next development might be a transverse clamp that is a small part of an oval or circle to increase the possibilities for half-pin positioning on a unilateral fixator. So, the concept

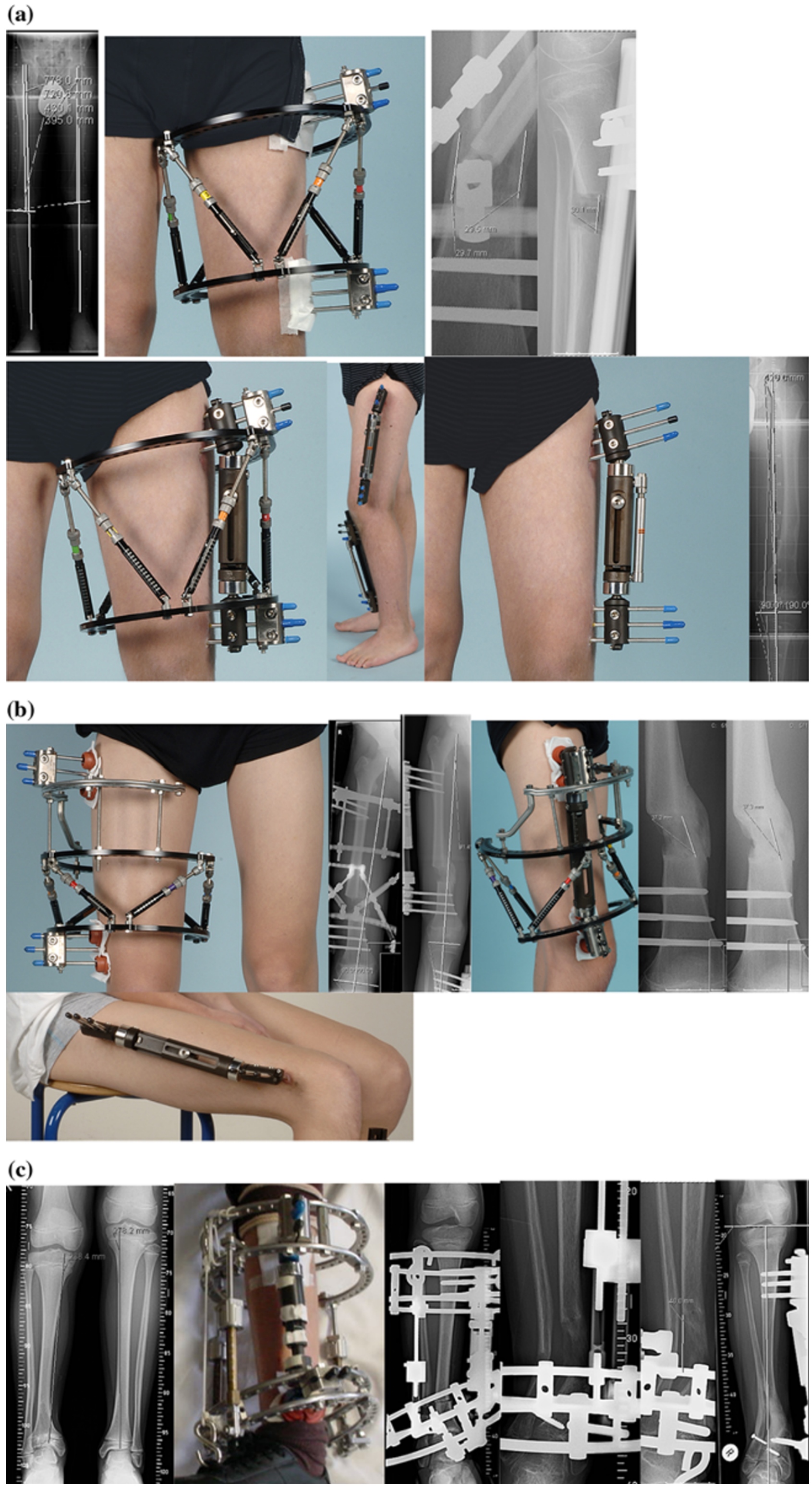

Fig. 3 **a** Patient with a limb length discrepancy of 6 cm and an extra 6° of valgus in the left femur (as compared to the axis of the right femur). The tibia is lengthened with an Orthofix LRS rail lengthener and the femur is lengthened and aligned with a Taylor Spatial Frame (TSF). After the lengthening–alignment procedure, the TSF and Orthofix Procallus 90000 series are easily exchangeable in the outpatient clinics. **b** Many variations in the concept are possible. These images show the TSF with some Ilizarov components to position the TSF rings more distally on the femur during lengthening and alignment. After changing from TSF to Orthofix Procallus, there is no change in the position of the bony parts during consolidation. **c** The use of a transverse clamp as shown in Fig. 2 to allow for an osteotomy close to the ankle joint

as shown is not restrained to longitudinal pin alignment for fixation to the bone.

Because we are gaining experience with this new concept, the half-pins are kept long as a safeguard to be able to mount the circular fixator back on the fixation to the bone in unforeseen circumstances. Since the Orthofix unilateral fixator seems to be very capable of maintaining the correction after lengthening, we have started to cut off the

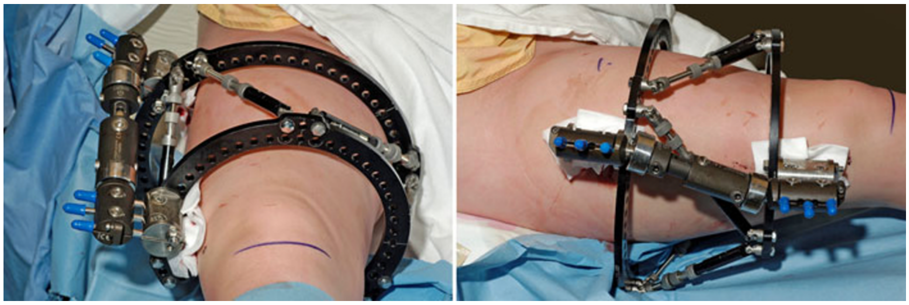

Fig. 4 In the latest construction of the Utrecht concept, the construction is built the other way around: TSF as close to the leg as possible and the unilateral fixator outside the TSF rings. During the lengthening and alignment, the unilateral fixator is removed and the lengthening and realignment is done with the TSF fixator. After finishing the TSF scheme, the unilateral fixator is mounted back on the half-pins outside the TSF rings in the outpatient clinic. After fixation of this temporary unilateral fixator, the TSF fixator is removed and a second unilateral fixator is mounted on the former location of the TSF fixator on the half-pins parallel to the more laterally temporary placed unilateral fixator. After firm fixation of the second unilateral fixator close to the bone, the first temporary unilateral fixator is removed. The second unilateral fixator close to the bone holds the bony parts in place until consolidation of the lengthened zone. In the last phase of the consolidation period, the possibilities of dynamization of the unilateral fixator can be used

half-pins in the outpatient clinic in the second half of the consolidation phase, when the risk of loss of deformity correction is reduced to a minimum. The next development in this concept might be a clamp on which the rings of the circular fixator and the monolateral body with multidirectional hinges can be simultaneously fitted (on the same clamp instead of using two clamps). This clamp would make the use of long pins redundant.

Conclusion

The concept of using both a circular and a unilateral external fixator in a construction that allows the exchange of the external fixators in outpatient circumstances combines the advantages of both systems, and creates more options in the different stages of bone deformity correction. Patient comfort is increased by the decrease of time needed to use the circular fixator. This concept is made possible by creating a device that allows a simultaneous but removable fixation of both the unilateral fixator and the circular fixator on the half-pins for fixation to the bone.

References

1. Manner HM, Huebl M, Radler C, Ganger R, Petje G, Grill F (2007) Accuracy of complex lower-limb deformity correction with external fixation: a comparison of the Taylor Spatial Frame with the Ilizarov ring fixator. J Child Orthop 1:55–61
2. Marangoz S, Feldman DS, Sala DA, Hyman JE, Vitale MG (2008) Femoral deformity correction in children and young adults using Taylor Spatial Frame. Clin Orthop Relat Res 466:3018–3024
3. Blondel B, Launay F, Glard Y, Jacopin S, Jouve JL, Bollini G (2009) Limb lengthening and deformity correction in children using hexapodal external fixation: preliminary results for 36 cases. Rev Chir Orthop Traumatol 95:425–430
4. International Application Published Under the Patent Cooperation Treaty (PCT) International Application Number WO 2008/147179. International Application Number PCT/NL2008/000141. System for correcting bones. Available online at: http://v3.espacenet.com/publicationDetails/originalDocument?CC=WO&NR=2008147179A1&KC=A1&FT=D&date=20081204&DB=EPODOC&locale=en_EP