Turk J Phys Med Rehab 2024;70(1):53-60
DOI: 10.5606/tftrd.2024.11715
Available online at www.turkishjournalpmr.com

Original Article

Rigid tape dynamic fixation in conservative treatment of acute anterior talofibular ligament tear: A retrospective cohort study

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ABSTRACT

Objectives: This study aims to compare results of rigid tape (RT) dynamic fixation and static fixation in conservative treatment of acute anterior talofibular ligament (ATFL) tear.

Patients and methods: Between September 2021 and December 2021, a total of 91 patients (41 males, 50 females, mean age: 28.5±6.5 years, range, 18 to 40 years) who were diagnosed with ATFL tear and underwent rigid tape (RT) or cast/brace rehabilitation protocol were retrospectively analyzed. The patients were divided into two groups as the RT group (n=36) and the control group (n=55). Follow-up (FU) was performed at six months. Outcomes included pain (Numerical Rating Scale [NRS]), ankle function (American Orthopaedic Foot & Ankle Society [AOFAS] hindfoot score), deviation of center of gravity (DCG), and symptoms after returning to sports.

Results: The difference at each time point of pain, AOFAS, DCG and SRS between the two groups was statistically significant (p<0.05 for all). Only one patient at Week 12 in the RT group had pain in the lateral side of the ankle, while 36 patients at Week 12 and 21 patients (18 in the medial side) at FU had pain in the control group.

Conclusion: Our study results suggest that RT dynamic fixation can accurately lock the ATFL function and may prevent pseudo-stability, so as to quickly repair injury, restore function, and return to sports earlier.

Keywords: Ankle lateral ligaments, athletic tape, conservative treatment, rehabilitation.

Ankle sprain is a common injury, particularly in athletes[1-3] which may account for 20 to 40% of all sports injuries.[4,5] It is most commonly seen in athletes participating in basketball, football, running, and ballet.[6] Up to 53% of basketball injuries and 29% of soccer injuries can be attributed to ankle injuries, and 12% of football game time lost is due to ankle injuries.[7] Three-quarters of ankle injuries involve the lateral ligament complex, and the incidence is equal in males and females.[8] About 85% of ankle sprains are caused by excessive varus.[9] Symptoms may include pain, swelling, and stiffness. Depending on the severity of the injury, athletes may be able to walk carefully with little or no pain, or may be unable or only partially able to bear weight on the injured ankle.[2,10,11]

Nearly 80% of acute ankle sprains can be completely recovered by conservative treatment, while 20% of acute ankle sprains would be mechanically or functionally unstable, leading to chronic ankle instability.[6,12,13] In a 10-year study by Harrington,[14] the degenerative changes of the medial ankle joint were more severe with weight-bearing films. Moreover, four out of five ankles with severe arthritis eventually required total ankle replacement.

Acute repair, plaster fixation, and functional rehabilitation of ankle sprains have achieved good

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Received: September 15, 2022 **Accepted:** March 23, 2023 **Published online:** October 31, 2023

Cite this article as: Du S, Wei L, Wang Q, Yao Y, Xu K, Ying S, et al. Rigid tape dynamic fixation in conservative treatment of acute anterior talofibular ligament tear: A retrospective cohort study. Turk J Phys Med Rehab 2024;70(1):53-60. doi: 10.5606/tftrd.2024.11715.

results. A study showed that patients undergoing surgery had higher objective scores, but concluded that, in most cases, surgery was not worth due to the additional costs, risks or complications.[15] Given that the results of the second repair are similar to the first repair, and the functional treatment produces similar results, surgery is rarely needed in acute situations. Martin et al.[16] recommended that clinicians should advise patients with an acute lateral ankle sprain to use external supports (taping and bracing) and to progressively bear weight on the affected limb. The type of external support and gait assistive device recommended should be based on the severity of the injury, phase of tissue healing, level of protection indicated, extent of pain, and patient preference. In more severe injuries, immobilization, ranging from semi-rigid bracing to below-knee casting, may be indicated.[16] However, for patients with anterior talofibular ligament (ATFL) tear, static fixation is still applied in most conservative treatment to “recover the injury” followed by functional rehabilitation, even if functional treatment is allowed in the early phase, static fixation is still applied on the ankle;[17] therefore, this is not good enough for the injury itself and functional recovery, and is more likely to increase the incidence of pseudo-stability, that is, bony stability rather than stability based on tensegrity structure. Bony stability weighs bones more and can cause more severe degenerative changes of the medial ankle joint.

A meta-analysis comparing the different functional treatment options (which included elastic bandage, tape, semi rigid ankle support, and lace up ankle support) could not make definitive conclusions, as the diversity of outcome results prevented pooling of different studies.[17,18] Besides, there are two types of tapes which are completely different; i.e., kinesiology tape and rigid tape (RT). The latter is used for athletic injury protection. Moreover, in clinical practice, many practitioners are failed to apply it on acute injuries due to diverse and professional application. Therefore, a method is provided in this study to apply RT on acute ATFL tear which can protect injured area and persist functions, and can be used in serious injuries, even may prevent degenerative changes of the medial ankle joint.

In the present study, we hypothesized that RT dynamic fixation applied on acute ATFL tear would promote functional recovery more effectively than static fixation. We, therefore, aimed to compare the results of two types of fixations in conservative treatment of acute ATFL tear.

PATIENTS AND METHODS

This single-center, retrospective cohort study was conducted at Shanghai Sixth People's Hospital Affiliated to Shanghai Jiao Tong University School of Medicine, Department of Rehabilitation between September 2021 and December 2021. Inclusion criteria were as follows: ATFL tear as evidenced by magnetic resonance imaging (MRI) or ultrasound (US); age between 18 and 40 years; first visit between January 2019 and December 2020 within two weeks after injury; and undergoing standardized RT or cast/brace rehabilitation protocol. Exclusion criteria were as follows: concomitant muscle, bone, and nerve injuries; comorbidities due to other osteoarthropathy; and incomplete data or lost to follow-up (FU). A total of 145 patients met the inclusion criteria. However, of the patients who underwent the standardized RT rehabilitation protocol, 12 accompanied by avulsion fracture, one accompanied by posterior tibialis tendonitis, 11 accompanied by calcaneofibular ligament tear and, of patients who underwent the standardized cast/brace rehabilitation protocol, 13 accompanied by calcaneofibular ligament tear, 15 had comorbidities due to other osteoarthropathy, and two with incomplete data or lost during FU were excluded from the study. Finally, a total of 91 patients (41 males, 50 females, mean age: 28.5±6.5 years, range, 18 to 40 years) were enrolled. The patients were divided into two groups as the RT group (n=36) and the control group (n=55).

Treatment

RT group: A standard RT rehabilitation protocol was applied. Dynamic fixation with RT was performed for eight weeks guided by three-dimensional (3D)/two-dimensional (2D) image registration technique[19] (Figure 1): *(i)* lock the fibula; *(ii)* lock of the anterior side of the medial malleolus, if there is pseudo-stability; *(iii)* lock the calcaneus to avoid abduction, if necessary; *(iv)* lock the lateral side of the calcaneus to lock the talus; and lock the calcaneus to avoid excessive varus and valgus. Rigid tape was performed by professional therapists and was applied after daily modalities before training and removed before going to bed (re-tape everyday). Meanwhile, patients were instructed to feel the direction of the RT pulling force to use the muscle strength accordingly. Weeks 1 and 2, progressive weight training and gait training with crutches (four-point gait to two-point gait); Weeks 3 and 4, gait training without crutches, static balance training, and proprioception training; Weeks 5 and 6, dynamic balance training and

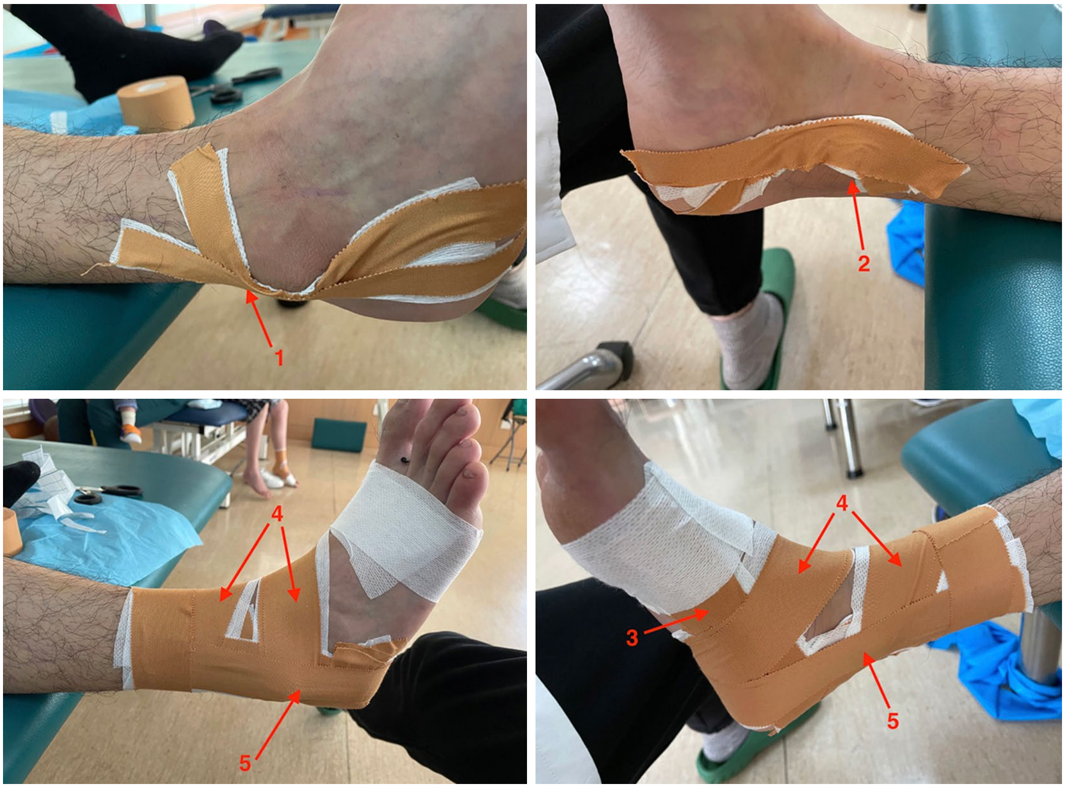

Figure 1. Patients who applied rigid tape. 1 denotes the tape locks the fibula, 2 denotes the tape locks of the anterior side of the medial malleolus if there is pseudo-stability, 3 denotes the tape locks the calcaneus to avoid abduction, if necessary, 4 denotes the tape locks the lateral side of the calcaneus to lock the talus, 5 denotes the tape locks the calcaneus to avoid excessive varus and valgus.

proprioception training; Weeks 7 and 8 return to basic sports training; and Weeks 9 and 12, return to normal sports training.

Control group: A standard cast or brace rehabilitation protocol was applied. Cast or brace was applied on the injured ankle for four-week immobilization, and functional rehabilitation (non-weight-bearing) with static fixation on ankle could be performed during this period. Week 5, progressive weight training and gait training with crutches (four-point gait to two-point gait); Week 6, gait training without crutches, static balance training, and proprioception training; Weeks 7 and 8, dynamic balance training and proprioception training; Weeks 9 and 10, return to basic sports training; and Weeks 11 and 12, return to normal sports training.

Strength training and range of motion (ROM) training were performed, if necessary. All the patients were also treated with modalities everyday (started at the first week in the RT group and the fifth week in the control group): US therapy (10 min), neuromuscular electrical stimulation (NMES, 20 min), and transcutaneous electric nerve stimulation (TENS, 20 min).

Assessments

Assessments included pain, ankle function, deviation of center of gravity (DCG), and symptoms after returning to sports (SRS).

Pain was measured during activity using the Numerical Rating Scale (NRS),[20] which is a point scale from 0 to 10, where 0 indicates no pain, 10 indicates unbearable pain. The patients were asked to choose a number from the above to describe the pain.

Ankle function was evaluated using the American Orthopaedic Foot & Ankle Society (AOFAS) hindfoot score.[21] It consists of pain (40 points), function (50 points), and arrangement (10 points).

The DCG was evaluated in all patients.[22] The patients were asked to stand on two body weight scales (one foot on one scale) naturally. DCG= the reading of the affected side/the total reading of the two scales ×100%.

Symptoms after returning to sports was evaluated in all patients.[23] The symptoms of the patients were collected during exercise. The presence of symptoms was recorded as Y, while the absence of symptoms as N.

Pain, AOFAS, and DCG were measured before intervention, and at Weeks 4, 8, and 12 after the beginning. The SRS was measured 12 weeks after the beginning, as well as six months of FU.

Statistical analysis

Statistical analysis was performed using the IBM SPSS for Mac version 23.0 software (IBM Corp., Armonk, NY, USA). Descriptive data were expressed in mean ± standard deviation (SD), median (min-max) or number and frequency, where applicable. Differences between these two groups in age, visiting time after injury (VTI) and body mass index (BMI) were assessed using independent t-test; in pain, AOFAS, and DCG were assessed using repeated measures models and multivariate analysis of variance (MANOVA), while the Bonferroni method was used due to the significant interaction effect in sex, affected side, classification,[24] and SRS was assessed using the chi-square test. Differences within each group in pain, AOFAS, and DCG were assessed using paired-samples t-test. The η^2 was used to represent the effect size of the interaction effect (group × time) for pain, AOFAS, and DCG values. A p value of <0.05 was considered statistically significant.

RESULTS

The baseline characteristics of the patients are shown in Table 1. Accordingly, there was no significant difference in age, sex, affected side, VTI, classification, and BMI between the groups (p>0.05). There were no statistically significant differences between the two groups during the initial measurement for all variables at baseline (Table 2).

However, there were significant time × group interactions for pain, AOFAS, and DCG (p<0.05 for all) and the Bonferroni method was used for adjustment. The effect size of DCG was the largest while the one of pain was the smallest (η^2=0.390, 0.774, 0.889 for pain, AOFAS and DCG respectively (Table 2). The difference at each time point (except for baseline) of pain, AOFAS, and DCG between the two groups was statistically significant (p<0.05 for all) (Table 2, Figures 2-4). In addition, a statistically significant difference was found in SRS (p<0.05 for all) (Table 2). Only one patient at Week 12 in the RT group had pain in the lateral side of the ankle, while 36 patients at Week 12 (all in the lateral side) and 21 patients (18 in the medial side, three in the lateral side) at FU had pain in the control group.

TABLE 1
Baseline characteristics of patients

	Rigid tape group (n=36)		Control group (n=55)				
	n	Mean±SD	n	Mean±SD	t/χ^2	*P* (sig)	95% CI
Age (year)		27.7±5.9		29.0±6.9	−0.935	0.352	−4.106-1.478
Sex					0.113	0.737	
Female	19		31				
Male	17		24				
Side					0.463	0.496	
Right	19		33				
Left	17		22				
Visiting time after injury (d)		8.22±3.55		7.24±4.10	1.180	0.241	−0.674-2.646
Classification					0.773	0.679	
1	6		7				
2	24		35				
3	6		13				
Body mass index		24.38±3.06		23.52±3.52	1.202	0.232	−0.563-2.288

SD: Standard deviation; t: t value of independent-test; χ^2: Chi-square value; CI: Confidence interval.

TABLE 2
Data of pain, AOFAS, DCG and SRS at various time points

	Baseline	4 Weeks	8 Weeks	12 Weeks	
	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Follow-up
Rigid tape group					
Pain	4.306±1.653	0.917±1.105	0.167±0.507	0.028±0.167	
AOFAS	37.056±14.650	80.667±14.311	97.222±7.990	99.444±3.333	
DCG	24.956±10.761	47.188±3.697	49.984±1.739	50.011±1.255	
SRS				1	0
Control group					
Pain	4.964±1.753	2.436±1.619	2.127±1.611	1.091±1.005	
AOFAS	35.600±16.459	43.673±9.446	67.618±15.814	80.418±12.050	
DCG	23.372±8.636	19.186±8.036	44.703±5.940	47.059±3.924	
SRS				36	21
P (sig) F					
Pain (η^2=0.390)	0.077 3.206	<0.001 24.269	<0.001 49.922	<0.001 39.424	
AOFAS (η^2=0.774)	0.668 0.185	<0.001 221.104	<0.001 107.828	<0.001 85.174	
DCG (η^2=0.889)	0.440 0.601	<0.001 382.940	<0.001 26.848	<0.001 19.046	
SRS				<0.001	<0.001
P (sig) χ^2				35.426	17.869

AOFAS: American Orthopaedic Foot & Ankle Society hindfoot score; DCG: Deviation of center of gravity; SRS: Symptoms after returning to sports; SD: Standard deviation; F: F value of MANOVA, χ^2: Chi-square value, η^2: The effect size of the interaction effect (group × time).

Differences at adjacent time point within each group were not statistically significant which at Week 12 on pain (t=1.963, p=0.058), AOFAS (t= −1.963, p=0.058), and DCG (t= −0.114, p=0.910) in the RT group and at Week 8 on pain (t=1.608, p=0.114) in the control group (Figures 2-4).

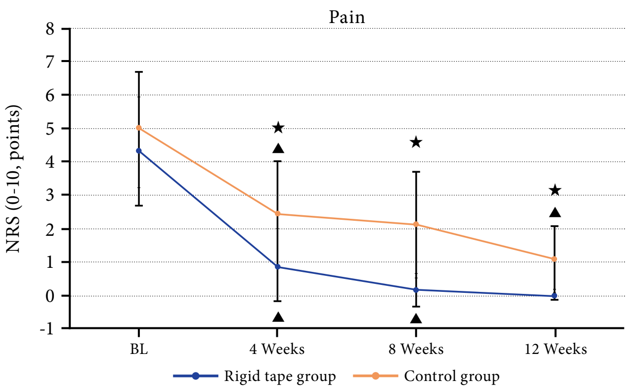

Figure 2. Pain (NRS; where 0= no pain and 10= worst imaginable pain).

★ Denotes significantly different between the two groups at p<0.05; ▲ Denotes significantly different at adjacent time point within each group at p<0.05.

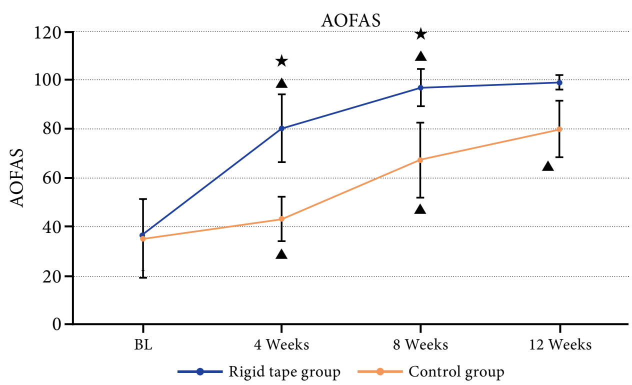

Figure 3. Ankle function (AOFAS).

★ Denotes significantly different between the two groups at p<0.05; ▲ Denotes significantly different at adjacent time point within each group at p<0.05.

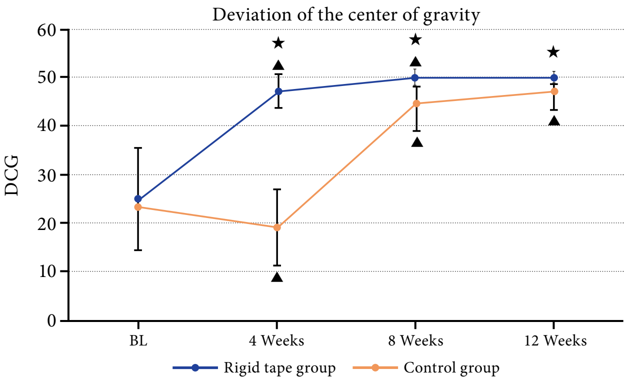

Figure 4. DCG (DCG = the reading of the affected side/the total reading of the two scales × 100%).

★ Denotes significantly different between the two groups at $p<0.05$; ▲ Denotes significantly different at adjacent time point within each group at $p<0.05$.

DISCUSSION

Given the healing of injured tissues, early activities after acute ATFL tear are not allowed. However, the results of this study showed that dynamic fixation with RT could promote recoveries of pain, function and proprioception, even might prevent pseudo-stability; therefore, this application could be more effective and less secondary issues for rehabilitation practitioners to intervene earlier.

Dynamic fixation can decrease pain more effective than static fixation. It is worth nothing that pain was not significant improved at Week 8 in the control group in our study. This finding indicates that the pain may persist for approximately one month, although it can be decreased immediately via immobilization. It also implies that the new tissue growth in the condition of RT dynamic fixation plus training may be more adaptable to weight-bearing. Thus, RT dynamic fixation may not only protect injured area,[25] but also can retain the weight-bearing capacity of the tissue.

The greatest contribution to improving AOFAS at Week 4 in the control group was the decreased pain, while the function and arrangement were not improved at all, indicating that static fixation would trade joint function recovery in exchange for pain relief. This sort of trade, in our opinion, is undeserved, as the function recovery at Week 4 in the RT group was equivalent to the one at Week 12 in the control group. Rigid tape dynamic fixation may contribute to a faster recovery time (8 weeks earlier) by enabling more aggressive training while safeguarding the affected region and maintaining the weight-bearing capacity. In the phase of sports, when the ankle rolls inward at a high speed, it may cause the lateral ligament complex to stretch or tear.[1,9] Most ankle sprains do not develop into lateral ligament instability, and those that occur are attributed to loss of mechanoreceptors.[6] Application of kinesiotape on the ankle resulted in an immediate improvement in the standing balance of healthy individuals; however, the effect was not sustained beyond 24 h.[26] In a report, the RT dynamic fixation guided by 3D/2D image registration technique could rebuild the balance of the movement of the ankle (by regulating dynamic trajectory of each bone: tibia, fibula, talus, and calcaneus) and the forefoot.[19] Therefore, the patients were instructed to feel the direction of the RT pulling force to rebuild musculoskeletal balance and stable subtalar joint and flexible talocrural joint was rebuilt which could make the better balance of stability and mobility and be necessary for available exercises.

The DCG is more important in sports than daily life. It is a remarkable fact that the four-week immobilization could significantly reduce the use of the affected side which led to travelling on the passive side of the road. Although training for four weeks could improve this condition, the DCG at Week 12 in the control group was equivalent to the one at Week 4 in the RT group. Again, this sort of trade is undeserved. What is more, the patients at Week 12 in the RT group could perform wantonly based on more than 50% of DCG. Thus, RT dynamic fixation could promote proprioception more effectively.[25]

Chronic ankle instability[14] and pseudo-stability can cause early degenerative changes in the ankle due to the unbalanced load on the medial side. Sports which involve repeated weight-bearing would speed up this process. In this study, no patients in the RT group had such situation, while 18 of 21 in the control group had. Although we cannot speculate that these 18 patients would develop chronic arthritis, this ratio is higher than the one in Harrington's study,[14] which was 14 out of 22. Thus, RT dynamic fixation may prevent pseudo-stability. We argue that this can be due to the stability based on tensegrity structure, indicating that the ankle is functionally, proprioceptively, controllably stable.

Based on the results of our study, RT dynamic fixation could help the patients to return to sports three times faster than the ones who applied static fixation. These results are consistent with the findings of Kannus and Renstrom[27] who reviewed 12 prospective studies and reported that patients who received functional therapy returned to work two to four times faster than patients who received acute repair, although no comparative analysis is available due to heterogeneity compared to this study. Besides, all patients receiving RT and 62% receiving static fixation had good results. However, in a comparative study, 87% of the patients receiving functional therapy and 60% receiving surgery reported good results.[28] In addition, patients who underwent surgery had a smaller ROM at the final follow-up.

Nonetheless, there are some limitations to this study. First, it is a retrospective cohort study which has lower level of evidence compared to the randomized-controlled trials. Second, the six-month FU is relatively short. Third, according to the complexity of 3D/2D image registration technique and the delayed visit (first visit more than two weeks after injury), the sample size of this study is relatively small. Moreover, the application of RT as this study is using requires practitioners to take relevant professional trainings which particularly include the application of 3D dynamic technique and analysis of congenital bony structures.[19] Skin breakdown may occur during treatment;[17,18,25] however, it was not recorded in the medical history in the patients of this study. Although it could be more helpful to indicate patients' pre-injury activity level, it is not available (quantitative evaluation), as all patients came to visit us after injury.

In conclusion, RT dynamic fixation guided by 3D/2D image registration technique can accurately lock the ATFL function, protect injured area, retain the tissue’s weight-bearing capacity, preserve joint function, promote proprioception, and even may prevent pseudo-stability, so as to quickly repair injury, restore function, and return to sports earlier. However, further large-scale, randomized-controlled studies are needed to confirm these findings.

Ethics Committee Approval: The study protocol was approved by the Ethics Committee of ShanghaiSixth People's Hospital Affiliated to Shanghai Jiao Tong University School of Medicine (date: 2021-10-08, no: 2021-KY-79[K]). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Patient Consent for Publication: A written informed consent was obtained from each patient.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: Idea/concept: S.D., K.C.; Design: S.D., K.C.; Control/supervision: K.C.; Data collection and/or processing: Q.W., K.X., S.Y.; Analysis and/or interpretation: S.D., L.W., Y.Y.; Literature review: S.D., L.W., Y.Y.; Writing the article: S.D.; Critical review: S.D., K.C.; Materials: K.C.

Conflict of Interest: The authors declared no conflicts of interest with respect to the authorship and/or publication of this article.

Funding: The authors received no financial support for the research and/or authorship of this article.

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