



Twisting technique for ulnar collateral ligament reconstruction of the elbow: new possibilities toward enhancing the strength of autografts



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Background: Although the ulnar collateral ligament reconstruction procedure has been increasing in popularity annually owing to its stable postoperative outcomes, the number of revision surgeries following ulnar collateral ligament reconstruction has increased. The success of the initial reconstruction surgery and further improvement in the return-to-play rates of the initial surgery are crucial. In this study, we report on ulnar collateral ligament reconstruction using the twisting technique, which aims to enhance the strength of the graft (palmaris longus tendon) to improve return-to-play rates.

Methods: We investigated the return-to-play rate and period in 60 cases (2016–2021) that underwent ulnar collateral ligament reconstruction using the twisting technique and 211 cases (2007–2019) that did not use the twisting technique. The twisting technique involved inserting the graft through the bone tunnel and then twisting the doubled tendon.

Results: According to the Conway-Jobe scale, the twisting technique group had 98.3% excellent, 1.7% good, 0% fair, and 0% poor results, with a mean return-to-play period of 9.8 months. The non-twisting technique group had 86.7% excellent, 9.0% good, 1.9% fair, and 2.4% poor results, with a mean return-to-play period of 11.4 months. The two groups showed significant differences in return-to-play rate ($P = .020$) and period ($P = .022$).

Conclusion: The clinical results of the twisting technique showed that the return-to-play rate of the twisting technique group was higher after than before the procedure, and the return-to-play period was shortened by more than 1 month. The twisting technique may improve the results of ulnar collateral ligament reconstruction surgery.

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The ulnar collateral ligament (UCL) is an important stabilizing mechanism for the valgus force in the elbow joint^{18,43,45} and is particularly crucial for overhead athletes. Among its components, the anterior oblique ligament plays a significant role in controlling valgus instability.^{43–46}

In the pitching motion performed during baseball games, the elbow joint is constantly subjected to valgus stress, which can lead to specific injuries to the UCL, particularly the anterior oblique ligament. Since Jobe³⁰ introduced UCL reconstruction surgery in 1974, where a graft is passed through bone tunnels in the figure of 8, various reconstruction methods have been reported. Currently, there are 13 different reconstruction techniques documented in the literature.^{2,5,7,10,20,26,33,35,41,47,49,50}

UCL reconstruction surgery has been increasing in popularity annually owing to its stable postoperative outcomes. According to various reports, the return-to-play (RTP) rate among baseball players from the procedure ranges between 75% and 96%, indicating favorable results.^{12–14,19,24,25,29,32,33,48–50}

In recent years, there has been an increase in the number of revision surgeries following UCL reconstruction, and various reports indicate that in cases where revision surgery is required after UCL surgery, the RTP rate can decrease to 50%–65% compared to that after the initial surgery, and complications may also increase.^{4,9,16,31,34,40} Therefore, the success of the initial reconstruction surgery is crucial.

We have been performing UCL reconstruction surgery using the muscle-splitting approach, where we create tunnels in the coronoid process (Jobe method) and fix the graft at the medial epicondyle foramen with an autograft bone peg harvested from the olecranon (devised by the coauthor, Itoh). This technique has been employed for UCL reconstruction in over 1000 cases of baseball players with UCL insufficiency between 1997 and 2016.

The ethical review board of Keiyu Orthopaedic Hospital approved this study. Reception number 3509.

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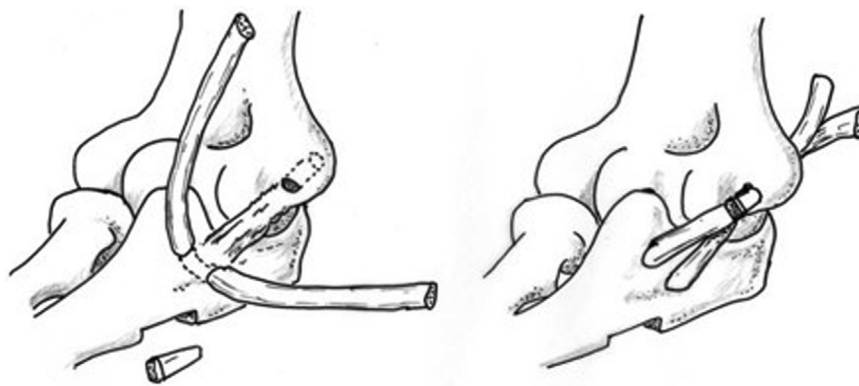


Figure 1 Schema of UCL reconstruction using autograft bone peg. UCL, ulnar collateral ligament.

The results have shown an excellent RTP rate of over 86%, which is comparable to that in other reports. However, while the outcomes have been favorable, we continue to investigate the reasons for not achieving a 100% postoperative RTP rate and believe that further improvement is needed. One of the factors that can be considered is the issue of laxity in the transplanted ligament. Therefore, to further improve the RTP rate, since 2016, we have devised a method to enhance the strength of the graft (palmaris longus [PL] tendon) by using autologous tendon transplantation. By incorporating twisting into the graft during reconstruction, the ratio of excellent postoperative outcomes increased. In this study, we report the effectiveness of UCL reconstruction using the twisting technique, which involves an additional twisting to the graft in our conventional UCL reconstruction procedure.

Materials and methods

Between 2016 and 2021, a total of 60 cases (TwT-Grp) underwent UCL reconstruction surgery using the twisting technique. The same surgeon (Furushima) performed the procedures, and the PL tendon was used as the graft in all cases. The exclusion criteria included the use of a thin fascial tendon as the graft, having undergone additional surgeries for conditions such as olecranon stress fractures, or the presence of other conditions affecting different areas, such as pitching shoulder injuries. The cases included 56 amateur baseball players (mean age: 19.4 years) and 4 professional baseball pitchers (mean age: 24.3 years) who had a follow-up of at least 2 years after surgery. The athletes' competitive levels were as follows: 4 middle school students, 21 high school students, 21 college students, 10 nonprofessional players, and 4 professional players. Among them, 46 were pitchers and 14 were field players.

In contrast, a comparison group comprised 211 patients (non-TwT-Grp) who underwent UCL reconstruction surgery without using the twisting technique and had a follow-up of at least 2 years (mean: 3.8 years) between 2007 and 2016. Non-TwT-Grp consisted of 154 amateur players (mean age: 18.8 years) and 57 professional baseball players (mean age: 25.2 years). The RTP levels and period were compared between the two groups. In addition, for the TwT-Grp, the difference in joint gap width between the affected and healthy sides based on plain radiography under valgus stress from the own weight of the elbow joint was evaluated before and after surgery. This measurement was possible in 15 cases after returning to full pitching activity.

The statistical results were compared using Fisher's exact test.

Evaluation

The RTP level was evaluated using the Conway-Jobe scale.¹¹ The RTP period was defined as the duration from surgery to the pitcher's return to pitching in games or the player's return to game participation for field players. After RTP, the participants were evaluated during a follow-up period of at least 1 year through examinations, questionnaire responses, and telephonic interviews.

Surgical technique

The main criteria for surgery indication included the following four factors: 1) inability to perform pitching at the competitive level, 2) localized tenderness limited to the area superior to the UCL, 3) resistance to conservative therapy with recurring elbow pain, and 4) clear evidence of ligament damage observed on magnetic resonance imaging.

UCL reconstruction was performed by the same method as the Jobe procedure for creating a bone tunnel at the ulnar coronoid process. The bone tunnel was created with a diameter of 3.2 mm, and the graft was passed through the anterior and posterior aspects of the ulnar coronoid process. Meanwhile, a 4.5-mm-diameter bone tunnel was created at the medial epicondyle, and both ends of the graft were passed through a single bone tunnel. For fixation, an autograft bone peg (approximately 3.0 mm in diameter and 20 mm in length) harvested from the olecranon was used. This method, devised by coauthor Itoh, allows for the secure fixation of the tendon using the patient's own bone without the need for special synthetic materials. The key feature of this method is the early achievement of physiological bone-tendon fusion between the graft and the bone tunnel, as well as the strong initial fixation strength of the graft (Figs. 1–4). Additionally, using an autograft bone peg as the graft allows for easy re-harvesting of the same bone tunnel in the event of a revision surgery, making subsequent reconstructions relatively straightforward.

The difference between the two techniques in this study lies solely in whether the graft is twisted. The surgical techniques, such as the position of the bone tunnels and the method of tendon fixation, are the same. In the twisting technique, after passing the graft through the bone tunnels at the ulnar coronoid process and the medial epicondyle, the doubled tendon is twisted from the posterior aspect of the exit of the medial epicondyle bone tunnel until the twisted portion is positioned immediately superior to the joint gap (Figs. 5 and 6). The tension of the tendon is confirmed during elbow flexion and extension, and the autograft bone peg is trimmed to an appropriate thickness at a position of elbow flexion



Figure 2 Harvested PL tendon and autograft bone peg. PL, palmaris longus.

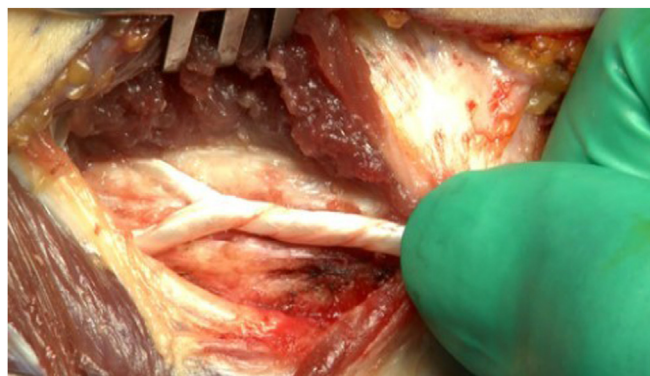


Figure 5 Transplanted ligament after twisting technique.



Figure 3 Autograft bone peg after trimming.

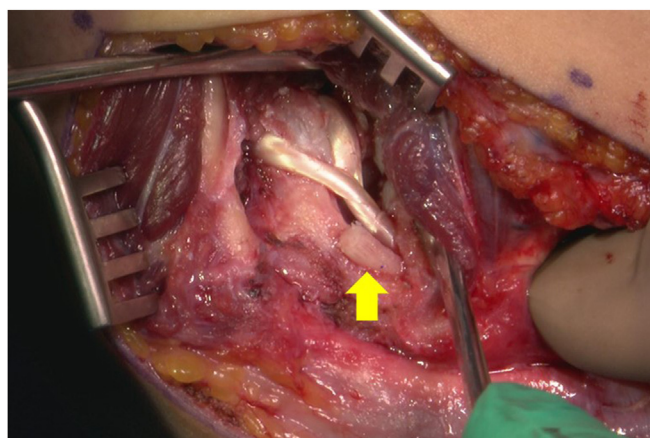


Figure 6 Transplanted ligament with twisting technique by autograft bone peg (↑).

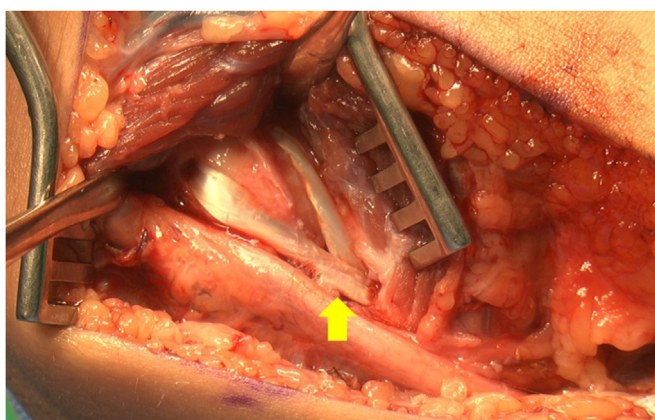


Figure 4 Transplanted ligament without twisting technique by autograft bone peg (↑) fixation.

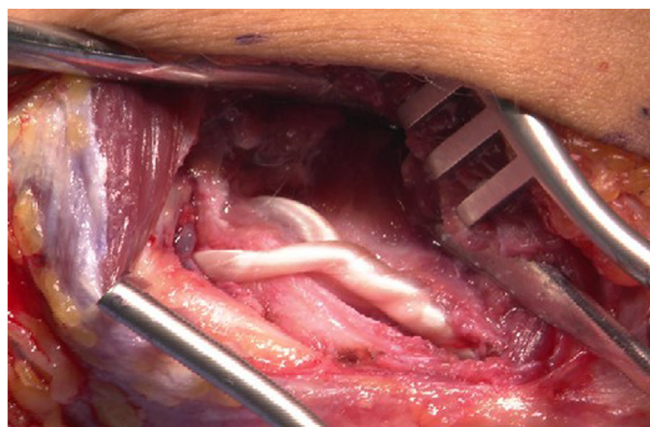


Figure 7 Fixation of the transplanted ligament.

of 45°-60° and then hammered into the bone tunnel on the medial epicondyle side for fixation (Fig. 7).

Results

By the Conway-Jobe scale,¹¹ the 60 cases of the TwT-Grp included 59 cases (98.3%) with excellent, 1 case (1.7%) with good, and 0 cases with fair/poor outcomes (Table 1). Four of the cases were professional baseball players, and all of them had excellent outcomes. The one case with good outcome developed symptoms of the ulnar nerve after resuming pitching action and subsequently

underwent neurolysis, which led to complete RTP. The mean postoperative RTP period was 9.8 (±2.2) months. In amateur players, the mean RTP period was 9.6 (±2.2) months and that in the four professional baseball players was 11.0 (±1.0) months.

In contrast, by the Conway-Jobe scale, the non-TwT-Grp had 183 cases (86.7%) with excellent, 19 cases (9.0%) with good, 4 cases (1.9%) with fair, and 5 cases (2.4%) with poor outcomes; the mean postoperative RTP period was 11.4 (±3.2) months. The 154 cases of amateur players had a mean postoperative RTP period of 10.8 (±2.4) months, while the 57 cases of professional baseball players had a mean postoperative RTP period of 12.5 (±3.2) months.

Table 1
Postoperative outcomes and RTP durations in TwT-Grp and non-TwT-Grp.

	TwT-Grp		Non-TwT-Grp	
	Amateur (56)	Professional (4)	Amateur (154)	Professional (57)
Average age (y)	19.6	24.3	18.8	25.2
Conway-Jobe scale (n, %)				
Excellent	51 (98.3)	4 (100)	134 (87)	49 (86)
Good	1 (1.7)	0	13 (8.4)	6 (10.5)
Fair	0	0	2 (1.3)	2 (3.5)
Poor	0	0	5 (3.5)	0
Duration of RTP (mo)	9.8 ± 2.2	11 ± 1.0	10.8 ± 2.4	12.5 ± 3.2

TwT-Grp, twisting technique group; non-TwT-Grp, non-twisting technique group; RTP, return-to-play.

In the preoperative and postoperative plain radiographs under valgus stress from the own weight of the elbow joint in the TwT-Grp, the mean difference in joint gap width between the affected and healthy sides improved from 1.5 (1.0-5.2) mm preoperatively to 0.3 (-0.5 to 1.5) mm postoperatively.

Comparison of the surgical results of the TwT-Grp and non-TwT-Grp showed significant differences between the two groups in terms of RTP rate ($P = .020$) and period ($P = .022$).

Discussion

We evaluated the effectiveness of the UCL reconstruction surgery using the twisting technique, a new approach, in 60 baseball players (including 4 professional baseball players). This technique increased the strength of the graft by providing an additional twist.

The RTP rate for the TwT-Grp players was 98.3% (59/60 cases). Previous reports indicate RTP rates of 80%-96%,^{6,8,17,27,36,37,39} but compared to the various reports and our conventional technique, the present new technique increased the ratio of excellent results, and the results were generally better.

While previous reports indicated RTP periods ranging from 12 to 20 months,^{6,8,15,17,36,38,39} by our technique, the non-TwT-Grp cases had a mean RTP period of 10.8 months for amateur players and 12.5 months for professional baseball players. The results here indicated a shorter RTP period than that in the autograft-based procedures reported previously. This finding can be explained by the earlier tendon-bone fusion realized by the autograft bone peg fixation devised by Itoh, which brought forward the resumption of pitching action.

Meanwhile, the TwT-Grp athletes in this study had a mean RTP period of 9.6 months for amateur players and 11.0 months for professional baseball players, and the overall RTP period was shortened by more than 1.6 months. This result suggests that the twisting technique enables earlier RTP.

Both groups followed the same protocol of postoperative rehabilitation. Pitching practice commenced 3 months after confirmation of tendon-bone fusion, increasing gradually in intensity and distance, and full-strength pitching commenced at 8 months. The shortening of the RTP period was primarily explained by the shortening of the duration from the start of full-strength pitching to the return to gameplay. Furthermore, some players were capable of earlier return than that in the protocol timeline, suggesting that revising the postoperative RTP protocol may allow even earlier RTP.

In the TwT-Grp, elbow joint radiography was performed to compare and evaluate the preoperative and postoperative instability. We confirmed that the mean difference in joint gap width between the affected and healthy sides, which was 1.5 (1.0-5.2) mm preoperatively, improved to 0.3 (-0.5 to 1.5) mm postoperatively. None of the cases had worse instability after surgery, thereby suggesting the maintained strength of the transplanted ligament.

UCL injuries used to be a threat to the careers of overhead athletes. However, numerous reconstruction techniques have been developed, and currently, surgery can provide a high expected RTP rate. The major surgical techniques reported can be broadly classified into three categories: figure-of-8, triangular, and linear constructs.²⁸

The Jobe method is based on the figure-of-8 construct and involves placing the graft in an 8-like shape, but postoperative ulnar nerve impairment was a concern. The RTP rate was 63%, and the RTP period was 12-18 months. In 1995, Andrews and Timmerman³ improved the surgical approach and the RTP rate to 83%. In addition, in the modified Jobe technique⁵⁰ announced by Thompson and Jobe in 2001, the bone tunnel in the humerus was corrected, and the requirement for ulnar nerve anterior transposition was eliminated, which resulted in an RTP rate of 82%.

With triangular construct, the Docking method developed by Rohrbough and Altchek et al⁴⁹ in 2002 produced good results. This technique had a reported RTP rate of 92% and came to be used widely in professional baseball players. Further improvements were made thereafter, such as the Docking Plus technique,⁴¹ and excellent results have been reported continuously.

As for the linear construct, Armstrong et al showed the importance of the anterior oblique fiber of the UCL in 2002, and Ahmad et al² proposed a new technique based on this. This technique used an interference screw to fix the graft, and the reported results were favorable. In addition, new techniques such as the David Altchek and Neal ElAttrache for Tommy John (DANE TJ) by Conway et al¹⁰ were reported. Further improvements were made in graft fixation, leading to reports of EndBotton,⁵ GraftLink,³⁵ and Double Docking technique.²⁰

The modern UCL reconstruction techniques and results are affected by various factors, including individual patient characteristics, skills and experience of the surgeon, and rehabilitation protocol after reconstruction. These advances have transformed the once career-ending UCL injury to one that may prolong the career, given appropriate treatment.

None of the previous reports specifically addressed the fixation method using autograft bone pegs and graft twisting. In addition to the existing techniques, the autograft bone peg fixation (Itoh method) and the twisting technique, which incorporates modifications to the graft, have been shown to achieve higher RTP rates and earlier RTP, equal to or surpassing the existing methods. Based on these findings, the fixation method using autograft bone pegs and the twisting technique may be useful treatment options for UCL injuries.

Our previous UCL reconstruction technique aligns with the triangular construct category. However, we have been using a method that involves fixing the ulnar side bone tunnel with autograft bone pegs at a single location (autograft bone peg fixation). Similar to those in previous reports, this technique consistently yielded excellent results, enabling earlier RTP.

While the results have been favorable, it was necessary to investigate the factors preventing the postoperative RTP rate from reaching 100%. We speculate that thoracic outlet syndrome²¹ and neural symptoms caused by the ulnar nerve are among the contributing factors. Therefore, in preoperative diagnosis, we carefully evaluate elbow pain associated with neural symptoms and, if there are concurrent injuries, provide simultaneous treatment to reduce postoperative poor outcomes. However, in cases where postoperative performance does not improve, one potential factor could be graft loosening. If the strength and durability of the graft are insufficient, it can loosen during elbow flexion-extension movements or even after the start of pitching, which may adversely affect postoperative outcomes.

Since 2016, we have introduced the twisting technique to improve the strength and durability of the graft and minimize intraoperative and early postoperative graft loosening. In some cases, the use of thinner PL tendons can lead to graft loosening. Additionally, owing to variations in the shape of the coronoid process and the medial epicondyle among individuals, it is difficult to ensure consistent graft tension during flexion-extension. In the conventional method, the graft was only fixed through the bone tunnel, which occasionally resulted in loosening during flexion-extension. Empirically, not all cases with graft loosening experience poor outcomes; however, loosening can also contribute to conditions such as olecranon bone spur impingement and stress fractures.^{1,22}

In this technique, the doubled graft is twisted up to the level immediately superior to the joint space (Fig. 5). This results in the V-shaped tendon transforming into a Y-shaped thick strand, increasing the stiffness of the tendon. During intraoperative observation, noticeable differences were observed in terms of the volume and stiffness of the ligament, as well as the elasticity of the ligament during elbow flexion-extension movements.

As a general principle in mechanical engineering, adding a twist to a string or rope increases its strength.⁴² This is attributed to several factors, including tension distribution, mutual reinforcement, and localization of damage. When a string is twisted, the pulling force is evenly distributed throughout the entire string, each section of which reinforces and supports the other sections. This configuration increases the overall strength of the string and allows for localized damage without affecting the integrity of the entire string. As a specific example, Adrian et al demonstrated that the tensile strength of a plied yarn is 2–3 times greater than that of a simple spun yarn.²³ In other words, adding a twist to a string-like graft may increase its strength. Furthermore, adding a twist to the string can provide a certain degree of elasticity, as the twisting causes the fibers within the string to be arranged in a spiral shape. When the twisted string is pulled, the spiral structure allows for partial elongation.

The clinical results after surgery using the twisting technique showed statistically significant differences. Regarding the RTP period and rates, the TwT-Grp demonstrated a favorable trend compared to the non-TwT-Grp. This result suggests that the effects of graft twisting, such as increased strength, durability, and elasticity, may affect these outcomes. Based on these findings, the twisting technique may be a new approach to UCL reconstruction surgery.

Limitations

This study has some limitations. Firstly, the strength, durability, and elasticity resulting from twisting can be influenced by the materials used and the degree of twisting, making it important to understand and utilize these characteristics appropriately. However, in this study, there is a lack of experimental data regarding the twisting strength, durability, and elasticity of the PL tendon. As a

result, our analysis primarily relies on clinical outcomes. This is a significant limitation of this study, and we recognize that future research should be supported by experimental data.

Another limitation is that this study focused exclusively on baseball players, and the number of patients who underwent surgery was limited to 60 individuals. Therefore, it remains uncertain whether the findings of this study can be applied to a more general patient population.

Lastly, various indicators are available to evaluate the effectiveness of the surgery. The Conway-Jobe scale, for example, includes subjective elements, which may introduce variability in the evaluation results. In this study, we used RTP rate, RTP period, and the difference in joint gap width between affected and unaffected sides measured by plain radiographs under valgus stress as evaluation indicators. However, these indicators have limitations, and it may be necessary to consider a broader set of functional assessment measures for a more comprehensive evaluation in the future. Such evaluation could provide a deeper understanding of the surgical outcomes and suggest additional avenues for improving patient recovery following surgery.

Conclusion

The twisting technique was applied to 60 baseball players undergoing UCL reconstruction surgery, and favorable results were obtained. The TwT-Grp showed higher RTP rates than those in previous studies, and the RTP period was also reduced by more than 1 month. Additionally, the stability of initial fixation achieved through autograft bone peg fixation (Itoh method) may have contributed to early RTP, per various reports.

In the preoperative and postoperative elbow stress radiographs, improvement in the UCL gap width was observed, and increased instability did not occur. However, the study was limited to baseball players only, and there was a limitation regarding the lack of experimental data on the twisting strength of the PL tendon. It is necessary to increase the number of cases and conduct further studies using a multidimensional evaluation approach in the future. The twisting technique presents new possibilities for UCL reconstruction surgery.

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