SYSTEMATIC REVIEW

Gradual Correction of Tibia Vara: A Systematic Review

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ABSTRACT

Background: Ring external fixators are used to create a gradual straightening of tibia vara through an osteotomy site. This systematic review aimed to examine the studies that reported the outcomes of gradual correction of tibia vara with ring fixators.

Methods: MEDLINE, Cochrane library, CINAHL databases have been enquired. Eligibility criteria included studies that were written in English and conducted on humans affected with tibia vara managed with ring fixators on gradual mode. Experimental studies on cadavers or virtual models, or studies with insufficient data were excluded. Two review authors have independently judged the individual studies for eligibility.

Results: Eleven studies containing 205 patients were included. Tibia vara gradual correction with ring fixator has shown satisfactory outcomes. Mechanical axis deviation improved Desired values of medial proximal tibial angle, and posterior proximal tibial angle have been restored by the end of treatment course.

Conclusions: The review demonstrated a utilitarian capability of ring fixators in running gradual correction programs in tibia vara. Flawless pre-operative planning is an essential prerequisite for perfect outcomes.

Keywords: genu varum; gradual correction; Ilizarov method; osteotomy; ring fixator; tibia vara

INTRODUCTION

Tiba vara is characterized by altered orientation of the proximal tibia leading to deviation of the leg toward the midline. Abnormal knee loading in tibia vara can accelerate degeneration process of the medial knee [1]. On the other hand, the lateral knee structures are overstretched which might result in laxity of the lateral collateral ligament. Tibial bone cut can be made surgically to allow angulation of bone segments relative to each other. Correction can be accomplished on acute or gradual basis [2]. However, higher degrees of correction are hard to be obtained with acute method due to limited tolerance of the surrounding neurovascular structures and soft tissues. Orthopedic surgeons have utilized external fixators to deliver a controllable gradual correction of bone fragments. Proper radiographs serve as a guide for the correction program. The bone segment of interest can be dragged to the desired location as long as the newly formed bone is malleable. Compared to mono-lateral bar external fixators, ring external fixators offers wider options for insertion of pins or wires [3].

However, the ultimate goal of the corrective surgery is to restore the normal alignment irrespective to the device used. It seemed that the literature about efficacy of ring external fixator in achieving satisfactory correction of tibia vara was not systematically reviewed so far. The main objective of this study was to provide a systematic review of pooled studies that have reported using ring fixators to treat the tibia vara on gradual fashion.

MATERIALS AND METHODS

The review strategy was performed according to Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [4]. Eligibility criteria included clinical studies that were published in English language and undertaken on human subjects who suffered from tibia vara and treated with ring fixators on gradual fashion. Case series, case-control, cohort, and non-randomized and randomized clinical trials in which the tibia deformity radiographic parameters were stated pre-operatively and post-operatively. Studies published earlier than 2000 have been not included. Reports contained subjects with severely distorted joint anatomy on top of tibia vara such as severe Blounts disease with medial plateau depression or degenerative worn-out medial knee compartment, were excluded. In addition, experimental studies performed on cadavers or virtual models as well as studies with insufficient data were excluded. Relevant research engines have been enquired including MEDLINE, Cochrane library, and CINAHL databases. References of the pooled studies were searched as well. The query terms used were “genu varum AND external fixator” and “genu varum AND gradual correction”. Titles and abstracts of the collected studies have been examined for eligibility by two independent reviewers. Any disagreement was resolved through discussion followed by a consensus. Three investigators were assigned for data collection from the retrieved studies. The collected data was double-checked independently by two researchers. Inconsistencies have been managed with discussion among the reviewers. The radiographic angular tibial parameters were collected including medial proximal tibia angle (MPTA) measured in degrees, posterior proximal tibial angle (PPTA) measured in degrees, and mechanical axis deviation (MAD) presented in millimeters. The normal ranges of MPTA and PPTA were defined as 85 to 90 and 77 to 84 degrees, respectively [5]. MAD values of 0 ± 3 millimeters were interpreted as normal. Study design, year of publication, level of evidence, participants’ number, and participants age have been collected for the individual studies. The risk of bias in the included studies was evaluated by two reviewers independently based on the Risk Of Bias In Non-randomized Studies - of Interventions (ROBINS-I) guidelines [6]. Bias risk judgement variations between the

reviewers were tackled through discussion. A third reviewer's opinion was sought in case of failure to reach a consensus. No meta-analysis was performed due to high heterogeneity of the included studies. Alternatively, Synthesis Without Meta-analysis (SWiM) reporting guideline has been adopted to obtain a quantitative synthesis of evidence [7].

RESULTS

Eleven studies have met the inclusion criteria containing 205 patients with 320 legs treated with ring fixator gradual correction method (Fig 1). Two patients out of Kurian series were treated with mono-lateral fixator that have been removed from analysis.[8][8] Characteristics of the included studies and relevant outcomes were summarized in table 1. Risk of bias was determined based on ROBINS-I tool risk domains as shown in table 2. Three out of 11 studies (27.3%) have been labelled as moderate risk whereas the rest of the retrieved study were judged as low risk of bias. Outcomes of the individual studies were presented in the table 3. The MAD was reported in 10 out of 11 studies with mean difference of 52.98 mm representing a decrease in the pre-operative MAD mean value (59.93 mm) to fall medially closer to the knee center by mean of 6.95 mm. Also, frontal plane parameters were obtained from 10 out of 11 studies. Pre-operative abnormally low MPTA values (average 73.81°) showed an increase toward the desired range (85-90°) reaching post-operative MPTA mean of 88.74 with absolute mean difference of 14.92°. Nine out of 11 studies have evaluated sagittal plane characteristics. No significant alteration of the sagittal plane has been observed in terms of PPTA pre-operative and post-operative values by 2.75° absolute mean difference. Owing to the observational nature of the pooled studies, we consider the overall quality of evidence presented as low.

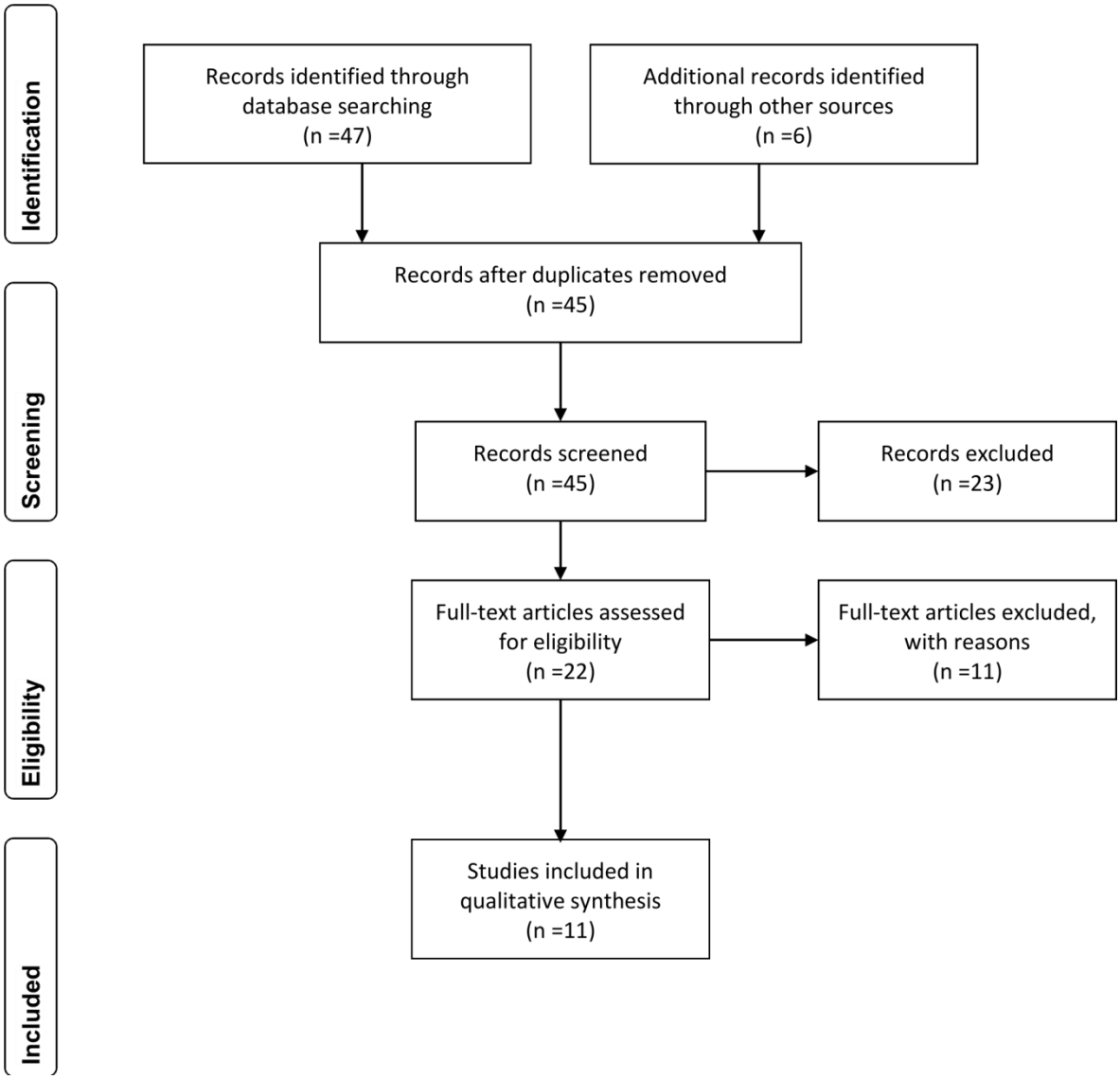

Figure 1: Flowchart summarizes the process adopted for identification and inclusion of the relevant studies.

Table 1: Characteristics of the retrieved studies.

Study, year of publication	Study design	Number of patients	Number of legs	Age (year)	Weight (Kg)	M:F	Etiology	Frame time (week)	Follow up (year)	Device
Feldman *et al.*, 2003	Case series	19	22	9.9	64.3	13:6	Blounts disease	14.6	2.8	TSF
Gordon *et al.*, 2005	Case series	15	19	14.9	113	-	Tibia vara	18	5	Ilizarov
Kim *et al.*, 2011	Case series	48	96	15	-	-	Skeletal dysplasia	-	2	Ilizarov
Li 2013	Retrospective cohort	14	14	13	127	9:5	Tibia vara	16.3	1.2	TSF
Park *et al.*, 2013	Case series	11	21	24.8	-	8.3	Tibia vara	24.7	3.8	Ilizarov
Sachs *et al.*, 2015	Case series	23	25	14.8	-	21:2	Blounts disease	14.9	-	TSF
Meselhy, 2016	Prospective cohort	11	11	15.7	-	7:4	Tibia vara	17.6	1.3	TSF
Özkul *et al.*, 2017	Case series	25	50	19.4	-	15:10	Blounts disease, rickets, skeletal dysplasia	20	2.4	Smart frame
El-Gafary 2019	Case series	7	10	14	-	3:4	Blounts disease	14	NA	Ilizarov
Kurian *et al.*, 2019	Case series	10	20	12.8	-	9:1	Achondroplasia	26.40	3.73	Ilizarov
Saw *et al.*, 2019	Case series	22	32	15	-	12:10	Blounts disease	37.6	3.6	TSF/Ilizarov
Total		205	230							

M:F; male-to-female ratio, TSF; Taylor Spatial Frame

Table 2: Risk of bias assessment of the included studies.

Study	Bias due to confounding	Bias in selection of participants into the study	Bias in classification of interventions	Bias due to deviations from intended interventions	Bias due to missing data	Bias in measurement of outcomes	Bias in selection of the reported result	Overall risk of bias
Feldman *et al.*, 2003	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Gordon *et al.*, 2005	Low risk	Moderate risk	Low risk	Moderate risk	Low risk	Low risk	Low risk	Moderate risk
Kim *et al.*, 2011	Low risk	Moderate risk	Low risk	Low risk	Low risk	Low risk	Low risk	Moderate risk
Li 2013	Moderate risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Moderate risk
Park *et al.*, 2013	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Sachs *et al.*, 2015	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Meselhy, 2016	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Özkul *et al.*, 2017	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
El-Gafary 2019	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Kurian *et al.*, 2019	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Saw *et al.*, 2019	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk

Table 3: Summary of pre-operative and post-operative values of the key deformity parameters of tibia vara in the reviewed studies.

Study	MAD								MPTA								PPTA							
	Pre-operative				Post-operative				Pre-operative				Post-operative				Pre-operative				Post-operative			
	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max
Feldman *et al.*, 2003	53.9	-	31	120	1.4	-	0	4	71.4	-	38	80	87.9	-	84	90	71.8	-	60	83	80.9	-	78	84
Gordon *et al.*, 2005	108	-	41	208	1	-	-30	20	71	-	61	77	88	-	83	98	71	-	58	88	77	-	57	89
Kim *et al.*, 2011	19.4	23	-	-	10	15.8	-	-	85.1	6.5	-	-	90.5	7.2	-	-	81.2	9.6	-	-	76.1	11.7	-	-
Li 2013	90	-	60	150	10	-	0	30	66	-	42	78	88	-	85	92	80	-	75	82	81	-	78	83
Park *et al.*, 2013	28.3	6.1	-	-	5.8	2.1	-	-	72.4	2.1	-	-	90.1	2.8	-	-	79.4	3.2	-	-	78.8	3.1	-	-
Sachs *et al.*, 2015	56.24	23.02	20	115	6.2	16.1	-10	57	74.32	5.05	57	80	89.88	3.44	80	97	76.68	6.68	67	96	79.84	4.66	69	89
Meselhy, 2016	75.73	14.7	60	107	12.18	11.36	-1	26	67.91	8.68	49	77	87.18	3.97	81	93	72.45	11.67	42	82	80.18	1.83	77	83
Özkul *et al.*, 2017	37.6	21.6	9	98	8.4	12.1	3	44	76	7.2	-	-	89	2.5	-	-	75.5	5.3	-	-	80.3	2.5	-	-
El-Gafary 2019	-	-	-	-	-	-	-	-	73.6	13.38	65.1	100	87.6	0.92	86.6	89.2	80.4	5.62	71.3	87.3	79.1	3.39	74.4	82.1
Kurian *et al.*, 2019	35.4	4.85	28	48	5.50	4.21	0	15	80.40	1.57	76	82	89.20	1.85	86	92	-	-	-	-	-	-	-	-
Saw *et al.*, 2019	94.7	51.4	-	-	9	37.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	59.93		9	208	6.95		-30	57	73.81		38	100	88.74		80	98	76.49		42	96	79.25		57	89

MAD; mechanical axis deviation, Max; maximum value, Min; minimum value, MPTA; medial proximal tibial angle, PPTA; posterior proximal tibial angle, SD; standard deviation.

DISCUSSION

In this systematic review, The MAD was reported in 10 studies containing 220 bowlegs that have undergone gradual correction with ring fixators. The post-operative MAD showed a favorable medial shift toward the knee center by mean of 6.95 mm. In fact, this value falls outside the normal range (0 ± 3 mm) indicating a residual limb deformity existence. However, MAD alone cannot be used for judgement of tibia vara correction because deviated limb mechanical axis could be attributed to other elements, besides tibia deformity, like concurrent deformed adjacent bones or lax joints [10,15]. Pre-operative and post-operative MPTA data derived from 288 legs, which have been presented in 10 studies, demonstrated post-operative optimized MPTA (88.74°). Unlike acute correction, limb angular correction with gradual techniques provides the treating surgeon with the ability to post-operatively adjust the joint orientation to the desired angle during the distraction period.[2]. This advantage can minimize the possibility of under-correction or over-correction. The PPTA of 268 affected tibias, included in 9 studies, was evaluated before and after gradual correction with ring fixator which displayed a relative stability of sagittal plane (r2.75°). Ring fixators offer a sufficient control over the bone fragments on either side of the osteotomy while steering the correction in the target plane as planned. It is desirable to keep the sagittal plane unaltered while addressing the frontal plane in cases of isolated tibia vara [1].

Overall assessment of the reviewed studies demonstrated a satisfactory efficacy of the gradual correction method with ring fixators in treatment patients of tibia vara. Moreover, in one systematic review, reported higher accuracy of gradual correction method compared to the acute method in treatment of Blounts disease [17]. The authors considered this evidence as low due to lack of randomized controlled trials (RCT). It can be challenging to run RCTs because tibia vara cases requiring surgical correction are relatively rare.

CONCLUSIONS

Based on the available literature, the authors found low evidence supporting superior accuracy of gradual correction method using ring external fixator for treatment of patients with tibia vara over acute correction strategy. However, certain advantages of ring fixators could make them more useful like post-operative adjustability and weightbearing mobility. Meticulous individualized pre-planning of tibia vara patients could help selecting the appropriate treatment strategy. Facility of ring external fixators should be ensured in all orthopedic institutions. Orthopedic surgeons should master the basic skills required for proper application of ring fixators.

Conflicts of Interest: None.

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REFERENCES

1. Robin JG, Neyret P. High tibial osteotomy in knee laxities: Concepts review and results. EFORT open Rev. 2016 Jan;1(1):3–11.
2. Feldman DS, Madan SS, Ruchelsman DE, Sala DA, Lehman WB. Accuracy of correction of tibia vara: acute versus gradual correction. J Pediatr Orthop. 2006;26(6):794–8.
3. Li Y, Spencer SA, Hedequist D. Proximal tibial osteotomy and Taylor Spatial Frame application for correction of tibia vara in morbidly obese adolescents. J Pediatr Orthop. 2013;33(3):276–81.
4. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews [Internet]. Vol. 372, BMJ (Clinical research ed.). School of Public Health and Preventive Medicine, Monash University, Melbourne, Australia matthew.page@monash.edu.; 2021. p. n71. Available from: http://europepmc.org/abstract/MED/33782057
5. Paley D, Herzenberg JE, Tetsworth K, McKie J, Bhave A. Deformity planning for frontal and sagittal plane corrective osteotomies. Orthop Clin North Am. 1994 Jul;25(3):425–65.
6. Sterne JAC, Hernán MA, Reeves BC, Savović J, Berkman ND, Viswanathan M, et al. ROBINS-I: a tool for assessing risk of bias in non-randomised studies of interventions. BMJ [Internet]. 2016 Oct 12;355:i4919. Available from: http://www.bmj.com/content/355/bmj.i4919.abstract
7. Campbell M, McKenzie JE, Sowden A, Katikireddi SV, Brennan SE, Ellis S, et al. Synthesis without meta-analysis (SWiM) in systematic reviews: reporting guideline. BMJ [Internet]. 2020 Jan 16;368:l6890. Available from: http://www.bmj.com/content/368/bmj.l6890.abstract
8. Kurian BT, Belthur M V, Jones S, Giles SN, Fernandes JA. Correction of Bowleg Deformity in Achondroplasia through Combined Bony Realignment and Lateral Collateral Ligament Tightening. Strateg trauma limb Reconstr. 2019;14(3):132–8.
9. Feldman DS, Madan SS, Koval KJ, van Bosse HJP, Bazzi J, Lehman WB. Correction of tibia vara with six-axis deformity analysis and the Taylor Spatial Frame. J Pediatr Orthop. 2003;23(3):387–91.
10. Gordon JE, Heidenreich FP, Carpenter CJ, Kelly-Hahn J, Schoenecker PL. Comprehensive treatment of late-onset tibia vara. J Bone Joint Surg Am. 2005 Jul;87(7):1561–70.
11. Kim S-J, Cielo B, Song S-H, Song H-R, Song S-Y. Gradual bilateral genu varum correction in skeletal dysplasia using the Ilizarov method. J Orthop Sci Off J Japanese Orthop Assoc. 2011 Jul;16(4):405–12.
12. Park YE, Song SH, Kwon HN, Refai MA, Park KW, Song HR. Gradual correction of idiopathic genu varum deformity using the Ilizarov technique. Knee Surg Sports Traumatol Arthrosc. 2013 Jul;21(7):1523–9.
13. Sachs O, Katzman A, Abu-Johar E, Eidelman M. Treatment of Adolescent Blount Disease Using Taylor Spatial Frame With and Without Fibular Osteotomy: Is There any Difference? J Pediatr Orthop. 2015;35(5):501–6.
14. Meselhy MA. Management of adolescent tibia vara using Taylor spatial frame. Acta Orthop Belg. 2016 Dec;82(4):745–53.
15. Özkul B, Çamurcu Y, Sokucu S, Yavuz U, Akman YE, Demir B. Simultaneous bilateral correction of genu varum with Smart frame. J Orthop Surg [Internet]. 2017 May 1;25(2):2309499017713915. Available from: https://doi.org/10.1177/2309499017713915
16. Saw A, Phang ZH, Alrasheed MK, Gunalan R, Albaker MZ, Shanmugam R. Gradual correction of proximal tibia deformity for Blount disease in adolescent and young adults. J Orthop Surg (Hong Kong). 2019;27(3):2309499019873987.
17. Gilbody J, Thomas G, Ho K. Acute versus gradual correction of idiopathic tibia vara in children: a systematic review. J Pediatr Orthop. 2009 Mar;29(2):110–4.