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Meta Analysis

Efficacy of trifocal versus bifocal bone transport on large tibial bone defect: a systematic review and meta-analysis

I. Wayan Subawa*, Putu Astawa, Priza Razunip, Anak A. G. D. Maha, Gede M. Putra, Agung K. Arnaya, Ryan Putra, Ketut K. A. Marta, Agus S. Putra, Nariswari A. Wiraputri

Department of Orthopaedic and Traumatology, Sanglah Hospital/Faculty of Medicine, University of Udayana, Bali, Indonesia

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***Correspondence:**
Dr. I. Wayan Subawa,
E-mail: seemadeepakmysore@gmail.com

ABSTRACT

One of the most common long-term complication of chronic osteomyelitis of tibia is segmental bone loss. One of the methods to manage the segmental bone loss in osteomyelitis is bone transport technique, which is able to reconstruct a defect of more than 6 cm. This paper aims to systematically review and analyze the outcome of bifocal and trifocal bone distraction technique on the tibial bony defect. A comprehensive literature search was performed using PubMed, Google Scholar, and Cochrane library. The inclusion criteria were any studies about comparison between bifocal bone transports with trifocal bone transport in management of large tibial bone defect. The outcomes assessed includes external fixation index, duration of regenerate consolidation, lengthening speed, bone transport distance, and operating time. Two studies reported shorter external fixation index in total of 57 fractures in the trifocal group and 61 fractures in the bifocal group. The meta-analysis showed significant difference in external fixation index between the two groups (Figure 1; RR=-44.37; 95% CI 73.73-15.01; p<0.0001) with significant heterogeneity (Chi square=11.38, p=0.0007); I2: 91%. Although only two studies were compared, both studies had almost similar subjects, and shown that trifocal bone transport technique had faster external fixator index compared to the bifocal bone transport group in the setting of severe bone loss in tibial fracture.

Keywords: Bone loss, Distraction osteogenesis, Bifocal bone transport, Trifocal bone transport

INTRODUCTION

One of the most common long-term complication of chronic osteomyelitis of tibia is segmental bone loss.[1] This bone loss may be caused by diminished blood supply, either due to damaged blood vessels or by chronic increase of intramedullary pressure from accumulation of purulent material inside the medulla, creating sequester.[2-4] This devitalized bone is not viable for bony regeneration and may become a focus of infection, thus its removal is mandatory for osteomyelitis management.[5,6] Soft tissue loss due to infection spread further complicates this attempt.[7] These aspects pose a great challenge for the orthopaedic surgeon on managing this disease.[8]

Various method has been created to manage the segmental bone loss in osteomyelitis, such as Masquelet technique, vascularized bone grafts, fibular graft, and bone transport technique.[9-13] Among these, only bone transport technique that is able to reconstruct a defect of more than 6 cm.[11] Using the Ilizarov frame this procedure transports a vascularized, osteotomized bone segment across the defect while simultaneously the bone healing process occur behind its trail, which is called distraction osteogenesis.[14] However, conventional Ilizarov fixator has its own flaws, such as a long period of fixation that leads to significant patient discomfort and stiffness of adjacent joint if physiotherapy is not applied properly. To overcome those drawbacks, the unilateral rail system was introduced which

requires less surgical techniques and has greater patient acceptance. Moreover, this device is also more acceptable to the patients because it is less cumbersome.[8]

Several variations have been developed on the bone transport technique. Two of the most commonly used are bifocal and trifocal bone transport.[15,16] These methods are developed to decrease the amount of time required for completion of the regeneration of the bone, hence shorten the duration of the patients to be attached with Ilizarov frame.[17] However, each of these methods has its own advantages and disadvantages. The trifocal method has been proven to have faster regeneration, which reduced the duration of distraction by 2.5 times, compared to bifocal method. However, this method requires more complex surgery and additional frame.[18,19]

This paper aims to systematically review and analyze the outcome of bifocal and trifocal bone distraction technique on the tibial bony defect.

METHODS

Search strategy

A systematic review was conducted in accordance to preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines (Figure 1).[20] A comprehensive literature search was performed to gather a full-length, peer-reviewed paper in English on comparison of outcome between bifocal and trifocal bone transport technique on large tibial bone defect until March 2021. We searched PubMed, Google Scholar, and Cochrane library. The focus in this systematic review is to compare bifocal bone transport with trifocal bone transport in treatment of large tibial bone defect. Keywords in the search matched the MeSH rule and term used for management ("bifocal bone transport" or "trifocal bone transport"), then terms for tibial location administered ("large tibial defect").

Inclusion criteria

The inclusion criteria were any studies about comparison between bifocal bone transports with trifocal bone transport in management of large tibial bone defect. The outcomes assessed includes external fixation index, duration of regenerate consolidation, lengthening speed, bone transport distance, and operating time. Given the limited number of researches, there are no limitation in patient's demographics, though literatures which is not in English were excluded.

Quality evaluation

Assessment of study quality and risk of bias assessed using criteria developed by the Oxford center for evidence-based medicine, perspicacity defined by the grades of recommendation assessment, development and evaluation (GRADE) working group, and sanction made by the agency for healthcare research and quality (AHRQ).

While the class of evidence is categorized into "class I" for good quality RCT, "class II" for moderate to poor quality RCT and good quality cohort, "class III" for moderate or poor-quality cohorts and case-control studies, "class IV" for the case series.

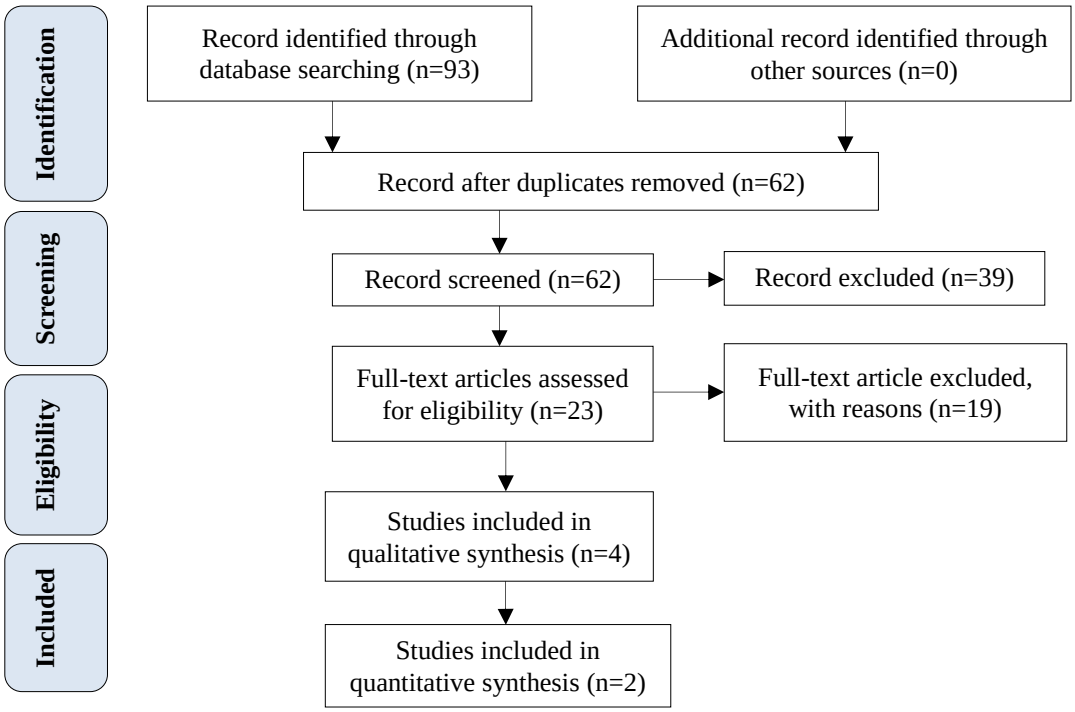

Figure 1: The strategy for conducting this study based on PRISMA guideline.

RESULTS

The preliminary electronic search of all databases resulted in 74 records, and were screened for duplicates, publication period, study methodology and language. This selection process yielded 4 final articles to be included in this review. The characteristic of patients and outcomes of included studies are shown in Table 1-4.

Prospective study by Zaidi et al assess the outcome of bifocal bone transport in tibial defective bone loss using functional and radiological association for the study and application of the method of ilizarov (ASAMI) in 15 patients, with 12 males and 3 females and mean age of 28.67 years old. Both functional and radiological ASAMI outcomes showed excellent result in 12 patient and good result in 3 patients. There was no major complication and union was achieved in all patients.[21]

Sala et al studied retrospectively total 12 patients which is divided into two groups. 6 patients treated by bifocal technique and 6 patients by trifocal. This study compared leghtening, bony result by ilizarov outcome score, functional result. In bifocal group, the average lenghtening obtained was 5.5 cm with a compression/distraction time of 15 weeks, and trifocal group, the average lenghtening obtained was 9.7 cm with a compression/distraction time of 14 weeks. 10 pateints got excellent (83%) and good (17%) in bony result by ilizarov outcome score. For functional score, 6 patients got excellent (50%), good (42%) in 5 patients, and fair (8%) in 1 patient. All 12 patients can back to preinjury work, no relaps of osteomyelitis and no significant residual deformities. The value angle of medial medial proximal tibia, lateral distal tibia, posterior proximal tibia, and anterior distal tibia were within normal range of measurement. Complete union was achieved and none of them needed surgical intervention because there is no progressive deformity in all patients.[22]

Study by Yushan et al suggest that the use of Ilizarov bone transport could eradicate infection and solve bone, soft tissue defect, but on the other hand there's downside of lengthy fixation time and risk of complication mostly pin tract infection. In this study mean EFI in trifocal group was 32.94±9.21 days/cm and in BF group 62.21±24.6 days/cm. Outcome in study by Yushan et al from 37 patient 12 achieved excellent results and 4 achieved good results.

Thus, author concludes that both bifocal and trifocal bone transport led to satisfactory bone and functional results, however trifocal group led to better functional outcomes than bifocal group, but in bony results bifocal group proved to be better than the trifocal group. This can be explained due to in trifocal group external fixator couldn't be removed sooner.[8]

Catagni et al conducted a retrospective study of 86 patients with a long tibial bone defect (≥8 cm), which 45 patients treated by bifocal bone transport and 41 patients by trifocal bone transport. The result of this study showed that trifocal bone transport group had significantly longer operating time ($p<0.001$) and increased bone transport distance ($p=0.017$) compared to bifocal bone transport technique. Also, the external fixation time ($p<0.001$), the healing index ($p<0.001$), and the number of true complications ($p<0.001$) were significantly reduced in trifocal bone transport group. Both groups achieved highly satisfactory ASAMI radiological and functional results, with no significant differences between them.[23]

Two studies reported shorter external fixation index in total of 57 fractures in the trifocal group and 61 fractures in the bifocal group (Table 5). The meta-analysis showed significant difference in external fixation index between the two groups (Figure 2; RR=-44.37; 95% CI 73.73-15.01; $p<0.0001$) with significant heterogeneity (Chi square=11.38, $p=0.0007$); I^2: 91%.

Table 1: List of studies included.

No.	Reference	Journal	Study design	Level of evidence
1	Aihemaitijiang 2020	Orthopaed Surg	Retrospective study	Level III
2	Zaidi et al 2016	Rawal Med J	Prospective study	Level II
3	Sala et al 2011	J Orthop Trauma	Retrospective study	Level III
4	Catagni et al 2019	Bone Joint J	Retrospective study	Level III

Table 2: Characteristic of patients.

No.	Reference	Total sample size	Bone transport technique		Age (years)	Gender	
			Trifocal	Bifocal		Male	Female
1	Aihemaitijiang 2020	37	16	21	40.11±10.32	28	9
2	Zaidi et al 2016	15	0	15	28.67	12	3
3	Sala et al 2011	12	6	6	44	8	4
4	Catagni et al 2019	86	41	45	43	77	9

Table 3: Outcome characteristics.

No.	Ref	Lengthening speed		External fixation index		Bone transport distance		Duration of regenerate consolidation		Compli-cation
		Bifocal (mm/day)	Trifocal (mm/day)	Bifocal (days/cm)	Trifocal (days/cm)	Bifoc-al	Trifo-cal	Bifoc-al	Trifo-cal	
1	Aihema-itijiang 2020	0.79±0.17	1.59±0.96	62.21±24.60	32.94±9.21	N/A	N/A	N/A	N/A	Without complica-tion
2	Zaidi et al 2016	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3	Sala et al 2011	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4	Catagni et al 2019	N/A	N/A	331.67±26.87	272.44±28.41	10.5 cm	12.5 cm	125 min	143 min	BFT: 28/45 TFT: 21/42

Table 4: Characteristic of ASAMI score.

No	Reference	ASAMI functional score		ASAMI radiological score		External fixation time		Healing index	
		Bifocal	Trifocal	Bifocal	Trifocal	Bifoc-al	Trifo-cal	Bifoc-al	Trif-ocal
1	Aihemaitijia-ng 2020	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	Zaidi et al 2016	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3	Aktuglu 2019	Excellent 172/502, good 156/502, fair 55/502, poor 10/502	Excellent 28/502, good 11/502, fair 3/502, poor 9/502	Excellent 275/502, good 132/502, fair 31/502, poor 16/502	Excellent 28/502, good 11/502, fair 3/502, poor 9/502	N/A	N/A	N/A	N/A
4	Sala et al 2011	12/15 (80%)	N/A	12/15 (80%)	N/A	N/A	N/A	N/A	N/A
5	Catagni et al 2019	Excellent 23/45 (51%), good 12/45 (27%), fair 8/45 (18%), poor 2/45 (4%)	Excellent 24/41 (59%), good 9/41 (22%), fair 6/41 (15%), poor 2/41 (5%)	Excellent 35/45 (78%), good 6/45 (13%), fair 2/45 (4%), poor 2/45 (4%)	Excellent 33/41 (81%), good 5/41 (12%), fair 1/41 (2%), poor 2/41 (5%)	345 days	261 days	44 days/cm	29 days/cm

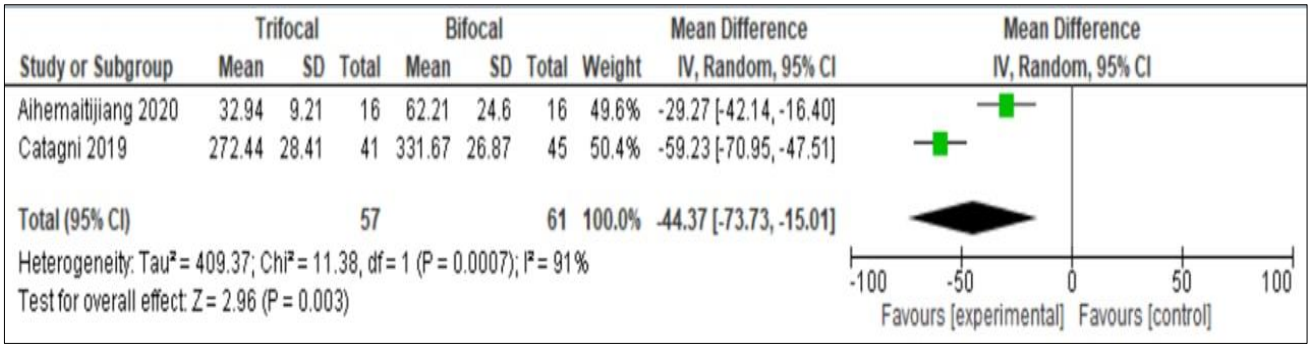

Figure 2: Forest plot of meta-analysis.

Table 5: Outcome of external fixation index.

No.	Ref	Trifocal		Bifocal	
		EFI (mean)	Samples	EFI (mean)	Samples
1	Aihemaitijiang 2020	32.94±9.21	16	62.21 ± 24.60	16
2	Catagni et al 2019	272.44±28.41	41	331.67±26.87	45

DISCUSSION

Bone transport has been used in management of tibial bone defect, and has been proven to achieve excellent outcome in various studies. Although there are several downsides in using bone transport technique, such us long period of frame usage, and frame related complication such as pin tract infection, and pin loosening.[23,24]

A study by Catagni et al reported that external fixation time and healing index were significantly reduced in trifocal bone transport group compared with bifocal group. This can be explained because trifocal bone transport was designed to accelerate bone defect closure and reduce time for treatment. Theoretically this technique could reduce regeneration time up to 50%. Furthermore, trifocal bone transport is also recommended as the treatment of choice in tibial defect >8 cm. Although trifocal bone transport shown better results than bifocal bone transport, there's also more difficulty in applying trifocal bone transport technique due to the complexity of procedure, thus further lengthen the operation time.[23]

Research from Aktuglu et al have large number of samples which is 619 samples, with mean age of 36 years, and author concludes bony union rate 88,8% whether using bifocal or trifocal bone transport. In this study bifocal bone transport is indicated for cases with bone defect <6 cm, and Trifocal bone transport is indicated for cases with bone defect >6 cm. This reason explains about lower score of bony union in the trifocal bone, compared to bifocal technique. Due to loss of bone defect greater than the bifocal group, it explains the bony union and functional score is lower than other studies. Author suggests that bone transport method (distraction osteogenesis) can be used using several methods, each with their own strengths and weaknesses. Author concludes that risk of refracture 3.7 times higher in tibial defect, and pin tract infection as the most common complication seen in using external fixator devices. Other conclusion in this study suggest that in order to produce satisfactory outcome in bone transport, radical debridement will be needed.[24]

Sala et al conducted a study in 22 patients with atrophic nonunion treated with nonunion resection and Ilizarov bone transport, and the result shown 100% union in all patients. Another important observation from the present study was the effectiveness of trifocal bone transport in terms of mean lengthening index (1.31 compared with 2.63 in the bifocal group) and average bone transport (9.7 cm versus 5.5 cm in the bifocal group).[22]

Zaidi et al also mentioned that success rate using the Ilizarov technique was 91%. Only pin-track infection is the most common complication using Ilizarov methods, and significant statistical heterogeneity was found for the complication. The rate of pin-track infection was 10-100% among included studies.[21]

Overall evidence

This systematic review and meta-analysis, retrospective studies dominated, reported external fixation index after bone transport procedure using bifocal or trifocal technique. Overall, the evidence was not sufficiently strong to determine which operative method was more superior. Although only two studies were compared, both studies had almost similar subjects, and shown that trifocal bone transport technique had faster external fixator index compared to the bifocal bone transport group.

CONCLUSION

In conclusion, this review reports the level of complication between each study was not significantly different, and author recommended trifocal bone transport technique due to significantly lower external fixation index, especially in the setting of severe bone loss in tibial fracture.

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