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Cohort Study

Acute-shortening and re-lengthening (ASRL) procedure with monorail fixator to treat femur/tibia nonunion: A retrospective study

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ABSTRACT

Background: The distraction osteogenesis procedure has a high potential to treat bone defect problems. The alternative technique to treat nonunion associated with a bone defect is the acute shortening and re-lengthening (ASRL) procedure. This study aimed to evaluate the outcome of ASRL procedure with a monorail fixator to treat femur/tibia nonunion associated with the bone defect.

Method: Retrospective analysis was performed to patients who received ASRL procedure with monorail fixator for femur or tibia nonunion from October 2018 to October 2020 at Prof. Dr. R. Soeharso Orthopaedic hospital. One case was loss to follow-up and excluded from the study. The rest of 16 cases were included for further analysis. The evaluation was performed to the demographic, intraoperative procedure, problems/complications, additional procedure, and final outcome.

Results: There were 13 male and three female patients with age ranged from 16 to 64 years old. The follow-up period ranges 9–31 months. ASRL procedures performed to 6 femur and 10 tibias. The problems/complications: two cases with problems associated with callus formation, two cases of fracture at corticotomy site, one case of skin necrosis, one case of osteomyelitis, one case of malrotation. Additional surgical procedures were needed 5/16 (31.2%) cases. Evaluation at the final follow-up period showed 14/16 (87.5%) cases had a complete bone union.

Conclusions: Acute shortening and re-lengthening (ASRL) could be reliable as a method of treatment for femur/tibia nonunion associated with the bone defect. Several possible complications need to be considered prior to perform this procedure.

1. Introduction

Nonunion of femur or tibia shaft associated with a bone defect after previous fracture treatment commonly occur and can be difficult to treat [1]. There were several alternatives to treat this condition. These include primary bone grafting, staged bone grafting with the membrane-induced procedure, staged surgery with internal fixation, and distraction osteogenesis procedure [2–4]. Distraction osteogenesis procedure has high potential to treat bone defect problems, including bone defects related to trauma, infection or bone tumor [4–6].

Several techniques in distraction osteogenesis are simple lengthening, internal bone transport (IBT), and acute shortening and re-lengthening (ASRL) [7]. Simple lengthening performed in the case of limb length discrepancy without bone defect or nonunion problem. The techniques to treat nonunion associated with the bone defect can be internal bone transport or acute shortening and re-lengthening (ASRL) [8,9]. The decision to choose one of those techniques is mainly based on the size of a bone defect. Bone defect with size 4 cm or more usually needs bone transport. A smaller bone defect can be treated with ASRL procedure [9].

Distraction osteogenesis can be performed with a various devices such as Ilizarov ring fixator, monorail fixator, intramedullary device, plate lengthening, and hexapod fixator [10,11]. Compared to the classic Ilizarov ring fixator, monorail fixator has possible advantages include: low profile device, less cumbersome, less soft tissue damage, and easier to maintain bone alignment. In the recent paper, we perform an evaluation to the patients who received distraction osteogenesis with ASRL procedure to treat nonunion associated with a bone defect of femur or tibia with the use of monorail fixator. This work has been reported in line with the STROCSS 2019 guidelines [12].

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Table 1
Distraction osteogenesis with acute shortening and re-lengthening (ASRL) cases.

No	Gender/ Age (years old)	Bone	Bone defect size (cm)	Procedures	Distraction site/Callus type	Problems/complications	Follow-up period (Months)	Additional procedure	Final outcome
1.	M/31	Tibia	2	ASRL with monorail fixator only	Diaphysis/ Straight	none	31	none	Complete bone union
2	Male/24	Tibia	3	ASRL with monorail fixator only	Proximal metaphysis/ Straight	Corticotomy site fracture	28	none	Complete bone union
3.	Female/ 20	Tibia	3	ASRL with monorail fixator only	Diaphysis/ Opposite	Osteomyelitis	27	Debridement	Complete bone union
4	Male/54	Tibia	4	ASRL with monorail fixator only	Proximal metaphysis/ External	Skin necrosis at acute docking site (treated with secondary intention), Docking site nonunion	25	Reconstruction of docking site nonunion with compression plate after soft tissue healing	Nonunion of the docking site
5	Male/25	Femur	5	ASRL with monorail fixator only	Diaphysis/ Straight	none	25	none	Complete bone union
6	Male/27	Tibia	4	ASRL with monorail fixator only	Diaphysis/ Attenuated	Malrotation	20	Re-alignment + plate and screw	Complete bone union
7	Male/29	Femur	3	ASRL with monorail fixator only	Distal metaphysis/ External	none	18	none	Complete bone union
8	Male/16	Tibia	3	ASRL with monorail fixator + compression screw at docking site	Diaphysis/ Straight	none	15	none	Complete bone union
9	Male/38	Tibia	3	ASRL with monorail fixator + compression screw at the docking site	Diaphysis/ Straight	none	14	none	Complete bone union
10	Male/28	Femur	6	ASRL with monorail fixator + compression plate and screw at the docking site	Distal metaphysis/ Straight	none	13	none	Complete bone union
11	Male/34	Femur	4	ASRL with monorail fixator only	Diaphysis/ Straight	none	12	none	Complete bone union
12	Female/ 22	Tibia	3	ASRL with monorail fixator only	Diaphysis/ Pillar	Poor callus formation at distraction site	12	Reconstruction and bone grafting	Partial Union at distraction site
13	Male/49	Tibia	4	ASRL with monorail fixator only	Diaphysis/ Straight	Corticotomy site fracture	11	none	Complete bone union
14	Male/64	Tibia	3	ASRL with monorail fixator, + K-wire at the docking site	Diaphysis/ Straight	none	11	none	Complete bone union
15	Female/ 44	Femur	5	ASRL with monorail fixator only	Diaphysis/ Straight	none	9	none	Complete bone union
16	Male/26	Femur	4	ASRL with monorail fixator only	Diaphysis/ Straight	Knee stiffness	16	Knee joint release	Complete bone union

2. Methods

A retrospective analysis was performed to patients who received distraction osteogenesis with monorail fixator for femur or tibia from October 2018 to October 2020 at Prof. Dr. R. Soeharso Orthopaedic hospital. There was a total of 45 patients received distraction osteogenesis of the femur/tibia during the period. Three (6.7%) patients received simple bone lengthening, 25 (55.5%) patients received internal bone transport (IBT), and 17 (37.8%) patients received acute shortening and re-lengthening (ASRL) procedures. The recent study included only patients who received ASRL procedures (17 patients). One case was a loss to follow-up and excluded from the study. The rest of the 16 cases were included for further analysis. The evaluation was performed to the demographic, intraoperative procedure, problems/complications, additional procedure, and final outcome.

All surgery was performed by a single surgeon (AS). Surgery performed under anesthesia in a supine position. Distraction osteogenesis of the femur performed with the use of 40 cm monorail fixator *(® B-fix, Aike, Shanghai Medical Instrument, China*) for femur cases and 30 cm monorail fixator for tibia cases. Decision to perform ASRL or IBT to treat bone defect stated intraoperatively by the performing surgeon. Freshening and resection of the nonunion site were performed until healthy bone was obtained. The docking site compression was performed with the use of a monorail fixator alone or in combination with other internal fixation implants such as plate, screw, or Kirshner-wire based on bone, soft tissue condition, and the presence of infection. Corticotomy/ osteotomy for lengthening site can be at diaphysis or metaphysis area depend on the case. The latent period for diaphyseal distraction osteogenesis was ten days, while metaphyseal distraction was seven days. Afterward, distraction osteogenesis was performed with rate 1 mm/day and can be modified by physician discretion. Post-operative follow-up was performed at two weeks, one month, and every 1 month thereafter. Standard rehabilitation protocol was performed on the patients. The patient was allowed for early ROM exercise and non-weight-bearing mobilization with the crutch. The patients were allowed to start partial weight-bearing after finishing the distraction phase. Clinical evaluation and radiological evaluation were performed during follow-up until patients were allowed to walk without an assistive device. Radiologic evaluation of callus formation at distraction site was performed with Hamanishi et al. classification [13].

3. Results

There were 13 (81.3%) male and 3 (18.7%) female patients with mean age 33.2 (range, 16–64) years old. The mean of follow-up period was 17.9 (range, 9–31) months. ASRL procedures performed to 6

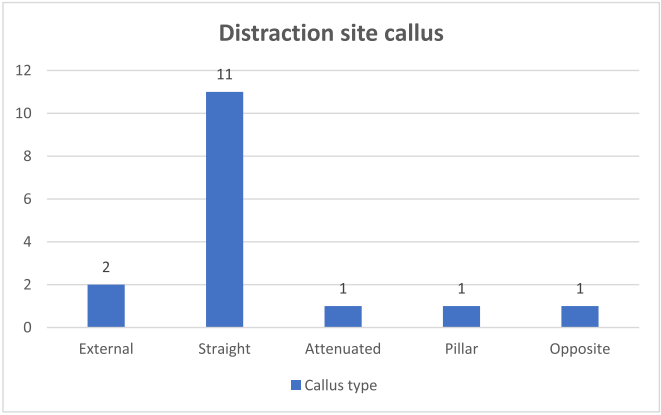

Fig. 1. Distribution of callus type at distraction site according to Hamanishi et al. [13] classification.

(37.5%) femur and 10 (62.5%) tibias. Compression at acute docking site performed with monorail fixator alone in 12 cases and in combination with internal fixation in 4 cases. Distraction site was performed at diaphysis in 12 cases and metaphysis in 4 cases (Table 1). Callus formation at distraction site evaluation based on Hamanishi et al. classification resulted in 11 straight types, 2 cases external type, one opposite type, one attenuated type, and one pillar type callus (Figs. 1–3). The range of bone gap at the nonunion site after the bone resection (poor quality) and freshening was range 2–6 cm.

Overall problems/complications occurred in 7/16 (43.7%) of the cases. The problems/complications: two cases with problems associated with callus formation, two cases of fracture at corticotomy site, one case of skin necrosis, one case of osteomyelitis, one case of malrotation. Additional surgical procedures were needed 5/16 (31.2%) cases. Evaluation at the final follow-up period showed 14/16 (87.5%) cases had a complete bone union Fig. 4.

4. Discussion

The ASRL procedure aimed to have acute docking to close the bone

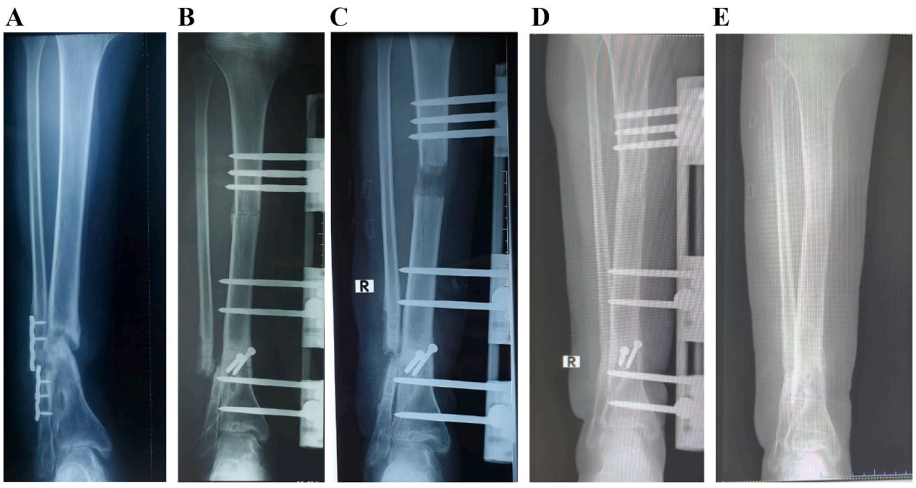

Fig. 2. Male 16 years old with infected non-union of right distal tibia. **A.** Preoperative radiograph, **B.** Immediate post-operative, patients received compression screw fixation at non-union site, **C.** During lengthening period showed 3 cm "straight type" callus at distraction site, **D.** Radiograph at final follow-up showed complete bone union of tibia and fibula. E. After removal of monorail fixator.

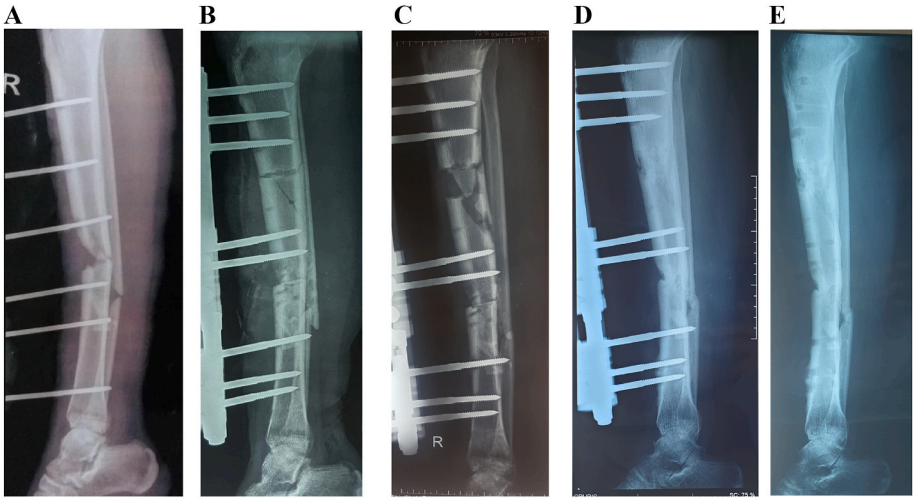

Fig. 3. Male 23 years old with infected non-union of right shaft tibia. **A.** Preoperative radiograph, **B.** Immediate post-operative, **C.** During lengthening period showed "corticotomy fracture" at distraction site, **D.** Radiograph at final follow-up, complete bone union both on distraction and docking site. **E.** After removal of monorail fixator.

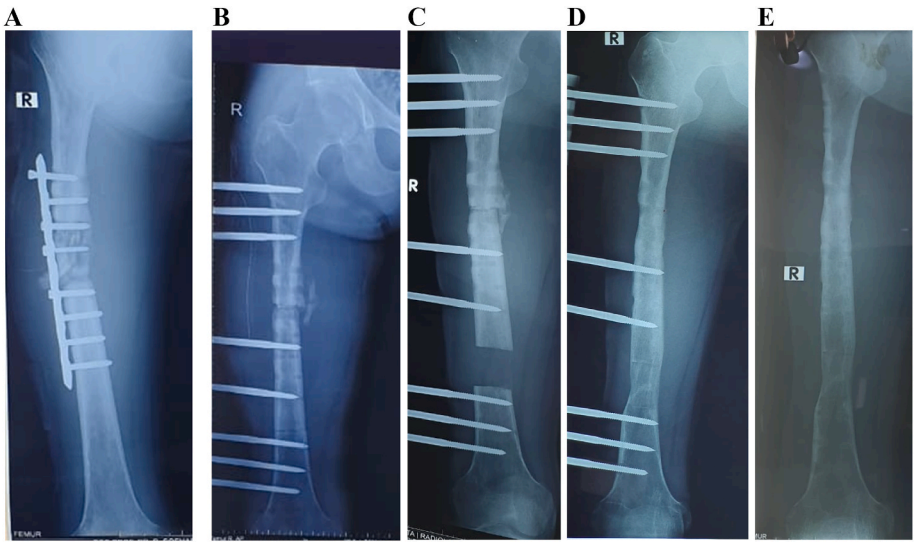

Fig. 4. Male 28 years old with infected non-union of right shaft femur after internal fixation with plate and screw. **A.** Preoperative radiograph, **B.** Immediate post-operative, **C.** During lengthening period showed 4 cm "Straight type" callus at distraction site, **D.** Radiograph at final follow-up showed complete bone union both on distraction and docking site. **E.** After removal of monorail fixator.

gap and distraction at the corticotomy site to achieve the necessary length. This technique has several advantages compared to bone transport include a higher union rate at the docking site, fewer complications, strong mechanical construct, easier to maintain alignment [9,14]. One of the difficult issues is docking site bone union which commonly fail in bone transport technique. Several problems which lead to the nonunion of the docking site were skin folding, soft tissue entrapment, and bone mal-alignment [7,8]. During ASRL procedure, direct compression between bone edges can be controlled and avoid any entrapment of soft tissue. Primary bone grafting also possible to perform during the compression procedure [14]. Therefore, the union of docking sites could be more predictable with ASRL technique. In our recent study, skin necrosis around the docking site of the tibia case leads to one case of docking site nonunion. Poor skin/soft tissue conditions along with shortening procedure may lead to skin necrosis and should be highly considered during performing ASRL procedure.

Distraction site callus formation was another issue to consider during this procedure. Metaphyseal distraction has a higher chance to have bone regeneration compared to diaphyseal distraction [15]. However, the decision to choose a distraction site can be different in each case. In our recent study, a diaphyseal distraction site was performed in the majority of the case. There were two cases of corticotomy fracture at the distraction site, which did not interfere with the callus formation, and good quality of bone was still obtained. The diaphyseal distraction process should be performed with closed follow-up. The performing surgeon should evaluate the decision to delay the distraction process during the follow-up period. One case of poor callus formation (Pillar type) occurred in our recent study. This was involving a tibia diaphyseal distraction case which has some period of loss of follow-up. Another problem included persistent infection, which leads to the "opposite type" of callus formation. Fortunately, the complete bone union still obtained and the patient could walk without an assistive device after debridement and removal of the monorail fixator.

Several studies have been reported the outcome of ASRL procedure. Baruah et al. reported a comparative study between ASRL and bone transport showed that the bone union rate was 100% and 95%, respectively [9]. They also found that complications are higher with IBT technique. Another study by Sigmund et al., showed that ASRL had lower rate of docking site surgery compared to bone transport (5% vs 66.7%) [7]. The ideal bone defect to be treated with ASRL procedure is < 3 cm. We found in our recent study that a bone defect up to 6 cm of the femur and 4 cm of tibia could be treated with ASRL procedure. This finding was also reported by Baruah et al. which bone defect 3–8 cm could be treated with ASRL procedure [9]. However, consideration to the soft tissue condition is mandatory.

This study has several limitations. This study was a retrospective series which has its own limitation in data collection and difference in follow-up period. The recent study also involved no comparative group with another procedure/device which may have different success/complication rate. However, we believe this study still could give some additional information to the previous literatures. The recent study support to the previous literatures on the larger size of tibia/femur bone defect (>3 cm) that can be treated with ASRL procedure. The possible problems/complications related to ASRL procedure also have been reported in this study.

5. Conclusions

Acute shortening and re-lengthening (ASRL) could be reliable as a method of treatment for femur/tibia nonunion associated with the bone defect. Several possible complications need to be considered prior to perform this procedure.

Declaration of competing interest

None.

Acknowledgment

None.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.amsu.2021.102621.

Provenance and peer review

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Conflicts of interest

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Ethical approval

The paper has been approved by Hospital Ethical committee.

Consent

Informed consent to the patients has been performed prior to this publication.

Author contribution

Asep Santoso: Perform surgery, writing the paper Hendra Cahya Kumara: Data collection and analysis Seti Aji Hadinoto: Data collection and Analysis Dimas Prasetyo Adi Prakoso: Data collection and analysis Mujaddi Idulhaq: Patients Clinical examination, writing the paper Tito Sumarwoto: Patients Clinical examination, writing the paper Ismail Mariyanto: Final evaluation.

Registration of research studies

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Guarantor

The Guarantor is the one or more people who accept full responsibility for the work and/or the conduct of the study, had access to the data, and controlled the decision to publish Asep Santoso, MD.

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