

Telescopic rods vs. non-telescopic rods in the treatment of osteogenesis imperfecta: A systematic review

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Abstract

Purpose: To compare revision and complication rates between telescopic and non-telescopic intramedullary rods in children with osteogenesis imperfecta (OI).

Methods: A systematic review was conducted according to Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines and registered in the PROSPERO database (CRD42021287054). Databases were searched up to December 2025. Studies reporting surgical outcomes of intramedullary fixation in OI were included. Meta-analysis was performed using random-effects models.

Results: Thirty-six studies including 1711 patients and 2459 treated bones were analyzed. Telescopic rods were associated with significantly lower revision rates compared to non-telescopic rods. No significant difference in overall complication rates was observed.

Conclusion: Telescopic rods provide improved implant survival and reduce the need for reoperation in growing children with osteogenesis imperfecta, supporting their preferential use in clinical practice.

Keywords: osteogenesis imperfecta, telescopic rods, intramedullary fixation, pediatric orthopedics, systematic review

Introduction

Osteogenesis imperfecta (OI) is a congenital connective tissue disorder characterized by qualitative or quantitative alterations in type I collagen. The main clinical manifestations include skeletal deformities and bone fragility, resulting from lower mineral density. Extra-skeletal features commonly associated with OI include blue sclera, dentinogenesis imperfecta, vascular fragility, and hearing loss.¹

Among the pharmacological treatments available, the use of bisphosphonates has gained recognition in recent years due to studies demonstrating their efficacy, supporting and recommending their application.² The concentration of bisphosphonates in the mineralized bone matrix inhibits bone resorption by osteoclasts and favors an increase in bone mineral density. The treatment is associated with outcomes such as increased cortical thickness, height of the vertebral body, and a reduction in musculo-skeletal pain and fatigue.³

Orthopedic surgery remains a cornerstone in the management of deformities and fracture prevention in moderate

to severe OI.⁴ Several devices are available for stabilizing fractures or bones that have undergone osteotomy. However, the bones of patients with OI are fragile, and some of these devices—such as an isolated plate—can create points of weakness at their ends, predisposing the bone to fractures. Intramedullary fixation is widely considered the most effective strategy for stabilizing fractures and osteotomies in OI. Non-telescopic intramedullary devices provide initial stability but lose effectiveness over time as the bone grows longitudinally, when the nail becomes proportionally smaller in

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relation to the bone.⁴ In a meta-analysis of non-telescopic intramedullary fixation in patients with OI, the reoperation rate was 39.4% across 7 studies ($n=229$ patients) that met the inclusion criteria.⁴

The telescopic rod was developed to provide stability and protection during bone growth. The rod occupies the medullary canal and telescopes as the bone grows longitudinally. Different types of telescopic rods are available, with the Fassier-Duval (FD) rod currently being the most widely used intramedullary growth device in the surgical treatment of OI.^{5–8} Unlike older telescopic rods, the FD rod can be inserted through a single incision at one end of the bone, preserving the other. This approach allows for a more biological procedure with reduced morbidity.^{8,9} However, the FD rod is more expensive and requires a longer learning curve compared to non-telescopic implants.^{10,11} Complications, including joint invasion, migration, limitations in telescoping, and structural deformity of the FD rod, have been documented.^{8,12}

Several studies^{13–18} have demonstrated the advantages of telescopic fixation over non-telescopic fixation. The aim of this study was to compare the rates of complications and reoperations associated with the use of telescopic versus non-telescopic rods in patients with OI. Through a systematic review, we seek to assess the frequency of complications and surgical revisions associated with each approach, while also estimating the relative risks of these outcomes between the two treatment modalities.

Methods

Registration and protocol

This review was registered in the PROSPERO database—registration number: CRD42021287054. The systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses¹⁹ guidelines and the methodological recommendations outlined in the Cochrane Handbook for Systematic Reviews of Interventions.²⁰

Eligibility criteria

The inclusion criteria for selecting studies were: publication in scientific journals between 01/01/2000 and 12/31/2025; evaluation of patients diagnosed with OI undergoing surgical treatment (osteotomies to correct deformities or fractures) with intramedullary bone fixation; reporting the number of procedures and their outcomes, including the number of complications and/or reoperations; and description of the type of rod used in the procedure.

Studies including populations with conditions other than OI, studies that did not specify the type of rod used, case reports, systematic reviews, meta-analyses, and studies published outside the specified date range were excluded.

Information sources and search strategies

The original literature search was conducted in January 2024 and was subsequently updated in April 2026 to identify newly published studies. Both searches were performed using the same predefined methodology and search strategy across three electronic databases: Medline/PubMed, Embase, and LILACS. The search strategy included the descriptors “osteogenesis imperfecta” and “surgery,” combined using the expression (“osteogenesis imperfecta” AND surgery). The updated search expanded the publication period to include studies published between 2000 and December 2025. No language or country restrictions were applied.

Study selection

The study selection process was conducted independently by two authors (M.O.C. and M.P.S.), with any divergence resolved by a senior researcher (R.Y.). The selection followed a three-stage process: (1) screening of titles, (2) screening of abstracts, and (3) retrieval and thorough reading of full texts to apply the eligibility criteria.

Data extraction process

Data from the included studies were independently extracted into a spreadsheet by three members of the research team. In cases of disagreement regarding the extracted data, the decision of the senior author was followed.

Data items

General study characteristics extracted included the year of publication, country, and study design. Population data included the number of patients assessed, gender distribution (when available), patient age, Sillence classification, and follow-up duration. Procedure- and outcome-related data included the total number of bone segments operated on, the number of operations by bone type, the number of procedures by rod type, the number and categories of complications, the number of revisions, and the interval between the initial surgery and the first revision.

In this study, a revision was defined as the need for reoperation of the rod after the initial procedure. The primary outcomes assessed were the occurrence of complications and the need for surgical revision.

Synthesis methods and effect measures

Data were described with frequency and confidence interval for qualitative variables, and measures of central tendency (mean and median) and measures of dispersion (standard deviation, interquartile range, minimum, and

maximum) for quantitative variables. All the statistical tests used a two-tailed α (p -value) of 0.05 and a 95% confidence interval (CI).

The number of bone segments that underwent surgical procedures and the assessment of the need for correction and revision were considered as the analytical unit for the combined effect of the studies. Data were grouped according to the type of rod used in the surgical procedure to compare outcomes (1) occurrence of complications and (2) need for revision. Pooled effects were calculated using meta-analysis models with the inverse variance method. Heterogeneity was considered substantial when I^2 exceeded 70%. When heterogeneity was not significant, fixed effects models were used. Heterogeneity between studies was assessed visually using Forest Plots and tested statistically with the I^2 test.

The analyses were performed using R Studio software (R Foundation for Statistical Computing, Vienna, Austria) with the metafor package.

Study risk of bias and certainty assessment

The methodological quality of individual studies was assessed using the Joanna Briggs Institute Critical Appraisal Tools,²¹ tailored to each study design. Studies were categorized as having low risk of bias ($\geq 80\%$ of “yes” responses), moderate risk of bias (60%–79% of “yes” responses), or high risk of bias ($< 60\%$ of “yes” responses). To evaluate the overall confidence in the review findings, the GRADE approach was employed, considering factors such as risk of bias, inconsistency, and imprecision in the evidence synthesis.

Assessment of publication bias

To evaluate the presence of publication bias, a funnel plot was constructed to visually assess asymmetry in the distribution of study effect sizes. As recommended by Higgins et al.²⁰ this analysis was performed only when at least 10 studies were included in the meta-analysis, ensuring sufficient statistical power to detect asymmetry.

Additionally, Egger’s regression test was conducted to statistically quantify the presence of asymmetry and potential publication bias. A p -value < 0.05 from Egger’s test was considered indicative of significant publication bias.

Results

Study selection

The search strategy resulted in 970 records: 492 in the Medline/PubMed database, 439 in Embase and 39 in LILACS. After excluding duplicates and screening by title

and abstract, 128 studies were carefully analyzed by the authors through full-text reading. Finally, 36 studies that met the eligibility criteria were selected for this systematic review. The flowchart representing the study selection is shown in Figure 1.

Study characteristics

The general characteristics of the included studies are presented in Table 1. The studies were published between 2000 and 2025, and the majority followed a case series design (33 out of 36—91.7%; 95% CI 79.4%–97.6%), with 2 cohort studies (5.6%; 95% CI 1.2%–16.6%) and 1 case-control study (2.8%; 95% CI 0.3%–12.3%). Only one study was prospective (2.8%; 95% CI 0.3%–12.3%) and all the other studies were retrospective (97.2%; 95% CI 87.7%–99.7%). The studies were conducted in 17 different countries, with the United States having the highest frequency (6/36 studies, 16.7%), followed by China, South Korea, France, and Turkey (3/36 each, 8.3%), Brazil, Egypt, India, Italy, Taiwan, and the United Kingdom (2/36 each, 5.6%). South Africa, Germany, Japan, Pakistan, Poland, and Romania each had one study (1/36, 2.8%).

Of the 36 studies included, 22 described the exclusive use of telescopic rods^{3,22–37} (61.1%; 95% CI 44.8%–75.7%), 8 described non-telescopic rods^{38–45} (22.2%; 95% CI 11.1%–37.6%), and 6 studies evaluated both types of rods^{13–17,46} (16.7%; 95% CI 7.3%–31.2%).

A total of 1711 patients underwent orthopedic surgery, with 1507 (88.6%) having their sex reported: 820 (54.4%) males and 687 (45.6%) females. The studies included an average of 49 patients, with sample sizes ranging from 5 to 626 patients.

A total of 2459 bones underwent intramedullary fixation across the included studies (Table 2). Two studies did not specify which bone segments were operated on,^{27,45} accounting for 179 bones (femur, tibia, or humerus). However, it was possible to identify procedures on 2358 bone segments (95.9%), including 1654 femurs (70.1%), 663 tibias (28.1%), and 41 humeri (1.7%). Most telescopic rods used were of the Fassier-Duval type.

According to the classification by Sillence et al.⁴⁷ most studies differentiated the OI types between patients and operated bone segments. De Jager et al.¹⁶ and Shin et al.³¹ related the Sillence types only to the bones that underwent surgery, while Cho et al.,²⁴ Azzam et al.²⁷ and others^{3,15,17,26,30,34,35,38,39,43,48–52} related the Sillence types only to patients (Table 3). Among the 1711 patients included, the Sillence classification was identified in 1492 (87.2%). Procedures were carried out on 246 patients classified as Sillence I or II (16.5%), 664 as Sillence III (44.5%), 559 as Sillence IV (37.5%), and 23 as Sillence V or higher (1.5%).

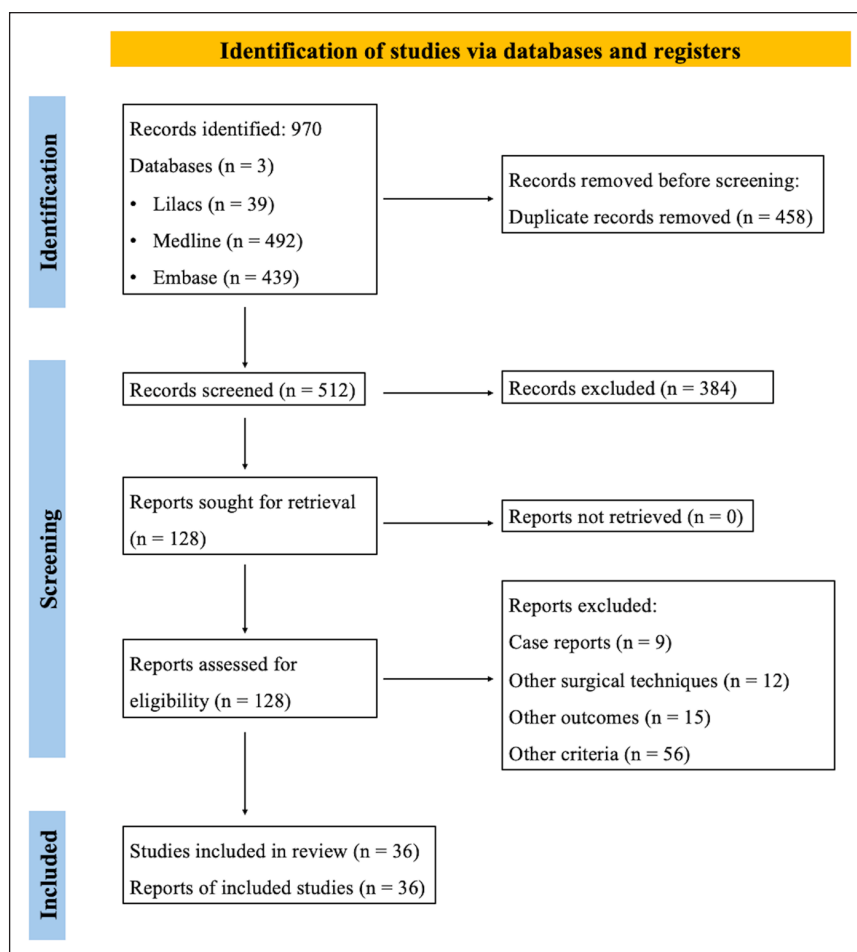


Figure 1. Flowchart for selecting studies on the treatment of patients with OI and the use of telescoped and non-telescoped rods. OI: Osteogenesis imperfecta.

The average follow-up for patients with bones fixed using telescopic rods was 5.6 years ($SD \pm 3.6$ years; range: 1–19 years), and for non-telescopic rods, it was 6.2 years ($SD \pm 2.3$ years; range: 3.1–11.4 years).

The patients who underwent intramedullary fixation described in the included studies had an average age ranging from 4 to 10 years, with an overall average of 6 years ($SD \pm 1.4$ years) for those with telescopic rods, and an average of 7 years ($SD \pm 1$ year), ranging from 5 to 10 years for those with non-telescopic rods. All reported procedures were primary surgeries, performed for either deformity correction or fracture stabilization. The most frequent complications for both rod types are summarized in Table 4, with migration being the most frequent complication for patients with telescopic rods and fracture being the most frequent for those with non-telescopic rods.

Among patients who required revision, the mean time to reoperation was 3.3 years in the telescopic group and 2.8 years in the non-telescopic group (Table 5).

Pooled effects

The pooled effects were calculated using the number of bones operated on as the analytical unit. For the frequency of complications and revisions using telescopic rods, data from 28 of the 36 included studies were used (77.8%), and for non-telescopic rods, data from 13/36 studies (36.1%) were used. Six studies compared the outcomes of both rod types and were included for calculating the pooled Odds Ratio (OR). All meta-analysis models created for this study are shown in Table 6.

When assessing the occurrence of complications (Figure 2), bones operated on using telescopic rods had a

Table 1. Characteristics of included studies (year, country, study design, number of patients, number of operated bones, and rod type).

Study	Year	Country	Study design	Type	N patients	N male	N female	N bones	Type of rod
Bilsel et al.	2000	Turkey	Case series	Retrospective	5	4	1	12	Telescopic
Karbowski et al.	2000	Germany	Case series	Retrospective	63	NR	NR	186	Telescopic
Mulpuri et al.	2000	India	Case series	Retrospective	16	NR	NR	47	Both
Boutaud et al.	2004	France	Case series	Retrospective	14	10	4	36	Non-telescopic
Joseph et al.	2005	India	Case series	Retrospective	43	NR	NR	75	Both
Abulsaad et al.	2008	Egypt	Case series	Retrospective	14	8	6	29	Non-telescopic
Waltz et al.	2009	United States	Case series	Retrospective	14	5	9	37	Non-telescopic
El-Adl et al.	2009	Egypt	Case series	Retrospective	10	NR	NR	23	Both
Cho et al.	2011	South Korea	Case series	Retrospective	25	11	14	72	Telescopic
Nicolaou et al.	2011	United Kingdom	Case series	Retrospective	22	9	13	66	Telescopic
Imajima et al.	2015	Japan	Case series	Retrospective	17	9	8	29	Non-telescopic
Li et al.	2015	Taiwan	Case series	Retrospective	18	10	8	32	Non-telescopic
Lee et al.	2015	South Korea	Case series	Retrospective	50	28	22	50	Telescopic
Azzam et al.	2016	United States	Case series	Retrospective	58	20	38	179	Telescopic
Rosemberg et al.	2018	Brazil	Case series	Retrospective	21	9	12	52	Telescopic
Sarikaya et al.	2018	Turkey	Case series	Retrospective	9	7	2	17	Telescopic
Persiani et al.*	2019a	Italy	Case-control	Retrospective	32	20	12	40	Telescopic
Shin et al.	2018	South Korea	Case series	Retrospective	38	NR	NR	59	Telescopic
Persiani et al.*	2019b	Italy	Case series	Retrospective	36	21	15	36	Non-telescopic
Spahn et al.	2019	United States	Case series	Retrospective	NR	NR	NR	64	Both
Landrum et al.	2019	United States	Case series	Retrospective	9	2	7	20	Telescopic
Cox et al.	2020	United Kingdom	Case series	Retrospective	34	NR	NR	72	Telescopic
Sterian et al.	2020	Romania	Case series	Retrospective	32	11	21	47	Telescopic
Suresh et al.	2020	United States	Case series	Retrospective	14	10	4	24	Telescopic
De Jager et al.	2021	South Africa	Case series	Retrospective	17	10	7	64	Both
Musielak et al.	2021	Poland	Case series	Retrospective	19	10	9	58	Telescopic
Gaume et al.	2022	France	Case series	Retrospective	22	14	8	38	Non-telescopic
Zhu et al.	2023	China	Cohort	Retrospective	211	118	93	NR	Non-telescopic
Hung et al.	2022	Taiwan	Case series	Retrospective	7	4	3	20	Telescopic
Yang et al.	2023	China	Case series	Retrospective	626	346	280	626	Both
Fralinger et al.	2023	United States	Case series	Retrospective	43	23	20	168	Telescopic
Goiano et al.	2023	Brazil	Case series	Retrospective	15	7	8	21	Telescopic
Ozer et al.	2025	Turkey	Case series	Retrospective	15	7	8	43	Telescopic
Jin et al.	2025	China	Case series	Retrospective	33	23	10	63	Telescopic
Georges et al.	2025	France	Case series	Retrospective	31	18	13	54	Telescopic
Tayyab et al.	2025	Pakistan	Cohort	Retrospective	78	46	32	NR	Telescopic

NR: Not reported.

*Persiani et al. 2019a evaluated tibial deformities treated with the Fassier–Duval telescopic nail, whereas Persiani et al. 2019b evaluated femoral fractures treated with elastic intramedullary nails.

complication frequency of 45% (95% CI 34%–57%), while those operated on with non-telescopic rods had a complication frequency of 56% (95% CI 45%–67%) (Figure 3). Both models presented high heterogeneity, demonstrated by the behavior of the data from the included studies (99% and 88%, respectively). As the confidence intervals overlapped, no significant difference was found between the frequencies of complications for both rod types.

When evaluating the complication outcomes in the studies that used both rod types the OR for bones with telescopic rod was found to be 0.67. However, the confidence interval (0.24–1.90) indicates a non-significant difference when compared to the group of non-telescopic rods, as shown in Figure 4.

The frequency of revisions showed a significant difference when telescopic rods were used (24%; 95% CI 16%–32%) (Figure 5) and was significantly lower compared to

Table 2. Types of rods and operated bones, including study identification, number of rods used, type of rod, number of T rods, number of NT rods, and number of femurs, tibias, and humeri operated on.

Study ID	Rods (N)	Rod type	T	NT	Femur	Tibia	Humerus
Bilsel et al.	12	Bailey-Dubow	12	—	10	2	—
Karbowsky et al.	186	Bailey-Dubow	186	—	101	71	14
Mulpuri et al.	47	34 Sheffield, 13 non-telescopic (11 Rush, 1 Kuntscher, 1 V-nail)	34	13	27	16	4
Boutaud et al.	36	Sliding Elastic Nail	—	36	24	10	2
Joseph et al.	75	35 single Rush, 18 dual Rush, 22 Sheffield	22	53	50	25	—
Abulsaad et al.	29	49 Rush, 6 Kirschner	—	29	17	12	—
Waltz et al.	37	27 Steimann, 1 Rush, 3 Nancy, 2 Luque, 4 Kuntscher	—	37	18	19	—
El-Adl et al.	23	14 Sheffield, 19 Rush	9	14	13	10	—
Cho et al.	72	3 Bailey-Dubow, 30 Sheffield, 39 interlocking telescopic	72	—	44	28	—
Nicolaou et al.	66	Sheffield	66	—	40	23	3
Imajima et al.	29	Kirschner	—	29	29	—	—
Li et al.	32	Rush	—	32	32	—	—
Lee et al.	50	34 interlocking telescopic, 9 Sheffield, 7 Bailey-Dubow	50	—	50	—	—
Azzam et al.*	179	Fassier-Duval	179	—	NR	NR	NR
Rosemberg et al.	52	TIR	52	—	52	—	—
Sarikaya et al.	17	Corkscrew-tipped (CTTN)	17	—	12	5	—
Persiani et al. 2019a	40	Fassier-Duval	40	—	—	40	—
Shin et al.	59	28 dual interlocking (D-ITR), 31 single interlocking (S-ITR)	59	—	—	59	—
Persiani et al. 2019b	36	36 Titanium Elastic Nail	—	36	36	—	—
Spahn et al.	64	26 Fassier-Duval, 24 Rush, 12 flexible nails, 2 Steimann pins	26	38	34	30	—
Landrum et al.	20	Fassier-Duval	20	—	9	11	—
Cox et al.	72	Fassier-Duval	72	—	45	27	—
Sterian et al.	47	Fassier-Duval	47	—	28	19	—
Suresh et al.	24	Fassier-Duval	24	—	3	21	—
De Jager et al.	64	26 Rush, 38 Fassier-Duval	38	26	38	26	—
Musielak et al.	58	Fassier-Duval	58	—	37	21	—
Gaume et al.	38	38 Sliding Elastic Nail	—	38	—	38	—
Zhu et al.**	NR	Peter-Williams	—	—	NR	NR	NR
Hung et al.	20	Fassier-Duval	20	—	10	10	—
Yang et al.	626	142 Improved Rush, 143 Rush, 19 Peter-Williams, 332 Fassier-Duval	322	304	626	—	—
Fralinger et al.	168	Fassier-Duval	168	—	91	77	—
Goiano et al.	21	Fassier-Duval	21	—	18	3	—
Ozer et al.	43	Telescoping rod—unspecified type	43	—	26	17	—
Jin et al.	63	Fassier-Duval	63	—	42	21	—
Georges et al.	54	Bailey-Dubow	54	—	54	—	—
Tayyab et al.	NR	52 Fassier-Duval, 26 Sheffield	78	—	NR	NR	NR
Total	2459	—	1852	685	1654	663	41

NR: Not reported; T: Telescopic rod; NT: Non-telescopic rod.

*Outcomes were reported for long bones as a whole; femur- and tibia-specific results were not stratified in the original study.

**Outcomes were reported per patient; the exact number of treated bones was not specified.

non-telescopic rods (56%; 95% CI 35%–77%) (Figure 6). Both models showed high heterogeneity (96% and 98%, respectively).

When evaluating the OR for the need for revisions between bones with both types of rods, statistical significance was found, indicating a protective effect for bones treated with telescopic rods compared to those treated with non-telescopic rods (Figure 7). The pooled OR indicated

that bones treated with telescopic rods had a 76% relative reduction in the odds of revision compared to non-telescopic rods.

Risk of bias and certainty assessment

For the 33 case series studies evaluated, 16 (48.5%) presented low risk of bias, 14 moderate risk (42.4%) and 3 a

Table 3. Sillence classification by patient and average follow-up (in years) for procedures with T and NT rods.

Study ID	Sillence I	Sillence III	Sillence IV	Sillence > IV	Follow-up T	Follow-up NT
Bilsel et al.	3	2	0	0	12.30	—
Karbowski et al.	*	*	*	*	5.60	—
Mulpuri et al.	*	*	*	*	5.60	5.5
Boutaud et al.	6	8	0	0	—	8
Joseph et al.	*	*	*	*	4.00	4
Abulsaad et al.	6	4	4	0	—	5
Waltz et al.	8	4	2	—	—	4.6
El-Adl et al.	*	*	*	*	7.20	7.2
Cho et al.	6	5	0	1	7.30	—
Nicolaou et al.	7	10	5	0	19.00	—
Imajima et al.	14	3	0	0	—	5.75
Li et al.	0	14	4	0	—	11.4
Lee et al.	7	14	0	0	6.80	—
Azzam et al.	9	29	20	0	5.00	—
Rosemberg et al.	1	9	11	0	9.96	—
Sarikaya et al.	2	4	3	0	2.60	—
Persiani et al. 2019a	0	32	0	0	1.50	—
Shin et al.	*	*	*	*	5.15	—
Persiani et al. 2019b	0	36	0	0	—	5
Spahn et al.	6	35	9	14	4.00	4
Landrum et al.	*	*	*	*	4.40	—
Cox et al.	*	*	*	*	4.16	—
Sterian et al.	17	15	0	0	7.00	—
Suresh et al.	5	6	2	1	7.20	—
De Jager et al.	*	*	*	*	3.70	3.1
Musielak et al.	1	18	0	0	4.40	—
Gaume et al.	3	17	0	2	—	8.6
Zhu et al.	40	62	109	0	—	9
Hung et al.	0	6	1	0	—	—
Yang et al.	72	234	324	0	5.24	5.66
Fralinger et al.	7	18	16	2	2.42	—
Goiano et al.	3	7	5	0	5.22	—
Ozer et al.	*	*	*	*	4.00	—
Jin et al.	5	18	10	0	4.50	—
Georges et al.	6	15	7	3	2.70	—
Tayyab et al.	12	39	27	0	1.00	—
Total	246	664	559	23	Mean 5.6 (SD $\pm$ 3.6)	Mean 6.2 (SD $\pm$ 2.3)

SD: Standard deviation; T: Telescopic rod; NT: Non-telescopic rod.

*No information reported.

high risk of bias (9.1%), as shown in Table 7. For the two case-control studies included, both were classified as low risk of bias, with 80% or more of the criteria achieving positive responses, and the cohort study presented a moderate risk of bias.

A deeper analysis of the individual criteria revealed areas with higher proportions of “unclear” or “no” responses, particularly in item 4 (consecutive inclusion of participants), item 9 (demographics of presenting sites/clinics), and item 10 (statistical analysis). In item 4, nine

studies were rated as “unclear,” indicating that many did not explicitly describe whether participants were included consecutively. This lack of clarity reduces the reliability of the sample by introducing potential selection bias. In item 9, 11 studies were rated “no” regarding the demographics of presenting sites or clinics, suggesting that many studies did not provide enough information about the geographic or demographic characteristics of the study settings, which is essential for determining generalizability. In item 10, ten studies were marked as “no,” suggesting that either

Table 4. Types of complications per patient described in the included studies.

Study ID	Migration		Angulation		Pseudoarthrosis		Fracture		Bone deformity	
	T	NT	T	NT	T	NT	T	NT	T	NT
Bilsel et al.	6	NR	0	NR	0	NR	0	NR	0	NR
Karbowski et al.	53	NR	0	NR	0	NR	1	NR	22	NR
Mulpuri et al.	24	3	3	2	0	1	2	3	0	NR
Boutaud et al.	0	NR	0	NR	0	NR	0	NR	0	NR
Joseph et al.	14	4	1	NR	0	NR	2	4	0	NR
Abulsaad et al.	0	NR	0	1	0	NR	0	3	0	NR
Waltz et al.	0	NR	0	NR	0	NR	0	3	0	6
El-Adl et al.	2	3	1	1	0	NR	0	1	0	NR
Cho et al.	0	NR	0	NR	0	NR	0	NR	0	NR
Nicolaou et al.	9	NR	4	NR	0	NR	15	NR	0	NR
Imajima et al.	0	4	0	6	0	NR	0	39	0	NR
Li et al.	0	2	0	NR	0	NR	0	2	0	NR
Lee et al.	7	NR	0	NR	0	NR	0	NR	0	NR
Azzam et al.	4	NR	10	NR	0	NR	21	NR	0	NR
Rosemberg et al.	9	NR	0	NR	0	NR	15	NR	0	NR
Sarikaya et al.	0	NR	0	NR	1	NR	1	NR	0	NR
Persiani et al. 2019a	0	NR	0	NR	0	NR	0	NR	0	NR
Shin et al.	15	NR	0	NR	5	NR	22	NR	4	NR
Persiani et al. 2019b	0	1	0	0	0	1	0	7	0	NR
Spahn et al.	0	4	1	12	0	NR	1	3	0	NR
Landrum et al.	8	NR	0	NR	0	NR	4	NR	0	NR
Cox et al.	37	NR	24	NR	0	NR	24	NR	0	NR
Sterian et al.	15	NR	0	NR	0	NR	0	NR	0	NR
Suresh et al.	6	NR	2	NR	1	NR	0	NR	0	NR
De Jager et al.	4	1	0	1	0	NR	0	2	0	NR
Musielak et al.	25	NR	0	NR	0	NR	3	NR	5	NR
Gaume et al.	0	NR	0	NR	0	NR	0	NR	0	NR
Zhu et al.	0	NR	0	NR	0	NR	0	20	0	32
Hung et al.	7	NR	3	NR	0	NR	2	NR	0	NR
Yang et al.	50	56	38	17	2	17	0	NR	0	NR
Fralinger et al.	12	NR	46	NR	0	NR	10	NR	0	NR
Goiano et al.	5	NR	4	NR	0	NR	12	NR	0	NR
Ozer et al.	0	NR	0	NR	0	NR	6	NR	0	NR
Jin et al.	9	NR	0	NR	0	NR	4	NR	0	NR
Georges et al.	7	NR	0	NR	0	NR	0	NR	0	NR
Tayyab et al.	4	NR	0	NR	0	NR	5	NR	0	NR
Total	332	78	137	40	9	19	150	87	31	38

T: Telescopic rod; NT: Non-telescopic rod.

inappropriate statistical methods were used or the analyses were poorly described, limiting the interpretability and reliability of the findings.

Publication bias was not assessed for the Odds Ratios calculation due to the limited number of studies included ($n=6$). Evidence of small-study effects was identified in some pooled analyses, suggesting potential publication bias; therefore, pooled estimates should be interpreted with caution. In contrast, no evidence of publication bias was found for complications with non-telescopic rods

($p=0.261$), with a bias estimate of 2.25. The pooled effect models for complications were rated as having low-quality evidence according to GRADE, reflecting the limitations of the included studies.

For the outcome of revisions with telescopic rods, significant evidence of publication bias was identified ($p<0.0001$), with a bias estimate of 5.09. Similarly, revisions with non-telescopic rods also showed significant publication bias ($p=0.005$), with a bias estimate of 9.44. The pooled effect models for revisions were rated as

Table 5. Time elapsed (in years) between the first surgery and the first revision surgery, with the revision rate (per number of bones) per study, according to the type of rod (T or NT).

Study ID	Time elapsed between first and revision surgery		Revision rate (%)	
	T	NT	T	NT
Bilsel et al.	*	*	25.00	NR
Karbowski et al.	*	*	25.35	NR
Mulpuri et al.	4.4	2.6	32.00	63.60
Boutaud et al.	NR	3.2	NR	75.00
Joseph et al.	3.9	3.4	14.00	22.00
Abulsaad et al.	NR	2	NR	NR
Waltz et al.	NR	2.6	NR	24.30
El-Adl et al.	*	*	42.20	26.10
Cho et al.	*	*	NR	NR
Nicolaou et al.	*	*	50.00	NR
Imajima et al.	*	*	NR	64.00
Li et al.	NR	3.36	NR	NR
Lee et al.	*	*	NR	NR
Azzam et al.	3.3	NR	NR	NR
Rosemberg et al.	6.43	NR	50.00	NR
Sarikaya et al.	0.37	NR	11.70	NR
Persiani et al. 2019a	*	*	NR	NR
Shin et al.	5.4	NR	35.00	NR
Persiani et al. 2019b	*	*	NR	75.00
Spahn et al.	*	*	NR	NR
Landrum et al.	2.42	NR	40.00	NR
Cox et al.	*	*	16.66	NR
Sterian et al.	*	*	36.00	NR
Suresh et al.	3	NR	58.30	NR
De Jager et al.	NR	1.83	NR	58.00
Musielak et al.	4	NR	24.10	NR
Gaume et al.	NR	4.9	NR	NR
Zhu et al.	NR	1	NR	23.70
Hung et al.	2.4	—	55	NR
Yang et al.	4.4	3.3	22.00	52.00
Fralinger et al.	2.1	NR	33.30	NR
Goiano et al.	2.55	NR	4.47	NR
Ozer et al.	3	NR	12.3	NR
Jin et al.	1.98	NR	20.63	NR
Georges et al.	*	NR	*	NR
Tayyab et al.	*	NR	*	NR
Mean ($\pm$ Standard Deviation)	3.31 ($\pm$ 1.50)	2.82 ($\pm$ 1.07)	30.40% ($\pm$ 15.18%)	48.37% ($\pm$ 22.06%)

T: Telescopic rod; NT: Non-telescopic rod.

*Data not described.

having low to moderate quality of evidence according to GRADE, reflecting the inherent limitations in study design and reporting.

Discussion

Osteogenesis imperfecta is characterized by bone fragility and progressive deformities that frequently require surgical intervention. Intramedullary fixation remains the cornerstone of orthopedic management; however, the optimal

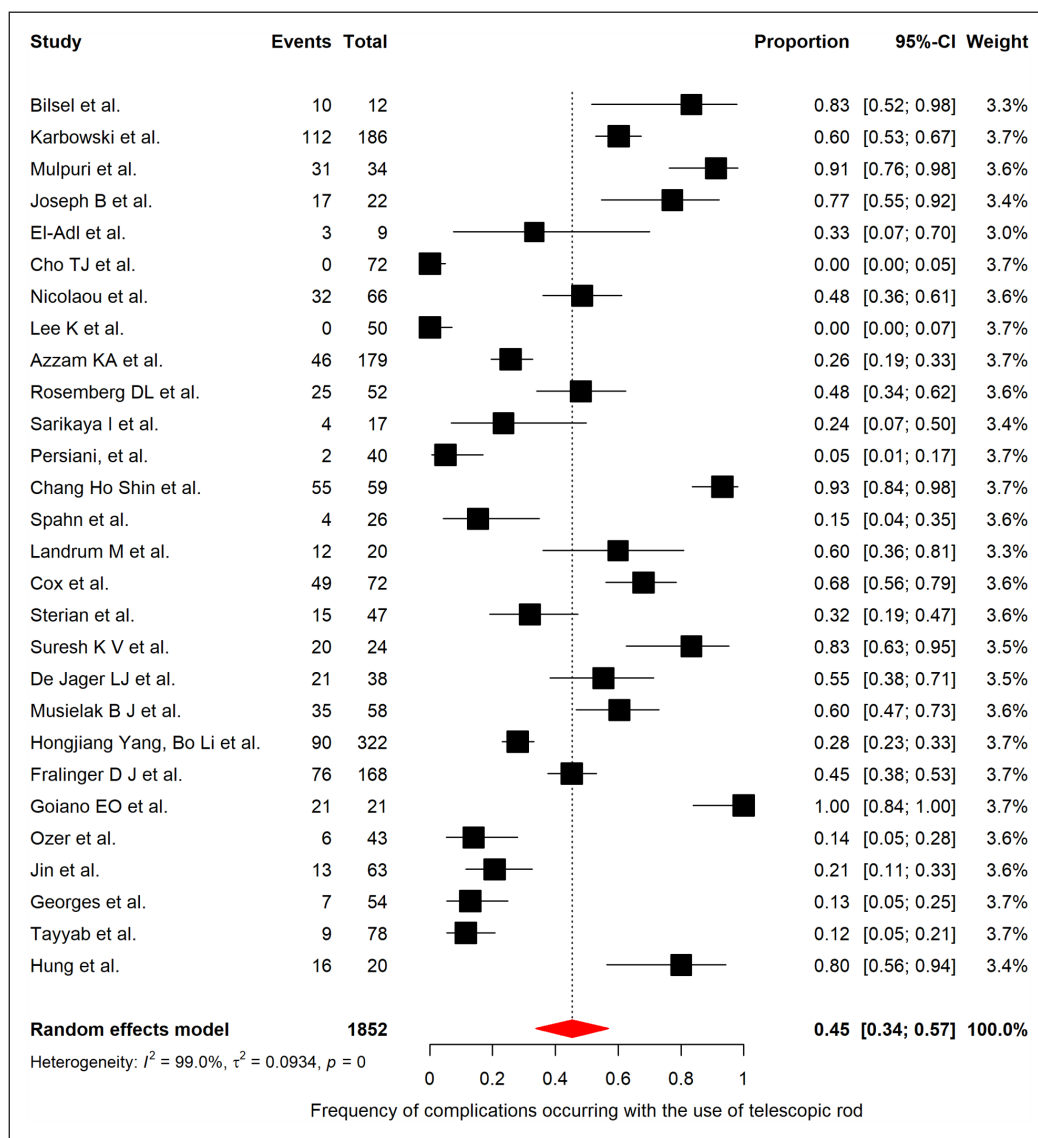
implant strategy continues to be debated. Although intramedullary devices provide additional structural support, high rates of complications and reoperations have been reported in small series.^{4-9,28} The aim of this study was to compare telescopic and non-telescopic intramedullary devices used in lower limb orthopedic surgeries in patients with OI.

Scollan et al.⁴ conducted a meta-analysis of seven studies published between 1986 and 2016, to evaluate surgical complications in pediatric patients with OI who underwent

Table 6. Meta-analysis models created to evaluate the frequency of complications and revisions, and the OR for operated bone segments with telescopic and non-telescopic rods, based on studies that assessed outcomes for both rod types.

Outcome	Pooled effect	CI 95%		Heterogeneity
		Lower	Upper	
Frequency of complications				
Telescopic rods	45%	34%	57%	$I^2 = 99\%$, $\tau^2 = 0.0934$, $p < 0.01$
Non-telescopic rods	56%	45%	67%	$I^2 = 88\%$, $\tau^2 = 0.0337$, $p < 0.01$
Frequency of revisions				
Telescopic rods	24%	16%	32%	$I^2 = 96\%$, $\tau^2 = 0.0462$, $p < 0.01$
Non-telescopic rods	56%	35%	77%	$I^2 = 98\%$, $\tau^2 = 0.1452$, $p < 0.01$
OR				
Complications	0.67	0.24	1.90	$I^2 = 82\%$, $\tau^2 = 1.2850$, $p < 0.01$
Revisions	0.24	0.08	0.68	$I^2 = 73\%$, $\tau^2 = 1.1292$, $p < 0.01$

OR: Odds ratio.

**Figure 2.** Forest plot showing the pooled effect of the frequency of complications in bones operated on using telescopic rods. Forest plot showing the pooled frequency of complications among bones treated with telescopic rods.

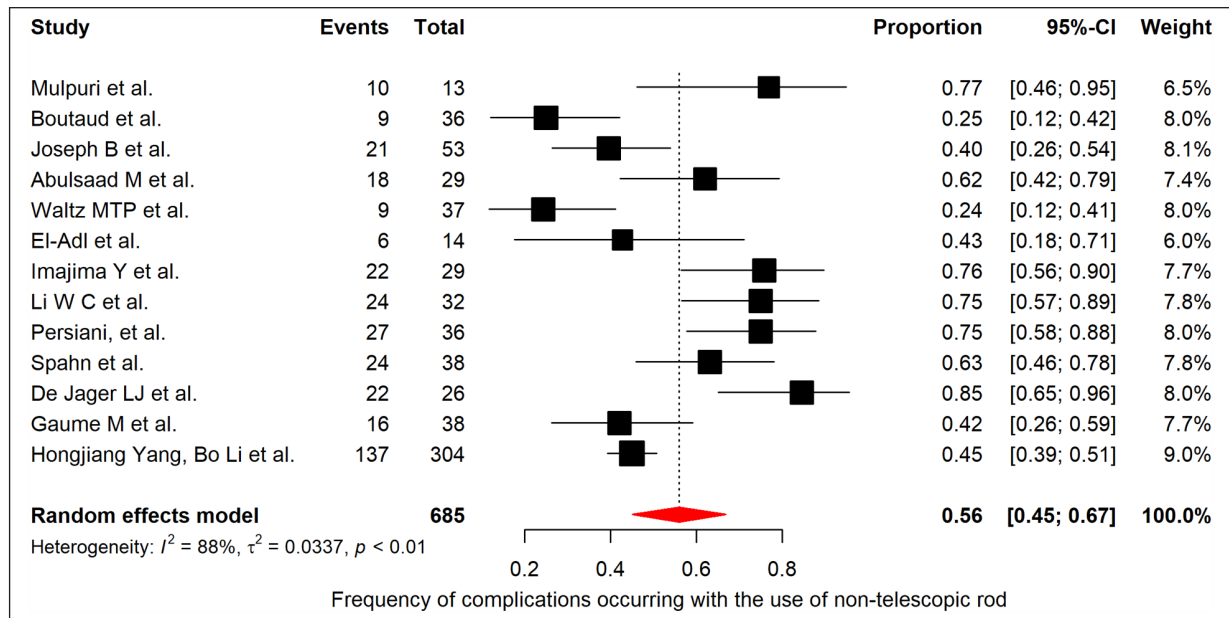


Figure 3. Forest plot showing the pooled effect of the frequency of complications in bones operated on using non-telescopic rods.

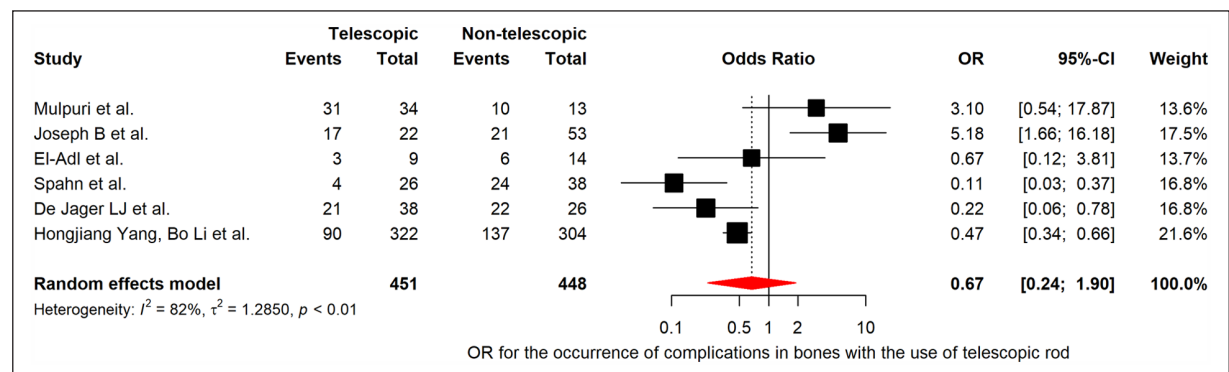


Figure 4. Forest plot showing the pooled OR effect of complications between bones operated on using telescopic and non-telescopic rods.

OR: Odds ratio.

non-telescopic intramedullary fixation. They found rod migration to be the main complication, followed by fractures and bone deformities. Over a mean follow-up of 5.25 years, the average reoperation rate was 40%. Yong et al.⁵³ reviewed 24 studies published between 1970 and 2020, including 594 patients. Six studies compared telescopic rods with non-telescopic rods, while 18 studies pooled data on telescopic rods only. Despite these previous findings, most available evidence remains limited by small sample sizes and heterogeneity, highlighting the need for updated and more comprehensive analyses. Their findings showed that the rates of complications and reoperations were lower with the use of telescopic rods compared to

non-telescopic rods. In addition, the evolution of telescopic rods contributed to reducing these rates. The inclusion of more recent studies further reinforces these findings. Jin et al.,⁵⁰ analyzing 63 long bones treated with Fassier-Duval rods, reported a revision rate of approximately 20%, with complications mainly related to refracture and implant failure. Similarly, Ozer et al.,⁴⁹ evaluating 43 lower limb bones treated with telescopic rods, described a lower overall complication rate, with revision events primarily associated with refracture, pseudoarthrosis, and rod migration. Georges et al.⁵¹ reported hardware migration in a subset of femoral procedures using telescopic rods, highlighting that mechanical complications remain relevant

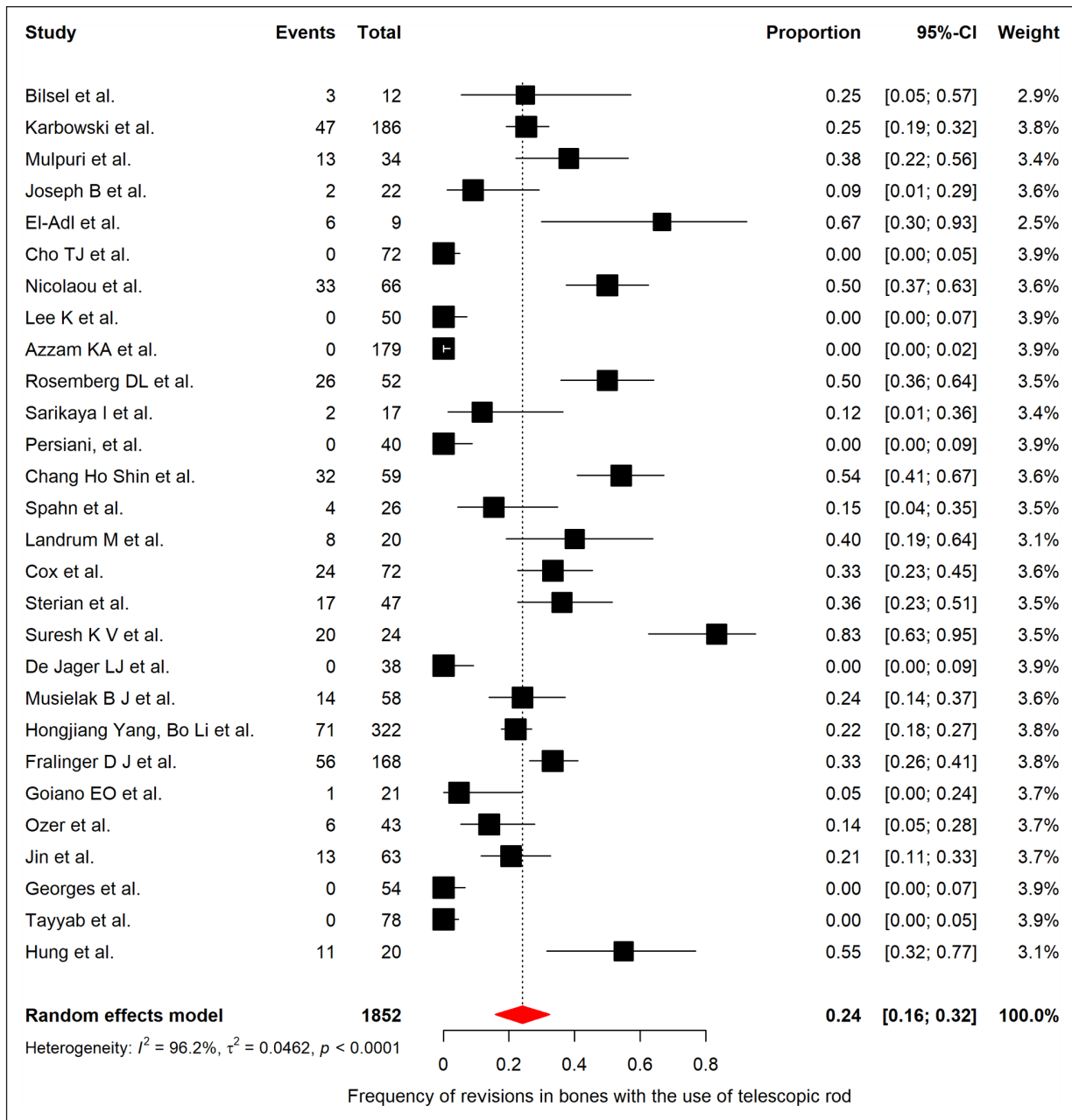


Figure 5. Forest plot showing the pooled effect of revision frequency in bones operated on using telescopic rods.

even with modern implants. These contemporary data are consistent with the overall trend observed in the present meta-analysis, further supporting the durability and improved survival of telescopic rods compared to non-telescopic devices.

Our study, which now includes 36 studies published between 2000 and 2025, represents 1 of the most comprehensive syntheses to date on intramedullary fixation in osteogenesis imperfecta. The inclusion of more recent studies strengthens the external validity of our findings while maintaining methodological consistency with

previous analyses. However, the reporting of variables across studies was heterogeneous and often incomplete.

The evolution of telescopic rod design over the past decades likely contributed to the improved outcomes observed. Earlier systems such as Bailey–Dubow⁵⁴ and Sheffield⁵⁵ rods were associated with higher rates of mechanical complications, whereas newer designs, particularly the Fassier–Duval rod⁵⁶ allow less invasive implantation and improved telescoping mechanics. The predominance of modern telescopic systems in recent studies may partially explain the lower revision rates

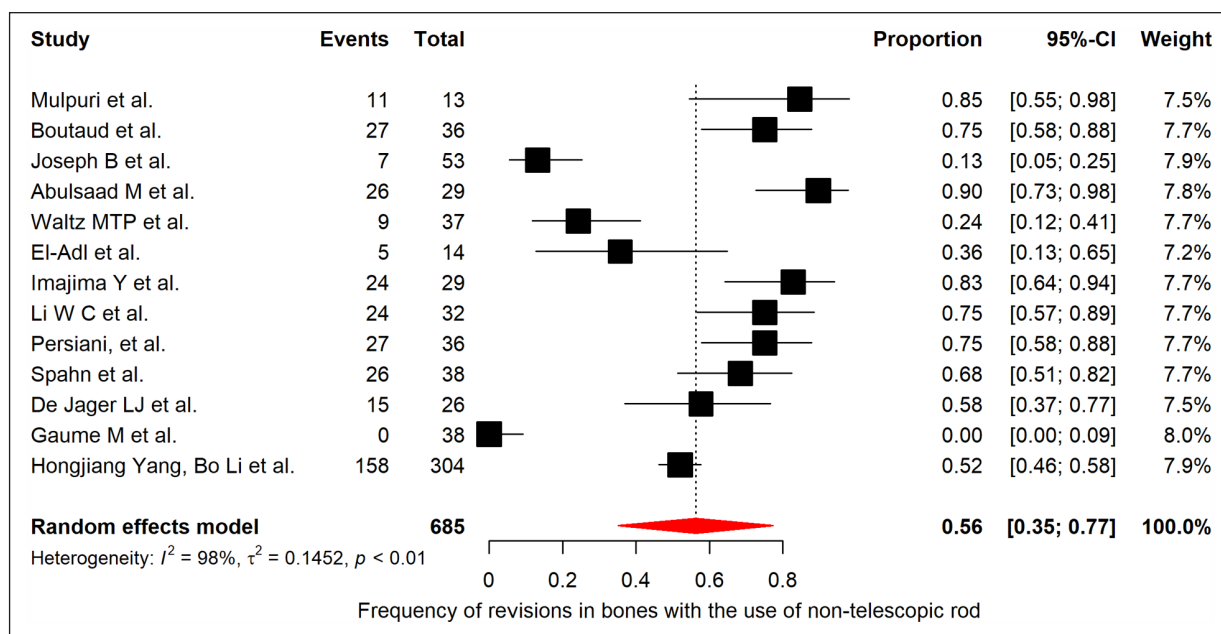


Figure 6. Forest plot showing the pooled effect of revision frequency in bones operated on using non-telescopic rods.

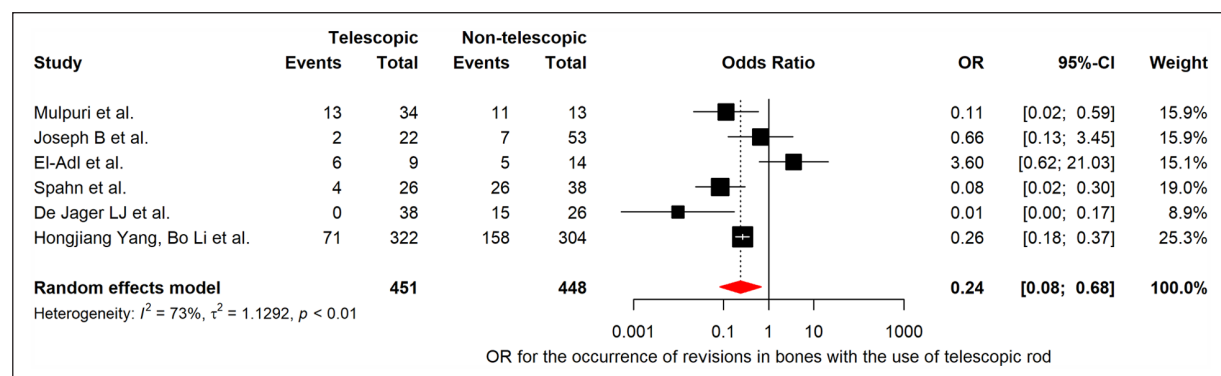


Figure 7. Combined effect of the OR for reoperation between bones operated on using telescopic and non-telescopic rods. OR: Odds ratio.

observed in the current analysis. This technological progression likely explains part of the improved outcomes observed in more recent studies included in this review.

In the selected studies, some reported the number of bones operated on, while others reported the number of patients. Some studies included both. Similar inconsistencies were also reported for gender, Sillence classification and complications. Nonetheless, the data provided valuable insights into the rates of complications and reoperations relative to follow-up duration. The most robust finding of this study is the significantly lower revision rate associated with telescopic rods. The pooled analysis demonstrated a substantial reduction in the need for reoperation, with an estimated 76% relative reduction in odds compared to non-telescopic implants. This

finding is clinically meaningful, as revision surgery in patients with OI is associated with increased morbidity, prolonged rehabilitation, and higher healthcare costs. This reinforces the role of telescopic rods as the preferred strategy for long-term skeletal management in growing patients.

Complications represent adverse events occurring during the postoperative recovery period. These include rod-related events such as migration, structural deformity or telescoping failure (in the case of telescoping or sliding stems), as well as patient-related occurrences such as fractures, pseudarthroses and pain. Infection is an event related to surgical procedures.

Rod migration and post-surgical fractures were the most frequently reported complications across studies for

Table 7. Individual assessment of risk of bias using the JBI critical appraisal checklist for case series or case-control studies.

Study ID	JBI checklist	1	2	3	4	5	6	7	8	9	10	Risk of bias
Bilsel et al.	Case series	Yes	Yes	Yes	Unclear	Yes	Yes	Yes	Unclear	No	No	Moderate
Karbowski et al.	Case series	Yes	Yes	No	Unclear	Yes	No	No	Yes	No	No	High
Mulpuri et al.	Case series	Yes	Yes	Yes	Unclear	Yes	No	No	Yes	No	Yes	Moderate
Boutaud et al.	Case series	Yes	Yes	Yes	Unclear	Unclear	Yes	Yes	Yes	Yes	No	Moderate
Joseph et al.	Case series	Yes	Yes	Yes	Unclear	Unclear	No	No	Yes	No	Yes	High
Abulsaad et al.	Case series	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Unclear	Yes	Low
Waltz et al.	Case series	Yes	Yes	Yes	Yes	Unclear	Yes	Yes	Yes	Yes	No	Low
El-Adl et al.	Case series	Yes	Yes	Yes	Unclear	Yes	No	No	Yes	Yes	Yes	Moderate
Cho et al.	Case series	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Low
Nicolaou et al.	Case series	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Low
Imajima et al.	Case series	Yes	Yes	Yes	Unclear	Yes	Yes	Yes	Yes	No	No	Moderate
Li et al.	Case series	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Low
Lee et al.	Case series	Yes	Yes	Yes	Unclear	Yes	Yes	Yes	Yes	Yes	Yes	Low
Azzam et al.	Case series	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Low
Rosemberg et al.	Case series	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Low
Sarikaya et al.	Case series	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Low
Shin et al.	Case series	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Low
Persiani et al. 2019b	Case series	Yes	Yes	Yes	No	No	Unclear	Yes	Yes	Yes	No	Moderate
Spahn et al.	Case series	Yes	Yes	Unclear	Yes	Yes	No	Yes	No	No	Yes	Moderate
Landrum et al.	Case series	Yes	Yes	Yes	No	Yes	No	No	Yes	No	No	High
Cox et al.	Case series	Yes	Yes	Yes	Unclear	Yes	No	Unclear	Yes	Yes	No	Moderate
Sterian et al.	Case series	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Low
Suresh et al.	Case series	Yes	Yes	Yes	No	Yes	Yes	No	Yes	No	Yes	Moderate
De Jager et al.	Case series	Yes	Yes	Yes	Yes	No	Yes	No	Yes	No	Yes	Moderate
Musielak et al.	Case series	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Low
Gaume et al.	Case series	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Low
Yang et al.	Case series	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Low
Hung et al.	Case series	Yes	Yes	Yes	Unclear	Yes	Yes	Yes	Yes	Yes	No	Low
Fralinger et al.	Case series	Yes	Yes	Yes	Unclear	Unclear	Yes	Yes	Yes	No	Yes	Moderate
Goiano et al.	Case series	Yes	Yes	Yes	Yes	Unclear	Yes	Yes	Yes	No	No	Moderate
Ozer et al.	Case series	Yes	Yes	Yes	Unclear	Unclear	Yes	Yes	Yes	No	No	Moderate
Jin et al.	Case series	Yes	Yes	Yes	Unclear	Yes	Yes	Yes	Yes	Yes	Yes	Low
Georges et al.	Case series	Yes	Yes	Yes	Unclear	Unclear	Yes	Yes	Yes	No	Yes	Moderate
Zhu et al.	Cohort	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Low
Tayyab et al.	Cohort	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Low
Persiani et al. 2019a	Case control	Yes	Yes	Yes	Unclear	Yes	Yes	No	Yes	Yes	Yes	Moderate

JBI: Joanna Briggs Institute.

both rod types. However, the reporting of complication subtypes was inconsistent, precluding reliable quantitative comparison between groups. Azzam et al.,²⁷ who used 179 FD rods, described structural deformity and pain after initial surgery as complications, with 100% reoperation rates.

De Jager et al.,¹⁶ using 26 smooth rods and 38 FD rods, and Persiani et al.,³⁰ using 40 FD rods, did not report revisions in their studies. Interestingly, despite the lower revision rates observed with telescopic rods, no significant difference was found in overall complication rates between

the two groups. This apparent discrepancy may be explained by the nature of the complications. While telescopic rods are still susceptible to mechanical issues such as migration or failure of telescoping, these events may not always require surgical revision. In contrast, complications associated with non-telescopic rods, particularly progressive deformity or loss of fixation due to growth, more frequently necessitate reoperation. Therefore, the clinical relevance of complications should be interpreted in the context of their impact on reoperation rather than their mere occurrence.

Revisions generally occurred several years after the index procedure, with mean times to revision of 3.3 years for telescopic rods and 2.8 years for non-telescopic rods. Although some studies did not describe the time between initial surgery and revision, others reported follow-up times averaging over 5 years. For example, Azzam et al.²⁷ reported 3.3 years for tibial surgeries and 4.3 years for femurs surgeries. Rosenberg et al.²⁸ reported 6.43 years, and Cho et al.²⁴ described revisions after a mean follow-up of 6.2 years. They showed that most revisions occurred after fractures and bowing of the rod at the internal or external intersection point of the components (male and female). These complications usually occur after growth of the telescopic mechanism, suggesting many fractures could be predicted. This would allow the surgeon to define more accurately time for component replacement, potentially avoiding fracture and rod breakage. Most studies did not specify the exact timing of these fractures or their relationship to rod telescoping. If these fractures could be prevented, migration might become the predominant complication. Careful attention to technical factors, such as rod insertion and fixation, can reduce migration rates.²⁶

Exploratory observations across studies suggested that younger age and greater surgical burden may be associated with higher complication and revision rates; however, these associations should be interpreted cautiously due to heterogeneity and study design limitations.

The high heterogeneity observed across studies is an important limitation and likely reflects variability in implant design, surgical technique, patient age, severity of disease, and duration of follow-up. Additionally, differences in reporting outcomes, particularly regarding bone-level versus patient-level data, contributed to variability in pooled estimates. Despite this heterogeneity, the direction of effect remained consistent across studies. However, no significant differences were found based on gender or Sillence classification.

Six studies compared both fixation mechanisms, showing that the need for surgical revision was statistically higher for non-telescopic rods compared to telescopic rods. Yang et al.¹⁷ reported revision rates of 22% for telescopic

rods and 52% for non-telescopic rods, with a follow-up of over 5 years.

This study has several important limitations. Most included studies were retrospective case series, with inherent risk of bias and limited control for confounding factors. Reporting heterogeneity was substantial, particularly regarding anatomical distribution, complication definitions, and Sillence classification. Additionally, some studies reported outcomes per patient rather than per treated bone, precluding their inclusion in the quantitative synthesis. The predominance of bone-level analysis may also limit direct comparison with studies reporting patient-level outcomes. Evidence of publication bias was also identified in revision outcomes, suggesting that pooled estimates should be interpreted with caution.

Conclusion

Telescopic rods are associated with significantly lower revision rates and improved implant survival compared with non-telescopic rods in children with osteogenesis imperfecta. Although overall complication rates remain similar between groups, telescopic devices appear to reduce the need for reoperation, representing a clinically relevant advantage in the long-term management of these patients.

These findings support the preferential use of telescopic rods in growing children with OI. However, given the heterogeneity and predominantly retrospective nature of the available evidence, further prospective and comparative studies are needed to better define optimal surgical strategies and long-term outcomes.

Author contributions

R.Y.: Conceptualization, Data collection, Manuscript drafting, Methodology.
M.P.S.: Data collection, Literature review, Manuscript revision.
M.O.C.: Data analysis, Manuscript revision.
M.P.N.: Critical revision, Final approval, Supervision.
All authors approved the final version of the manuscript.

Data availability

All data supporting the findings of this study are available within the article and its supplementary materials.

Declaration of conflicting interests

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Ethical approval

Not applicable. This study is a systematic review of previously published studies.

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