Treatment for Symptomatic Genu Recurvatum

A Systematic Review

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Background: Symptomatic genu recurvatum is a challenging condition to treat. Both osseous and soft tissue treatment options have been reported to address symptomatic genu recurvatum.

Purpose/Hypothesis: The purpose of this article was to review the current literature on surgical treatment options for symptomatic genu recurvatum and to describe the associated clinical outcomes. We hypothesized that anterior opening-wedge proximal tibial osteotomy (PTO) would be the most common surgical technique described in the literature and that this intervention would allow for successful long-term management of symptomatic genu recurvatum.

Study Design: Systematic review; Level of evidence, 4.

Methods: A systematic review was performed according to PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines, with the inclusion criterion of surgical treatment options for symptomatic genu recurvatum. Recurvatum secondary to polio, cerebrovascular accident, or cerebral palsy was excluded from this review.

Results: A total of 311 studies were identified, of which 6 studies with a total of 80 patients met the inclusion criteria. Causes of genu recurvatum included physeal arrest; soft tissue laxity; and complications related to fractures, such as prolonged immobilization and malalignment. Mean follow-up times ranged from 1 to 14.5 years postoperatively. There were 5 studies that described anterior opening-wedge PTO, 2 of which used the Ilizarov distraction technique. All 3 studies that used PTO without the Ilizarov technique reported correction of recurvatum and increased posterior tibial slope; 2 of these studies also included subjective outcomes scores, reporting good or excellent outcomes in 70% (21/30) of patients. Of the studies that used the Ilizarov technique, both reported correction of recurvatum and increased posterior slope from preoperative to postoperative assessments. Both of these studies reported good or excellent subjective outcomes postoperatively in 89.5% (17/19) of patients. Additionally, 1 study successfully corrected recurvatum by performing a retensioning of the posterior capsule to address knee hyperextension, although follow-up was limited to 1 year postoperatively.

Conclusion: Anterior opening-wedge PTO, with or without postoperative external fixation with progressive distraction, was found to be a reliable surgical treatment for symptomatic genu recurvatum. After surgical management with PTO, patients can expect to achieve correction of knee hyperextension, restoration of a more posterior tibial slope, and increased subjective outcome scores.

Keywords: genu recurvatum; proximal tibial osteotomy; complex knee; tibial slope; heel height

Symptomatic genu recurvatum, which has been defined as symptomatic hyperextension of the knee beyond 5°, is a challenging condition to treat.[22] The most common symptoms associated with this condition include pain, weakness, instability, leg-length discrepancy, and decreased range of motion.[7,25] Genu recurvatum can be congenital[33] or acquired secondary to trauma,[14] cerebrovascular accident, polio,[23] physeal arrest,[6] Osgood-Schlatter disease,[25] or prolonged casting.[5]

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Dejour et al[11] described 3 primary types of genu recurvatum: (1) pure osseous deformity, in many cases due to damage to the tibial tubercle growth plate; (2) chronic hyperextension secondary to soft tissue laxity either from trauma or gradual tissue stretching; and (3) a mixed-type deformity resulting from a combination of osseous and soft tissue abnormalities. The source of symptomatic genu recurvatum can also be idiopathic.[25]

Given the distinct pathological origins of the condition, treatment of symptomatic genu recurvatum can be grouped into 3 major categories: osseous surgical management, often entailing osteotomy of the tibia; soft tissue surgical management, aimed at tensioning the posterior soft

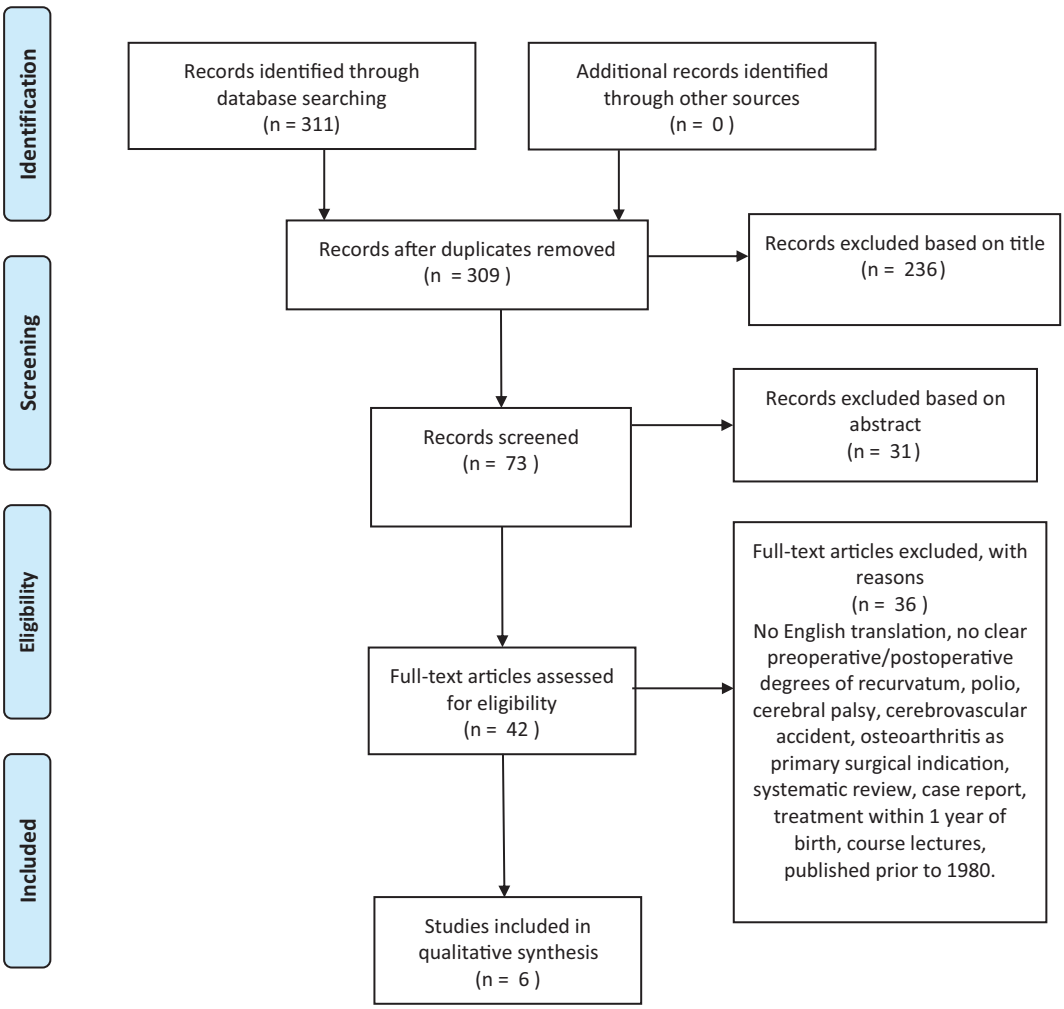

Figure 1. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flowchart describing application of selection criteria to the studies identified using the search strategy.

tissues; and nonoperative management, which focuses on strengthening the supporting musculature, bracing the knee, or correcting gait patterns.[11] The purpose of this study was to review the current literature on surgical treatment options for symptomatic genu recurvatum and to describe the associated clinical outcomes. We hypothesized that anterior opening-wedge proximal tibial osteotomy (PTO) would be the most common surgical technique described in the literature and that this intervention would allow for successful long-term management of symptomatic genu recurvatum.

METHODS

Article Identification and Selection

A systematic review of articles was completed through use of the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines on the surgical treatment options for symptomatic genu recurvatum using PubMed (1980-2019); the query was performed in July 2019 (Figure 1).[32] Registration of this systematic review was performed in August 2019 via the PROSPERO international

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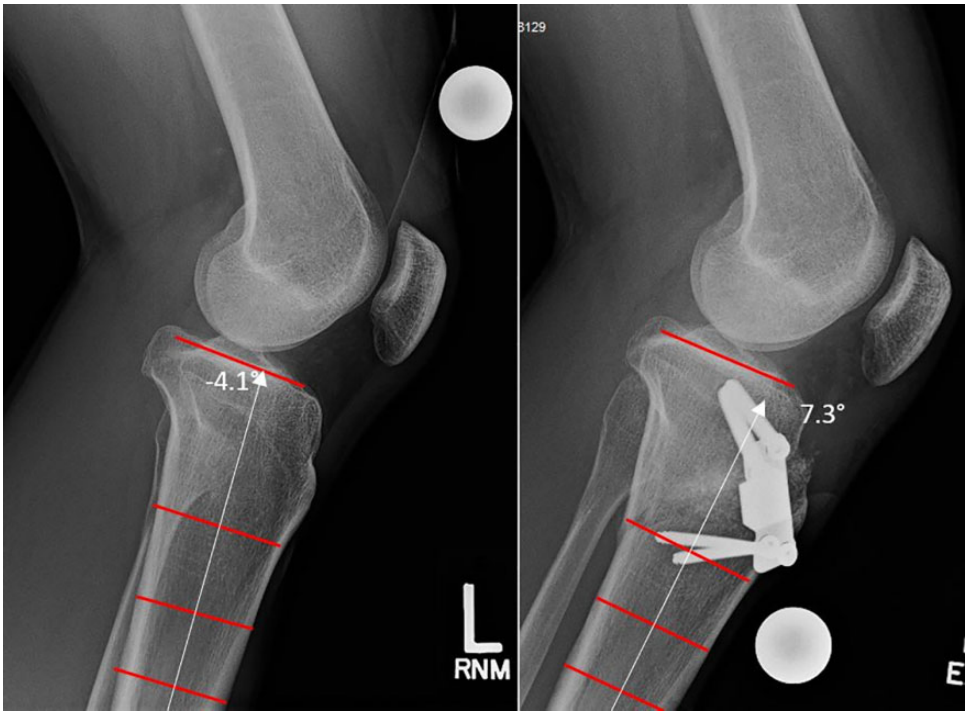

Figure 2. Example of lateral radiographic images demonstrating the correction of symptomatic genu recurvatum using an anterior opening-wedge proximal tibial osteotomy from our practice. The posterior tibial slope (PTS) was corrected to a more posterior position; the tibial slope of the preoperative image (left) was –4.1° (tibial slope in the anterior direction), and the PTS after correction (right) was 7.3°.

prospective register of systematic reviews (ID No. 145707). The search terms used were "Genu recurvatum" AND "Treatment" OR "Management" OR "Outcomes" OR "Surgery" OR "Operation."

The inclusion criteria consisted of English-language studies on the treatment of symptomatic genu recurvatum. Genu recurvatum was defined as a pathologic hyperextension of the knee joint beyond 5°. Exclusion criteria were recurvatum secondary to polio, cerebrovascular accident or cerebral palsy, studies published before 1980, diagnosis of genu recurvatum after previous knee surgery, surgery-induced recurvatum, treatment of skeletally immature patients, systematic reviews, course lectures, case reports (level 5 evidence), and studies that failed to state the degree of recurvatum before or after treatment. Additionally, studies that considered patients with combined anterior/posterior cruciate ligament and posterolateral knee insufficiency were not included in the current review because ligament reconstruction is the well-established gold standard for surgical management of this cause of genu recurvatum. Two investigators (R.S.D., N.R.G.) independently reviewed the abstracts from all identified articles. If necessary, full-text articles were obtained for review to allow further application of the established inclusion and exclusion criteria. Additionally, reference lists from the included studies were reviewed and reconciled to verify that all eligible articles were considered. Studies were grouped by specific surgical technique for subanalysis.

Data Collection

The variables of interest that were extracted from each study included the degree of posterior tibial slope identified on plain radiographs; the change in posterior tibial slope after intervention (Figure 2); preoperative and postoperative knee range of motion (ROM); and postoperative outcome scores, including the outcome scoring system described by Lecuire et al[20] (Table 1). This scoring system provides a numerical value (0-200) and corresponding categorical assessment (poor, <80; fair, 80-125; good, 130-170; excellent, 175-200) through a combination of anatomic measurements (degree of recurvatum, tibial slope, and patellar height) and subjective functional results (pain, instability, ROM, weakness, sports activity, and self-evaluation). Extracted from all studies were patient demographics, surgical technique, and preoperative and postoperative measurements of recurvatum measured in degrees beyond neutral. For continuous variables (eg, age, outcome scores), the mean and standard deviation were obtained when available.

RESULTS

The literature search identified 311 studies, of which 6 were included in the final analysis (Table 2). In total, the studies included for analysis entailed 80 patients. Among studies included for analysis, the reported causes of

TABLE 1
Outcome Scoring System According to Lecuire et al[20]

Results	Points
Anatomic (radiographic) results	
Angle of recurvatum	
0°-3°	40
4°-6°	30
7°-9°	20
10°-12°	10
>12°	0
Tibial slope	
2° to 10°	30
–2° to 1° or 11° to 14°	20
–6° to –3° or 15° to 18°	10
≤−6° or >18°	0
Patellar height (A:B ratio)[a]	
0.66-0.94	30
0.51-0.65 or 0.95-1.09	20
0.36-0.50 or 1.10-1.24	10
<0.36 or >1.24	0
Total anatomic (radiographic) score	
Excellent	90-100
Good	70-80
Fair	40-60
Poor	<40
Functional results	
Pain	
None	20
Slight	10
Mild	5
Severe	0
Instability	
None	15
Mild or slight	5
Severe	0
Range of motion	
Full	20
Decreased 1°-20°	10
Decreased >20°	0
Weakness	
None	15
Slight	10
Mild	5
Severe	0
Sports activity	
Yes	10
No	0
Patient evaluation of the result	
Excellent	20
Good	10
Fair	5
Poor	0
Total functional score	
Excellent	85-100
Good	60-80
Fair	40-55
Poor	<40
Total combined score	
Excellent	175-200
Good	130-170
Fair	80-125
Poor	<80

[a]A:B ratio is the Blackburne and Peel patellar height ratio.

symptomatic genu recurvatum included prolonged immobilization, physeal arrest related to fracture, physeal arrest of unknown origin, soft tissue laxity, malalignment secondary to fracture treated nonoperatively, and idiopathic osseous deformity. Our search identified 5 studies that evaluated patients who underwent an anterior opening-wedge PTO to correct their deformity[2,7,17,25,33]; of these, 2 studies used the Ilizarov method, which implements postoperative progressive distraction to increase tibial slope via an external fixator.[2,7] Additionally, 1 study evaluated patients who underwent retensioning of the posterior soft tissues via advancement and rotation of 2 bone blocks containing the femoral origin of the posterior capsule.[29]

All but 1 study reported the mean preoperative degree of recurvatum. Each of the other studies reportedly measured the degree of preoperative and postoperative recurvatum on either standing or supine lateral radiographs.[2,7,17,25,29] None of the included studies reported the amount of knee hyperextension on clinical examination as a measure of genu recurvatum. Among studies that reported the mean preoperative genu recurvatum, the mean degree of hyperextension on radiographs ranged from 17° to 32°.[2,7,17,25,29]

Proximal Tibial Osteotomy

Among the 5 studies that used a PTO for treatment of genu recurvatum, correction demonstrated a reduction in hyperextension, with mean knee hyperextension ranging from 0° to 7° postoperatively.[2,7,17,25,33] Posterior tibial slope was reported to increase (ie, become more posterior) postoperatively among all studies that used an anterior opening-wedge PTO for treatment, with a range of 9.4° to 24.5° increase in tibial slope.[2,7,17,25,33] Further, 4 of the 5 osteotomy studies reported that anterior tibial slope was present preoperatively, which was corrected to a posterior tibial slope postoperatively (Table 2).[2,7,17,25]

A total of 3 studies performed an isolated opening-wedge PTO technique.[17,25,33] All 3 studies reported a correction of symptomatic genu recurvatum and an increased amount of posterior tibial slope postoperatively (Table 2).[17,25,33] We noted that 2 of these studies reported the Lecuire subjective outcome scores. In the study by Kim et al,[17] all 5 patients demonstrated good or excellent postoperative outcomes, whereas Moroni et al[25] reported that 18 of 27 knees in 25 patients demonstrated good or excellent postoperative outcomes.

We found that 2 studies performed a PTO with postoperative progressive distraction using the Ilizarov method to treat genu recurvatum.[2,7] Both studies reported a correction of recurvatum and an increased posterior tibial slope among all patients (Table 2).[2,7] Lecuire subjective outcome scores were reported in both studies: 9 of 10 patients reported by Choi et al[7] and 8 of 9 patients reported by Babu et al[2] demonstrated good or excellent postoperative outcomes (Table 3).

Posterior Soft Tissue Tensioning

Only 1 study reported clinical outcomes with soft tissue retensioning of the posterior capsule for the treatment of

TABLE 2
Study Characteristics and Measures[a]

Lead Author (Year)	No. of Patients	Mean Follow-up, y	Procedure	Preoperative Recurvatum[b]	Postoperative Recurvatum[b]	Decrease in Recurvatum	Preoperative Tibial Slope[b,c]	Postoperative Tibial Slope	Increase in Tibial Slope
Moroni[25] (1992)	25 (18 M, 7 F)[d]	14.5	PTO (mix of distal and proximal to tibial tubercle)	28.9 ± 4.6	5.9 ± 4.6	–23.0	–15.0 ± 10.5	9.0 ± 8.3	24.0
Choi[7] (1999)	10 (4 M, 6 F)	4.4	Ilizarov	19.6 ± 3.1	3 ± 2.2	–16.6	–13.4 ± 7.2	5 ± 3.0	18.4
Piriou[29] (2002)	11	1	Bone-block reinsertion	32.3 ± 7.2	3.6 ± 4.5	–28.6	NR	NR	NR
van Raaij[33] (2006)	20 (3 M, 17 F)	7.4	PTO (anterior, proximal to tibial tubercle)	≥15	0	NR	11.7 ± 3.5	21.1 ± 5.7	9.4 ± 5.1
Babu[2] (2012)	9 (6 M, 3 F)	4.4	Ilizarov	28 ± 6.3	7.1 ± 4.4	–20.9	–21.4 ± 4.6	3.1 ± 2.5	24.5
Kim[17] (2017)	5 (3 M, 2 F)	3.9	PTO (anterior oblique distal to tibial tubercle)	17 ± 4.2	0.4 ± 3.3	–16.6	–10.2 ± 6.6	8.4 ± 2.4	18.6

[a]Recurvatum and tibial slope are expressed in degrees as mean or mean ± SD. F, female; M, male; NR, not reported; PTO, proximal tibial osteotomy.
[b]Measurements were taken on plain film radiograph.
[c]Negative values indicate anterior tilted tibial slope.
[d]Study reported on 27 knees from 25 patients.

TABLE 3
Subjective Clinical Outcomes Scores Described by Lecuire et al[20] [a]

Study	Mean Follow-up, y	No. of Patients	Outcome Score, n (%)[b]			
			Excellent (175-200)	Good (130-170)	Fair (80-125)	Poor (<80)
Choi[7] (1999)	4.4	10 (4 M, 6 F)	3 (30.0)	6 (60.0)	1 (10.0)	0 (0.0)
Babu[2] (2012)	4.4	9 (6 M, 3 F)	5 (55.6)	3 (33.3)	1 (11.1)	0 (0.0)
Kim[17] (2017)	3.9	5 (3 M, 2 F)	3 (60.0)	2 (40.0)	0 (0.0)	0 (0.0)
Moroni[25] (1992)	14.5	25 (18 M, 7 F)[c]	10 (37.0)	8 (29.6)	8 (29.6)	1 (3.7)

[a]F, female; M, male.
[b]Number and percentage of patients within each study with subjective outcomes in the respective category.
[c]Study reported on 27 knees from 25 patients.

genu recurvatum. The study included 11 patients, with a mean 32° ± 6.9° of hyperextension preoperatively. The investigators reported a mean 3.6° ± 4.5° of hyperextension postoperatively, with no significant loss of correction at 1 year postoperatively[29] (Table 2).

Complications

Patients who underwent PTO had the following reported complications: infection at the operative site (n = 2; 2.9%),[2,7] transient neuropathy (n = 2; 2.9%),[2,7] patella infera (n = 1; 1.4%),[7] pain over the lateral thigh (n = 2; 2.9%),[33] anterior cruciate ligament (ACL) rupture 2 years postoperatively (n = 1; 1.4%),[33] and a 7° loss of correction at an unspecified time postoperatively (n = 1; 1.4%).[33] Moroni et al[25] reported a 13-fold increased relative risk for a fair or poor subjective outcome score in patients without a purely osseous origin of genu recurvatum relative to patients with a purely osseous deformities. Further, it was reported that patients who had a PTO distal to the tibial tubercle had a relative risk of a fair or poor outcome 36 times that of patients with PTOs proximal to the tibial tubercle.[25]

DISCUSSION

The most important findings of this systematic review were that clinical evidence supports surgical management of symptomatic genu recurvatum by increasing tibial slope through use of an anterior opening-wedge PTO. Overall, patients demonstrated a reduction in the degree of knee hyperextension, a more posterior tibial slope, and good or

excellent subjective postoperative outcome scores. However, this systematic review revealed a relative paucity of objective reporting on the surgical treatment of genu recurvatum. Additionally, studies were inconsistent in reporting their specific technique for measurement of hyperextension. Future research investigating the treatment of symptomatic genu recurvatum would benefit from using and documenting a more objective, reliable measurement of knee hyperextension.

We found that 5 of the included studies determined the degree of preoperative and postoperative hyperextension using measurement techniques on either standing or supine lateral radiographs.[2,7,17,25,29] A more objective way that clinicians can identify and measure genu recurvatum, both preoperatively and postoperatively, is by evaluating side-to-side differences in heel height.[8] Previous clinical studies have reported that 1 cm of increased heel height corresponds to 1.06° of knee extension.[30] The heel-height test has demonstrated a high correlation with the traditional use of a goniometer and is more reliable in determining subtle side-to-side differences.[19,31] Given its efficiency and reliability, measurement of heel height is a more clinically relevant and objective technique than is evaluation with a goniometer for assessment of surgical correction intraoperatively and at postoperative follow-up.

In the current systematic review, 5 studies performed a PTO for the correction of symptomatic genu recurvatum; 3 studies performed PTO as a 1-step procedure, whereas the other 2 studies additionally used postoperative progressive distraction via the Ilizarov technique.[2,7,17,25,33] Each of these studies reported a reduction in the degree of knee hyperextension and an increased amount of tibial slope postoperatively. Of note, all but 1[33] of the studies that reported tibial slope found that patients with symptomatic genu recurvatum had an anterior tibial slope before the osteotomy surgery. It was theorized that correcting the anterior tibial slope to a more anatomic, posterior orientation allowed the ligaments to return to their normal tension and restored the native knee biomechanics.[1,4,13] Variations in tibial slope have previously been correlated with the degree of knee hyperextension; specifically, a greater degree of posterior tibial slope correlates with a lesser degree of knee hyperextension.[35]

We noted that 1 study included in the current review reported a mean preoperative slope of 11.7° for patients with genu recurvatum, which is closer to the reported mean posterior tibial slope of the healthy individuals. After PTO in this study, the patients' tibial slope was increased to a mean of 21.1° postoperatively.[33] Although this study reported improved subjective outcome scores according to the Hospital for Special Surgery scoring system (mean, 90.3 ± 9.0) and a high rate (83%) of patient satisfaction, such a significant degree of postoperative tibial slope may increase the risk of ACL instability at later follow-up.[3] This same study reported only 1 case of a postoperative ACL tear; however, such a large increase in posterior tibial slope compared with normal ranges increases the risk of future ACL tears and must be considered when surgically correcting genu recurvatum using a tibial osteotomy.[3,12,34]

The reviewed studies that entailed osteotomies reported similar degrees of preoperative genu recurvatum in patients treated using either PTO alone or the Ilizarov method. Both corrective techniques also demonstrated similar subjective postoperative outcomes.[2,7,17,25,33] The literature has reported that postoperative proximal tibial distraction techniques are typically used to correct severe genu recurvatum that is beyond the corrective scope of a single-stage PTO alone.[21] However, the reviewed studies indicated that this may not be necessary, as PTO with or without proximal tibial distraction demonstrated similar degrees of correction.

Most studies included in the current review identified anterior (decreased) tibial slope as the predominant cause of genu recurvatum. In a biomechanical study, Morgan et al[24] reported that knees with decreased tibial slope had an increased amount of hyperextension after ligament injuries of the knee. Thus, it is logical that increasing tibial slope using a PTO was the most common surgical treatment of the chronic injuries because most patients had an anteriorly tilted (decreased) tibial slope in this systematic review.

Although only 1 soft tissue correction study met the current inclusion criteria, several soft tissue operations have previously been described for genu recurvatum secondary to capsuloligamentous insufficiency that were not included in this systematic review. Older studies have suggested surgically inserting a restrictive soft tissue graft at the posterior aspect of the knee to prevent hyperextension.[15,16,28] Noyes and Barber-Westin[26,27] addressed knee hyperextension in the setting of chronic multiligament knee instability through plication or advancement of the posterolateral capsule. These studies were each limited by a lack of patient outcomes and follow-up data related to the sustained correction. Included in the current review, Piriou et al[29] reported a reduction in recurvatum (from 32° to 3.6°) that was maintained at 1-year follow-up using their capsular bone-block reinsertion technique. However, the short-term follow-up reported in this study warrants observation beyond 1 year because soft tissue corrections may stretch over time and cause a patient's knee to revert back to hyperextension. To date, an anatomic-based surgical reconstruction to treat genu recurvatum has not been proposed in the biomechanical or clinical literature. Furthermore, genu recurvatum secondary to soft tissue laxity is often chronic in nature,[22,27] and the literature consistently reports that treatment of chronic ligamentous laxity demonstrates inferior outcomes compared with treatment in the acute setting.[9,10,18] A previous biomechanical study showed that the oblique popliteal ligament's midtibial attachment is the most significant restraint to knee hyperextension.[24] As such, it is essential to identify and treat ligamentous causes of symptomatic knee hyperextension in the acute setting when possible.

We acknowledge that this systematic review has some limitations. First, despite composing a significant proportion of the cases of genu recurvatum, patients who developed genu recurvatum secondary to stroke, polio, or cerebral palsy were not included in the analysis because they often require individualized, multifactorial, and often complex treatment strategies that are not generalizable to the field of orthopaedic sports medicine. Additionally, the

specific method of measurement for the degree of recurvatum was not uniformly detailed in each study. Because all studies that met inclusion criteria were level 4 evidence, we were unable to conduct a risk of bias analysis. Finally, there was a paucity of long-term clinical outcome measures after treatment of genu recurvatum; as such, only the degrees of recurvatum and tibial slope were included as objective outcome measures. Future research should examine treatment options with additional validated, subjective and objective, long-term outcome data to help properly develop a treatment protocol.

CONCLUSION

Anterior opening-wedge PTO, with or without postoperative external fixation with progressive distraction, was found to be a reliable surgical treatment for genu recurvatum. After surgical management using a PTO, patients can expect to achieve correction of knee hyperextension, restoration of a more posterior tibial slope, and increased subjective outcome scores.

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