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Original Research Article

Strong Correlation Between Disabilities of Arm, Shoulder and Hand Score and Modified Mayo Wrist Score Affected by Radius Union Scoring System and C-Reactive Protein in Patients with Conservatively Managed Distal Radius Fracture

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Abstract

Introduction:
Fractures of the distal radius are the most common fractures in the upper extremity. The conservative management of these fractures often yields favorable outcomes, which can be measured using various scoring systems, and are often associated with controlled inflammatory response. This study aims to determine whether the Modified Mayo Wrist Score (MMWS) can be an alternative to the gold standard Disabilities of Arm, Shoulder and Hand (DASH) score. Additionally, we investigate the effect of the Radius Union Scoring System (RUSS) and the C-Reactive Protein (CRP) inflammatory marker to those scores.
Material & Methods:
Patient samples were consecutively taken from a population of patients with conservatively managed distal radius fractures using a cast. The patients were treated with a cast for 6 weeks, followed by a radiographic evaluation to assess the RUSS score and blood sampling in the 9th week to measure CRP level. In the 12th week, the DASH and MMWS were assessed.
Result:
Correlative analysis showed a strong correlation between MMWS and DASH score, and a predictive correlation between RUSS and CRP level toward MMWS and DASH score.
Conclusion:
The MMWS scoring system correlates with the DASH score, making it a promising scoring system in clinical practice, while a high RUSS score and low 9th-week CRP level can cause better functional outcomes in patients with conservatively managed distal radius fracture.

Introduction

Distal radius fracture is the most common fracture of the upper extremity, Its conservative management has been proven to be effective and resulted in comparable clinical outcomes to surgical management, especially in elderly patients.[1] These clinical outcomes can be measured with various scoring systems, where Disability of Arm, Shoulder, and Hand is the most commonly used system, with high validity and reliability.[2] However, this scoring system has 30 items on its inventory, thus taking roughly 20-30 minutes to finish in clinical practice.[3] Modified Mayo Wrist Score (MMWS) is another scoring system developed to measure the outcome of wrist procedures, where it consists of only 4 items combining subjective and objective parameters.[4] Yet, this score has not been researched as much as DASH and still has varying results regarding its validity and reliability.[5]

The clinical outcome for distal radius fracture management is also correlated with several aspects. A higher degree of union, which can be measured with the Radius Union Scoring System (RUSS), is correlated with better outcomes,[6,7] similarly, controlled inflammation response also contributes to it, where prolonged inflammation of more than 9 weeks after the trauma is correlated with poor outcomes.[8]

This paper aims to determine whether MMWS can be an alternative to the gold standard DASH score and to determine the effect of inflammatory markers on clinical outcomes in patients with distal radius fractures treated conservatively.

Methods

This study is a longitudinal observational study and was conducted at Prof. Dr. Ngoerah Hospital on March 2023 until August 2023. Thirty-five consenting patients with distal radius fractures treated conservatively with cast immobilization are enrolled in this research consecutively. The inclusion criteria are patients with age more than 18 years old and consent to be enrolled in the study. The exclusion criteria are a history of ipsilateral upper extremity fracture, having an infectious disease in the course of study, having a cognitive impairment, suboptimal reduction quality after cast application, and patients with multiple fractures.

The cast is maintained for 6 weeks, with weekly visits to evaluate the cast quality and reapplication of the cast when loosening occurs. The cast was removed after 6 weeks, followed by plain radiography examination to determine the RUSS score. A 6-week physiotherapy was commenced on the patients, and was followed up weekly for the progress. On the 9th week, a blood sample was collected to determine the CRP level as the inflammatory marker, and on the 12th week, the DASH score and MMWS were measured, using a goniometer for a range of movement measurement, and hydraulics hand dynamometer for grip strength evaluation.

The correlation between the DASH score and MMWS was measured using the Spearman correlation test to determine correlation coefficient (r), while the correlation between RUSS and CRP level to the DASH score and MMWS was measured using linear regression analysis. Statistical analysis was done using SPSS Statistics version 26 (IBM Corp., Armonk, New York).

Results

A descriptive analysis of 35 patients enrolled in this study is presented in range, median, and interquartile range (IQR). The sample consists of 17 males and 18 females. The median age for male subjects was 36 year-old (IQR 38), and females is 44.5 year-old (IQR 45). Median for RUSS score is 6 (IQR 1), while for CRP is 0.75 (IQR 0.55). DASH score has a median of 2.5 (IQR 7.5), and MMWS 80 (IQR 25). Descriptive analysis for the samples is described in Table 1.

Table 1. Descriptive analysis of variables

Variable	Range	Median	IQR
Age (year)	17-71 (Male) 17-80 (Female)	36 (Male) 44.5 (Female)	38 (Male) 45 (Female)
RUSS	4-8	6	1
CRP (mg/L)	0,29-1,78	0,75	0,55
DASH	0-23,3	2,50	7,5
MMWS	50-100	80	25

Correlation analysis was done for DASH, MMWS, CRP, and RUSS as previously described, which can be seen in table 2.

Table 2. Correlation analysis of variables

Variable Pair	Correlation coefficient (r)	p-value
DASH-MMWS[a]	-0.919	0.000
RUSS-DASH[b]	-0.826	0.000
RUSS-MMWS[b]	0.904	0.000
CRP-DASH[b]	0.779	0.000
CRP-MMWS[b]	-0.837	0.000
a: Spearman correlation test; *b*: linear regression test		

Spearman correlation test for DASH and MMWS resulted in a strong very strong significant inverse correlation with r -0.919 and $p < 0.05$, showing lower DASH score is correlated with higher MMWS. Linear regression test for RUSS and DASH score resulted in a very strong significant inverse correlation with r -0.826 and $p < 0.05$, showing lower RUSS is correlated with lower DASH score. While linear regression test for RUSS and MMWS resulted in a very strong significant correlation, with r 0.904 ad $p < 0.05$, showing higher RUSS is correlated with higher MMWS. Similar results are also found in CRP and DASH score and CRP and MMWS correlation analysis using linear regression test, where CRP and DASH score is shown to have strong significant correlation with r 0.779 and $p < 0.05$, and CRP and MMWS has very strong significant inverse correlation with r -0.837 and $p < 0.05$.

Discussion

This study sample, which is taken consecutively, consisted of 17 male patients and 18 female patients.

This data is in line with the general epidemiology of distal radius fracture, where the female has a higher incidence compared to the male.[9] Meanwhile, the median age in the male group is 36 years, and for female 44.5 year. This finding is also following the epidemiology, where the female population has a higher mean age compared to males.[10]

Correlation analysis of DASH score and MMWS has shown a very strong significant inverse correlation between these two scores, with a correlation coefficient of -0.919 and $p < 0.05$. Previously, this correlation has never been studied specifically. The author made a systematic search for papers using these two variables in their analysis, and found 10 journals, which contain 26 pairs of DASH score and MMWS. From these 10 pairs, correlation analysis was made using the Pearson test, resulting in a very strong significant inverse correlation with a correlation coefficient of -0.861 and $p < 0.05$.[11–20] This analysis result is in line with the findings in this paper. DASH score has been previously researched extensively, showing good internal consistency, test-retest, and responsivity.[5]

A similar result is also found in correlation analysis between RUSS and DASH, showing a very strong significant inverse correlation between variables ($r = 0.826$, $p < 0.05$). Previously, there was no study researching this correlation. Two studies using these two parameters as its variable have shown that the group with higher RUSS, has a lower DASH score, thus supporting the finding of the current study.[7,21] Analysis of RUSS and MMWS pointed to the same direction, showing a strong significant correlation between them ($r = 0.904$, $p < 0.05$), indicating better union results in better outcomes. No previous study has researched the correlation between these scores, however, two prior studies using these two parameters as its measurement exhibit higher RUSS in groups with higher MMWS.[22] Numerous prior researches have shown a correlation between union and outcome of fracture management, although not specific to RUSS nor DASH score. This indirectly concludes that better RUSS will yield a better DASH score and MMWS.[23,24]

Linear regression analysis of CRP level to DASH score and MMWS has shown a strong significant correlation ($r = 0.779$, $p < 0.05$) to the former, and a very strong significant correlation ($r = 0.837$, $p < 0.05$) to the latter. This result signifies the effect of controlled inflammation to a better functional outcome. Previously, there is no study has researched the relationship between CRP level to DASH score and MMWS. However, it is well-researched that controlled inflammatory response is crucial for the fracture healing process.[25,26] Attenuation of the inflammation in the early phase of fracture healing leads to delayed and non-union.[27] On the other hand, prolonged inflammation process in this population is correlated with worse functional outcomes.[28] research by de Jong et al shown CRP level at week 4 in patients with distal radius fracture is correlated with pain and wrist range of motion on week 12.[29] While research by Sadighi et al. concluded that patients with higher CRP levels in fracture cases complicated with metabolic syndrome has a higher rate of nonunion, thus resulting in worse functional outcome.[30]

This study has several drawbacks. Firstly, the limited number of samples resulted in a non-normal spread of data, which can be a potential bias in the statistical analysis. Lastly, the lack of samples with high CRP levels makes the potential sampling bias.

Conclusion

MMWS has been shown to have a very strong correlation with DASH score, making it a comparable option to be used on daily practices, while controlled inflammation, as reflected as normal CRP level at week 9 post-trauma, and good union quality, as scored with RUSS, is correlated with strongly with DASH score and MMWS, making it a promising predictor of functional outcome in patients with distal radius fracture treated conservatively.

Conflict of Interests

The authors have no conflict of interest. All resources used in this research are funded by the authors.

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Original Basic Article

The Relationship between Morphometry of The Proximal Femur Bone and The Type of Proximal Femur Bone Fracture in The Elderly Female Population at RSUP H. Adam Malik Medan from 2017 to 2022

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Abstract

Background:
Fractures of the pelvic bone are frequently encountered in elderly patients and are often associated with increased mortality rates. At the moment, identifying osteoporosis as a risk factor for proximal femur fractures is the primary focus. The morphometry of the proximal femur can also be utilized to predict the risk factors for proximal femur fractures. This study was conducted to assess the relationship between proximal femur bone morphometry and proximal femur fractures in elderly women at H. Adam Malik General Teaching Hospital, Medan.

Material & Methods:
This study is an observational analytical research aimed at investigating the relationship between the morphometry of the proximal femur bone and the type of proximal femur bone fracture in an elderly female population. The study will adhere to predetermined inclusion and exclusion criteria. The morphometric variables measured in this study are hip axis length (HAL), femoral head diameter (FHD), femoral neck length (FNL), femoral neck diameter (FND), horizontal offset (HO), and femoral neck shaft angle (FNSA).

Result:
This study collected 90 samples, with 15 of them not meeting the inclusion and exclusion criteria, resulting in a final sample size of 75. Out of 75 research samples, the Hip Axis Length (HAL) has an Eta test value of 0.264. The Femoral Head Diameter (FHD) has an Eta test value of 0.162. The Femoral Neck Diameter (FND) has an Eta test value of 0.276. The Femoral Neck Length (FNL) has an Eta test value of 0.277. The Horizontal Offset (HO) has an Eta test value of 0.277. The Femoral Neck Shaft Angle (FNSA) has an Eta test value of 0.488.

Conclusion:
This study reports a weak correlation between the morphometry of hip axis length, femoral neck diameter, femoral neck length, femoral neck diameter, and horizontal offset of the proximal femur with proximal femur fractures. Furthermore, a moderate correlation was found between the morphometry of the femoral neck-shaft angle of the proximal femur and the type of proximal femur fracture.

Introduction

Osteoporosis is a disease characterized by decreased bone mass and increased risk of fractures. Fractures of the pelvic bone are frequently encountered in elderly patients and are often associated with increased mortality rates.[1] Fracture of proximal femur is commonly found in elderly patients and guidelines for managing this type of fracture are still evolving.[2] Fractures occur when external forces exceed the bone's capacity to absorb energy due to changes in elasticity.[3] The risk of trauma is caused by various factors such as senile dementia, neurological disorders, hemiplegia, alcohol abuse, and psychotropic drugs.[4]

Proximal femur fracture occurred in approximately 7% of young people and 24% of older people.[5] Researchers estimate that the number of proximal femur fractures will reach 6.3 million cases worldwide in 2050, including 3.25 million cases in Asia. The mortality rate within the first year after a proximal femur fracture is estimated to be between 20% and 33%.[6]

Currently, the examination of osteoporosis as a risk factor for proximal femur fractures is the primary reference. The examination that can be performed using the Dual Energy X-Ray Absorptiometry (DXA) device is used to assess bone mineral density. The Singh Index can also assess bone density by evaluating trabeculae in the proximal femur bone. The morphometry of the proximal femur can also be utilized to predict the risk factors for proximal femur fractures.[1,2,7] This study was conducted to assess the relationship between proximal femur bone morphometry and proximal femur fractures in elderly women at H. Adam Malik General Teaching Hospital, Medan.

Methods

This study is observational analytical research using a case series approach to investigate the relationship between morphometry of the proximal femur bone and the type of proximal femur bone fracture in the elderly female population at RSUP H. Adam Malik Medan. This research was conducted at the Department of Orthopaedics and Traumatology, Faculty of Medicine, Universitas Sumatera Utara / RSUP H. Adam Malik Medan. The study sample consisted of patients who underwent radiological examination of X-Ray Pelvis AP from January 2017 to December 2022, and met the inclusion and exclusion criteria.

The inclusion criteria for this study are elderly women who underwent radiological examination of the Pelvis AP with a diagnosis of femoral neck fracture, intertrochanteric femur fracture, and subtrochanteric femur fracture. The exclusion criteria for this study are subjects with congenital abnormalities in the proximal femur bone, tumors in the proximal femur bone, infections in the hip joint, osteonecrosis abnormalities in the femoral neck, and fractures in the pelvic bone.

The morphometric variables investigated in this study are Hip Axis Length (HAL), Femoral Head Diameter (FHD), Femoral Neck Length (FNL), Femoral Neck Diameter (FND), Horizontal Offset (HO), and Femoral Neck Shaft Angle (FNSA). This variable was measured by two experienced orthopaedic specialists using AP pelvis X-ray images (Figure 1). Next, a normality test will be conducted on the variable. Subsequently, the relationship between morphometry and proximal femur fractures will be analyzed using the Eta test.

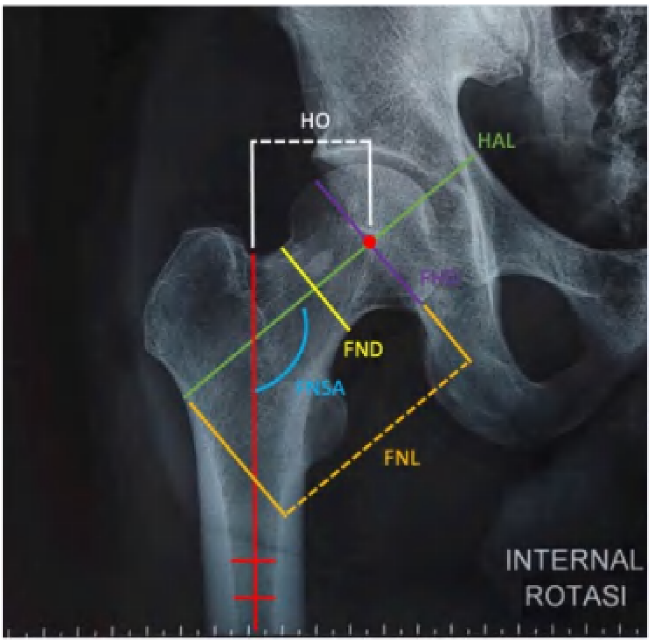

Figure 1. Morphometry of the proximal femur bone

Results

This study collected 90 samples, with 15 of them not meeting the inclusion and exclusion criteria, resulting in a final sample size of 75. Table 1 displays the characteristics of the sample in this study. The most commonly observed fractures in this study were intertrochanteric and femoral neck fractures, with frequencies of 29 patients (38.6%) each.

This study was conducted by measuring the hip axis length, femoral head diameter, femoral neck diameter, femoral neck length, horizontal offset, and femoral neck-shaft angle. This research was conducted by two individuals who possess the same qualifications, namely the Orthopaedic and Traumatology Specialist Doctor Education Programme. Table 2 presents the results of the Kappa test and the normality test for the data on proximal femur morphometry measurements.

Out of 75 research samples, the Hip Axis Length (HAL) has an average value of 10.0 ± 0.65 (Intertrochanteric Fracture), 10.5 ± 0.82 (Neck Fracture), and 10.5 ± 1.2 (Subtrochanteric Fracture) with an Eta test value of 0.264. The mean values for Femoral Head Diameter (FHD) are 4.62 ± 0.34 (Intertrochanteric Femur Fracture), 4.68 ± 0.38 (Femoral Neck Fracture), and 4.79 ± 0.53 (Subtrochanteric Femur Fracture), with an Eta test value of 0.162. The mean values for Femoral Neck Diameter (FND) are 2.98 ± 0.23 (Intertrochanteric

Table 1. Sample characteristics in the study

Characteristics	Frequency (%)	Ages (Mean)
Type of Fractures		
Intertrochanter Femur	29 (38.6)	75.1 ± 6.8 (62 – 87)
Collum Femur	29 (38.6)	73.4 ± 7.5 (60 – 92)
Subtrochanter Femur	17 (22.8)	67.1 ± 5.0 (61 – 78)

Table 2. Kappa test and Normality on proximal femur morphometry measurement results

Variables	Value (Uji Kappa)	Normality test
Hip Axis Length	0.851	0.200
Femoral Head Diameter	0.836	0.200
Femoral Neck Diameter	0.877	0.200
Femoral Neck Length	0.878	0.200
Horizontal Offset	0.864	0.197
Femoral Neck Shaft Angle	0.851	0.200

Femur Fracture), 3.16 ± 0.33 (Femoral Neck Fracture), and 3.11 ± 0.26 (Subtrochanteric Femur Fracture) with an Eta test value of 0.276. The mean values for Femoral Neck Length (FNL) are 6.91 ± 0.56 (Intertrochanteric Femur Fracture), 7.21 ± 0.50 (Femoral Neck Fracture), and 7.33 ± 0.81 (Subtrochanteric Femur Fracture), with an Eta test value of 0.277. The average value of the Horizontal Offset (HO) is 3.68 ± 0.50 (Fracture of the Intertrochanteric Femur), 3.87 ± 0.40 (Fracture of the Femoral Neck), and 7.33 ± 0.81 (Fracture of the Subtrochanteric Femur), with an Eta test value of 0.277. The average value of the Femoral Neck Shaft Angle (FNSA) is 125.8 ± 03.0 (Intertrochanteric Femur Fracture), 125.6 ± 2.9 (Femoral Neck Fracture), and 130.1 ± 4.4 (Subtrochanteric Femur Fracture) with an Eta test value of 0.488.

Discussion

The research findings indicate that the mean HAL value in intertrochanteric femur fractures is significantly smaller, with a value of 10.0 ± 0.65, compared to fractures in the femoral neck and subtrochanteric region, which have an Eta test value of 0.264, suggesting a weak correlation. The study conducted by Barrido et al found that the mean HAL value in intertrochanteric fractures was 10.33 ± 0.53, which is smaller compared to subtrochanteric femur fractures and femoral neck fractures. A smaller HAL value is considered protective against intertrochanteric fractures, with a value of 0.85 (p=0.011).[6] In their study, Nayak et al examined the association between HAL and proximal femur fractures using the Pearson correlation test. However, they concluded that no correlation was found, with a p-value of 0.53.[8]

The research findings revealed that the mean FDH value in intertrochanteric femur fractures is significantly lower at 4.62 ± 0.34 compared to fractures in the femoral neck and subtrochanteric femur, with an Eta test value of 0.162, indicating a weak correlation. The study conducted by Yang et al found that the mean FHD value for intertrochanteric femur fractures was 4.87 ± 0.25, which was lower than the value of 4.95 ± 0.23 for femoral neck fractures. However, after conducting a statistical test using ANCOVA, no relationship was found between the type of fracture and FHD.[4] Nayak et al also found no correlation between FHD and the type of fracture in the proximal femur (p=0.658).[9]

Table 3. Results of morphometric analysis with proximal femur fracture

Variables	Fracture of Intertrochanter (n = 29)	Fracture of Collum (n = 29)	Fracture of Subtrochanter (n = 17)	The value of Eta's analysis
Hip Axis Length	10.0 ± 0.65 (8.4 – 11.7)	10.5 ± 0.82 (8.9 – 12.3)	10.5 ± 1.2 (8.5 – 12.1)	0.264
Femoral Head Diameter	4.62 ± 0.34 (4.05 – 5.62)	4.68 ± 0.38 (3.90 – 5.44)	4.79 ± 0.53 (3.92 – 5.65)	0.162
Femoral Neck Diameter	2.98 ± 0.23 (2.57 – 3.57)	3.16 ± 0.33 (2.37 – 3.80)	3.11 ± 0.26 (2.67 – 3.36)	0.276
Femoral Neck Length	6.91 ± 0.56 (5.95 – 8.40)	7.21 ± 0.50 (6.12 – 8.02)	7.33 ± 0.81 (5.92 – 8.58)	0.277
Horizontal Offset	3.68 ± 0.50 (2.34 – 4.74)	3.87 ± 0.40 (2.95 – 4.57)	3.84 ± 0.43 (3.23 – 4.88)	0.198
Femoral Neck Shaft Angle	125.8 ± 3.0 (120 – 135)	125.6 ± 2.9 (121 – 132)	130.1 ± 4.4 (123 – 136)	0.488

The research findings revealed that the mean FND value in intertrochanteric femur fractures is significantly lower, with a value of 2.98 ± 0.23, compared to fractures in the femoral neck and subtrochanteric femur fractures, with an Eta test value of 0.276, indicating a weak correlation. Han et al. obtained a mean FND value of 3.18 ± 0.23 and found a significant association with intertrochanteric femur fractures (p<0.001).[7] The study conducted by Pires et al also concluded that there is no association between FND and proximal femur fractures, as indicated by the Kolmogorov-Smirnov test for data distribution (0.105) and a p-value of >0.200.[10]

The research findings revealed that the mean FNL value in intertrochanteric femur fractures is significantly lower at 6.91 ± 0.56 compared to fractures in the femoral neck and subtrochanteric femur fractures, with an Eta test value of 0.277, indicating a weak correlation. The research conducted by Kazemi et al concluded that the mean FNL value in sub-trochanteric femur fractures is greater compared to intertrochanteric and femoral neck fractures, and a relationship was found between FNL and the type of proximal femur fracture with a p-value of 0.032.[3] Sayit et al conducted a study on the relationship between FNL and types of proximal femur fractures and concluded that there is no association between the type of proximal femur fracture and FNL, with a p-value of 0.722.[5]

The research findings indicate that the average Horizontal Offset value in intertrochanteric femur fractures is significantly smaller, with a value of 3.68 ± 0.50, compared to fractures in the femoral neck and subtrochanteric femur fractures, with an Eta test value of 0.198, suggesting a weak correlation. Barrido et al. conducted a study using the ANCOVA statistical test and found that an increase in HO is associated with an increased risk of intertrochanteric femur fracture, with a p-value of 0.036.[6]

The research findings reveal that the mean FNSA value for intertrochanteric femur fractures is significantly lower at 125.8 ± 3.0 compared to femoral neck fractures and subtrochanteric femur fractures, with an Eta test value of 0.488, indicating a weak correlation. Barrido et al. conducted a study using the ANCOVA statistical test and found that an increase in FNSA (Femoral Neck Shaft Angle) would increase the risk of intertrochanteric femur fracture, with a p-value of 0.033.[6] The research conducted by Pires et al and Lima et al concluded that there is no correlation between FNSA and the type of fracture in the proximal femur.[8,10]

Conclusion

This study indicates a weak correlation between the femoral neck diameter, femoral neck length, and horizontal offset proximal femur with the types of femur fractures—femur intertrochanter, neck femur , and subtrochanteric femur. Furthermore, a moderate correlation was found between the morphometry of the femoral neck-shaft angle of the proximal femur and the types of intertrochanteric femur fracture, femoral neck fracture, and subtrochanteric femur fracture.

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Literature Review

Returning to Sport After Anterior Cruciate Ligament Reconstruction in Active Non-Athlete Individual: A Literature Review

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Abstract

Anterior cruciate ligament (ACL) tears frequently occur as sports injuries, particularly in active young individuals. ACL reconstruction is a standard treatment for active individuals seeking to return to sports. Prehabilitation and post-operative rehabilitation therapy play crucial roles in strengthening the quadriceps and hamstrings before ACL reconstruction, facilitating the healing process, and enabling a return to sports at the pre-injury level. However, determining the appropriate time to resume sports activities after the injury is a complex and multifaceted decision-making process. Many criteria are considered for returning to sport after ACL reconstruction. Most surgeons suggest that individuals return to sports after nine months, with a limb symmetry index greater than >90% symmetry LSI criteria in hop tests and individuals exhibiting greater psychological readiness were more likely to return to sports.

Introduction

An anterior cruciate ligament (ACL) was crucial for knee stabilization. It is responsible for supporting dynamic-static stability and coordinating knee joint movements. The anterior cruciate ligament (ACL) experiences the highest injury frequency among all knee ligaments. Injury to the ACL severely impacts knee mobility and balance, leading to diminished sensory feedback and compromised knee joint function and stability.[1] ACL rupture stands out as one of the prevalent sports injuries among active young individuals, with 3.000 people suffering from ACL injury annually in the USA.[2,3] The age group most affected is individuals between 15 and 25.[4] Rehabilitation following ACL reconstruction plays a crucial role in restoring knee function and stability.[3] Returning to sports earlier will increase the risk of re-injury.[5] In contrast, a delayed return to sport may influence motivation and psychological readiness.[6]

After an ACL reconstruction, many patients expect to return to the pre-injury level of sports involving jumping, pivoting, and cutting.[7,8] However, a recent study reported that only 65% of patients return to their pre-injury level of sports, and males are more likely to return to sports than females.[8] Several studies have evaluated return-to-sport (RTS) criteria after an ACL reconstruction.[6,8-11] However, RTS decisions are complex, and many factors may influence the decisions.[10]

ACL ANATOMY AND THE MECHANISM OF INJURY

The ACL is one of the most important of the knee ligaments, which consists of 2 significant bundles: the posterolateral (PL) bundle and the anteromedial (AM) bundle (Figure 1). Both bundles originate on the posteromedial side of the lateral femoral condyle and are inserted on a region just anterior to the intercondylar tibial eminence.[12] The ACL plays a crucial role in knee joint stability, primarily restraining anterior translation of the tibia relative to the femur. Research has demonstrated that with the knee flexed from 20 to 90 degrees, there is an increase in tension on

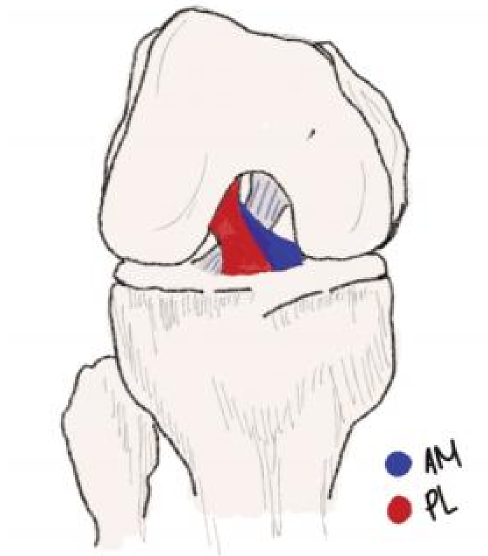

Figure 1. Illustration of a standard ACL consisting of 2 bundles (anteromedial and posterolateral

The anteromedial bundle of the ACL. In contrast, tension in the posterolateral bundle increases when the knee is extended.[12,13]

The mechanism of ACL tear injury can be categorized into two main types: contact and non-contact. Non-contact injuries to the ACL among athletes consistently demonstrate a specific knee flexion angle ranging from 30 degrees to full extension at the time of injury.[14,15] The rotation of the tibia plays a pivotal role in the non-contact ACL injury mechanism, with the lower leg experiencing either internal or external twisting relative to the femur. Tibial rotation exacerbates the strain on the ACL, with internal tibial torque resulting in more significant strain than external tibial torque. Rapid deceleration or landing actions are often considered provocative factors in non-contact ACL injuries occurring during soccer.[14] Boden et al. documented that landing motions frequently result in varus or valgus collapse of the knee, leading to subsequent ACL failure, with varus angulation imposing a tremendous strain on the ACL than the valgus.[15]

ACL injuries resulting from direct contact typically occur due to the application of an excessive valgus force on the knee. In soccer, this force is commonly inflicted by an opponent striking the lateral aspect of the player's leg, often during a slide tackle[14] (Figure 2).

ACL RECONSTRUCTION

Surgery is still the gold start of treatment for ACL surgery where it can reinstate stability and reduce the risk of progressive knee degeneration and instability.[4] Early surgical intervention may expedite the return to work or sports; conversely, delayed ACL reconstruction could lead to postponed early rehabilitation due to heightened muscle atrophy and diminished strength.[16] ACL reconstruction was traditionally performed by the open method. Arthroscopic ACL reconstruction has become a standard procedure. Initially, arthroscopic ACL reconstruction utilized a two-incision technique involving drilling the femoral bone tunnel from outside. Subsequently, a one-incision technique became prevalent, where the femoral bone tunnel was drilled from the inside out, passing through the tibial tunnel.[17]

PRE-OPERATIVE REHABILITATION PROGRAMS

Several studies have shown that patients with a full extension range of motion (ROM) before ACL reconstruction will reduce the chance of postoperative complications such as arthrofibrosis.[18,19] Furthermore, a deficit in quadriceps strength of 20% or more indicates a significant strength deficit until two years after ACL reconstructions.[20] These previous findings can be avoided with pre-operative rehabilitation, known as prehabilitation.[21] Prehabilitation programs are often performed to prepare the knee for reconstruction surgery, improve rehabilitation outcomes, reduce the risk of pivot shift episodes, which can often cause progressive joint damage, and enhance recovery after reconstruction.[22] Several studies suggest that individuals should achieve 90% of their quadriceps and hamstring strength and capacity for hopping on the injured leg compared to the uninjured leg before undergoing ACL reconstruction surgery.[23,24] A study reported the relevance of pre-operative rehabilitation (prehabilitation) programs to improve RTS rates and two years of self-reported knee function.[25] Shaarani et al. reported that a 6-week progressive prehabilitation program for patients undergoing ACL reconstruction, with a 12-week follow-up, led to improved knee function based on the single-legged hop test and self-reported knee function.[20] There are various rehabilitation protocols; however, stretching, balance exercises, and muscle strengthening, focusing on the quadriceps and hamstring muscles, are commonly

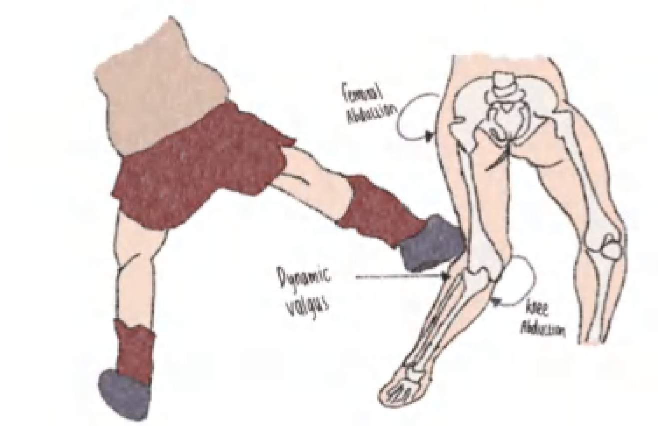

Figure 2. Illustration of the mechanism of the injury which leads to a valgus load.

included.[21] Furthermore, several studies reported high compliance and tolerance for participants with early stages of ACL injury.[20,26] Recently, a systematic review reported that prehabilitation improves quadriceps strength and single-leg hop scores three months after ACL reconstruction compared with no prehabilitation. However, the studies included needed more high-quality evidence due to a high risk of bias.[27]

POSTOPERATIVE REHABILITATION PROGRAMS

Post-reconstruction rehabilitation therapy is imperative for facilitating knee function healing and returning to sport to the pre-injury level.[21] However, the collaboration between the surgeon and physical therapist is crucial in tailoring the postoperative rehabilitation program to each patient's specific needs and conditions. Factors such as the surgical technique used, the type of graft, the presence of meniscal injuries, cartilage damage, ligamentous injuries, and any surgery-related complications all play a role in determining the appropriate rehabilitation approach. This individualized and collaborative approach helps optimize the recovery and outcomes for patients undergoing rehabilitation after ACL reconstruction.[28]

Rehabilitation following ACL reconstruction typically starts immediately after surgery and can continue for 9 to 12 months. Home-based rehabilitation programs can be a practical alternative for patients far from physical therapy centers or having difficulty scheduling frequent visits. Studies have shown that home-based programs can be as effective as supervised rehabilitation, particularly for patients with good compliance and motivation.[29] However, it's important to note that these programs may not be suitable for individuals participating in high-intensity sports, as they may require more specialized and closely monitored rehabilitation protocols to ensure optimal outcomes and prevent re-injury.[30] Grindem et al. reported that a comprehensive approach involving both rehabilitation and postoperative rehabilitation resulted in better self-reported knee function after a 2-year follow-up compared to postoperative rehabilitation only.[23]

Regardless of the surgical approach, postoperative rehabilitation is essential for a full recovery. Goals should align with the surgical technique to regulate strain on the healing ACL graft or repair. Repair techniques that minimize tissue damage may permit accelerated rehabilitation.[31,32] However, there has been no definitive consensus on postoperative rehabilitation. A recent study evaluated the Multicenter Orthopaedic Outcomes Network (MOON) guidelines and the Cavanaugh and Powers 2017 review to create the standard protocol after ACL reconstruction (Tables 1 and 2). However, any progression through phases is based on meeting functional criteria rather than the time since surgery. Some patients may be ready to advance sooner than the indicated time frame, while others may require more time.[33,34]

Table 1. Rehabilitation protocol after anterior cruciate ligament reconstruction

Bracing	**Week 0-3:** Surgeon dependent
Range of Motion	110° flexion by ~week 2 Full ROM should be achieved by ~week 6
Weightbearing	Immediate partial, progress to WBAT D/C crutches by ~week 2
Neuromuscular and Proprioception	**Week 2-6:** Prop board/balance system/contralateral Theraband exercises
Exercises	**Week 4-6:** Light weights + sport cords **Week 2-6:** AAROM exercise, mini squats, weight shifts **Week 7-12:** Advance strengthening, hops, squats, straight line run **Week 13-16:** Aggressive strengthening, agility training, pylometrics
Run	**Week 7:** running training **Week 12-14:** running allowed
RTP	**Week 17-20:** sport-specific training **Week 24:** return to play

ROM, range of motion; WBAT, weight bearing as tolerated; D/C, discontinue; AAROM, Active Assisted Range of Motion

RE-INJURY RATE AFTER ACL RECONSTRUCTION

The rate of ACL re-injury following ACL reconstruction is approximately 15%.[35] Many risk factors might contribute to re-injury. Grindem et al. found that patients who returned to level I (jumping, pivoting, and intricate cutting) sports after ACL reconstruction had more than a fourfold increase in re-injury rates over two years. However, this rate decreased if an RTS occurred at least nine months or more after surgery, and having symmetrical quadriceps strength before RTS was crucial in reducing the re-injury rate.[36] Furthermore, re-injury was more frequent in younger individuals than 18 years old, and men had a greater risk of re-injury than women.[37,38]

CRITERIA OF RETURN TO SPORT AFTER ACL RECONSTRUCTION IN ACTIVE NON-ATHLETE INDIVIDUAL

Numerous criteria are utilized to assess whether an individual is suitable to return to sports (RTS) following ACL reconstruction: (1) time, (2) performance and functional test, and (3) psychological readiness.[39,40]

Phase 1 (weeks 0-2)	Phase 2 (weeks 2-6)	Phase 3 (weeks 7-12)	Phase 4 (weeks 13-16)	Phase 5 (weeks 17-20)
• Control post-operative pain/swelling • ROM: active flexion to 110° • Quadriceps control (20 SLR with no lag) • Weight bearing with crutches, should d/c before progressing	• Full ROM • Improve muscular strength functional in daily activities • Neuromuscular training to improve muscular control • Minimal pain • Satisfactory self-evaluation of knee function	• Maintain full ROM • Running and hopping without pain or swelling • Ascend 8" step without pain or deviation • Able to perform neuromuscular and strength exercises without difficulty	• Running patterns without difficulty at 75% speed • Jumping and contralateral hops without difficulty or instability • Satisfactory self-evaluation of knee function	• More than 85% normal contralateral strength and on-hop tests • Sport-specific training without pain, swelling, or difficulty • Isokinetic strength test(60°/sec) • Acceptable quality movement assessment (hop tests, vertical jump, deceleration shuffle test)

Table 2. Summary of rehabilitation goals.[34]

Time

The time of RTS is one of the criteria that surgeons should consider in each individual. A scoping review found that 11 out of 88 studies reported that the time needed to RTS ranges between 6 to 12 months.[39] These findings align with the research conducted by Hildebrandt et al., which suggests that the RTS after ACL reconstruction should be postponed from the current 4- to 6-month period to at least nine months post-surgery.[12] In a similar study, Grindem et al. demonstrated that for each month the patient's RTS was delayed up to 9 months, there was a 51% decrease in the re-injury rate.[36] Additionally, a study reported a sevenfold increased risk of re-injury if athletes returned to the sport in less than nine months.[41]

Performance and functional test

Barber-Westin and Noyes discovered, through a survey of 211 expert surgeons who are members of the German Arthroscopic Association (AGA), that the criterion most commonly utilized regarding muscle strength is a cut-off value of >90% isokinetic strength compared to the contralateral side.[42,43] Alternatively, other parameters, such as a quadriceps index >90% and weighted leg extension >90%, may also be employed.[44]

Over 50% of clinicians in the United States utilize manual muscle testing to evaluate muscle strength.[45] However, this approach has several limitations, including poorly defined boundaries between grades "4" and "5".[46] Frequently, a limb symmetry index (LSI) is used, which is the ratio of the score of the involved limb score to that of the uninvolved limb score, expressed as a percentage. When returning to sports after ACL reconstruction, most surgeons consider an LSI greater than 90% acceptable for recreational and non-pivoting sports.[47] In addition to pivot, contact, and competitive athlete, an LSI >100% has been recommended.[13]

Another standard test used is the hop test. These tests are the single hop for distance, triple hop for distance, triple cross-over hop, and the 6-m timed hop (Figure 3).[48] The LSI >90% symmetry could be used as cutoff scores for hop tests. A study demonstrated that at six months post-surgery, performance on each of the four hop tests could predict the return to previous levels of sport at the 2-year mark.[49] Moreover, patients who scored >85% LSI in single hop for distance and triple hop for distance at the time of return to sport were more likely to resume their previous activity levels.[50]

In contrast, several studies have reported that athlete performance during these tests at six months post-surgery could not predict a return to sport 12 months after rehabilitation. Strength testing and subjective patient rating of function provided more relevant information in these cases.[51,52] A recent meta-analysis reported that symmetry in hop distance may not necessarily mean knee function is also symmetrical. Therefore, clinicians should rely on something other than the LSI to assess functional performance changes after ACL reconstruction, as it may lead to over-estimating functional improvement and neglecting potential worsening of contralateral limb function.[53]

Psychological Readiness

Besides physical impairments, an ACL injury also has a psychological impact. Psychological readiness is the most significant factor linked to returning to pre-injury activity.[52] Multiple studies have indicated that a significant proportion of athletes when questioned about resuming their prior sporting activities, expressed concerns regarding fear of new injury, re-injury, and lack of confidence in their knee.[54] Athletes who exhibited higher psychological readiness were more inclined to return to their pre-injury level, resume

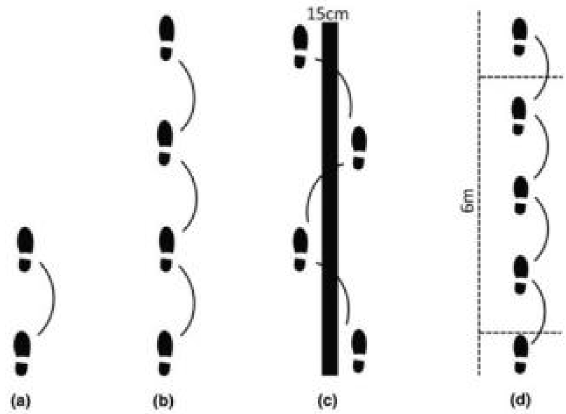

Figure 3. Depiction of the 4 single leg hop tests commonly used in return to sport protocols: a single hop for distance, b triple hop for distance, c cross-over hop for distance, d 6-m timed hop.[48]

sporting activities faster, and perceive better performance upon RTS.[54]

Conclusion

ACL reconstruction is essential to restore stability, minimize the risk of progressive knee degeneration and instability, and facilitate the return of individuals to sports and activities at a level comparable to their pre-injury state. However, rehabilitation plays a crucial role in achieving this outcome. The recommended rehabilitation following ACL reconstruction includes several key components: bracing, weight-bearing techniques, proprioceptive and neuromuscular training, various exercise methods, running, and sport-specific training. Several studies have indicated that the optimal timing for returning to sports activities after ACL reconstruction is within the first nine months following surgery with an LSI index greater than >90% symmetry in hop test and individuals with greater psychological readiness were more likely to return to sports.

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Literature Review

Current Update in Achilles Tendon Rupture Management: Operative or Nonoperative?

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Abstract

The Achilles tendon is the most commonly ruptured tendon in the foot and ankle region. The peak incidence of Achilles tendon rupture occurs in the age range of 30-49 years, with a higher prevalence among males. Various risk factors, including aging, obesity, episodic athletic activity, engagement in high-impact sports, antibiotic use, and systemic factors, contribute to the occurrence of Achilles tendon rupture. Beyond the injury mechanism, it is crucial to assess any history of minor or repetitive trauma to the Achilles tendon and identify associated risk factors. Thorough examination and comparison of both the affected and unaffected sides are essential. While the diagnosis of Achilles Tendon Rupture is primarily clinical, radiological imaging can aid in visualizing the tendon gap. Treatment options for Achilles tendon rupture include conservative and surgical approaches. Despite a lower re-rupture rate associated with surgical treatment, recent evidence suggests that conservative treatment provides comparable results. However, return to activity was found to be better in surgical treatment with early rehabilitation

Introduction

Achilles Tendon Rupture (ATR) is one of the most common injuries found in young athletes and those engaged in recreational sports. Most of the injuries are sustained in men aged 30-39 years old from high-impact sports.[1] Although the Achilles is one of the strongest tendons in the human body, it is also the most commonly ruptured tendon around the foot and ankle.[2] The incidence of ATR is approximately 40 per 100.000 person-years and seems to have increased over the last few decades.[3,4] Until now, there is still controversy regarding optimal management for ATR. In the past, surgical techniques were recommended over conservative management.[5] However, conservative treatment nowadays gives comparable results, therefore operative treatment is not the mainstay treatment anymore.[6] Nevertheless, other factors must be considered when deciding on treatment options, such as return to activity, particularly in athletes. The objective of this study is to investigate the current trend in Achilles tendon rupture management.

Results

ANATOMY

The Achilles tendon, also known as the calcaneal tendon, is the largest and strongest tendon in the human body, connecting the gastrocnemius and soleus muscles to the calcaneus.[7] In its course toward the calcaneus, this tendon rotates 90 degrees laterally, causing the gastrocnemius fibers to insert laterally onto the posterior calcaneus, while the soleus fibers insert medially. When the gastrocnemius and soleus muscles contract, a translational force is generated through the Achilles tendon, resulting in plantar flexion of the foot which facilitates movements such as walking, running, and jumping.[8,9] In this position, the Achilles tendon bears the heaviest load in the body, with a tensile load 10 times the body weight.[10] The Achilles tendon consists of type II fast twitch fibers, type I collagen, and elastin, making its structure strong and elastic to facilitate movement.[11] It is also surrounded by a loose connective tissue sheath, known as the paratenon, allowing it to stretch and withstand significant forces.[12]

The Achilles tendon is supplied by two main blood vessels: the posterior tibial artery and the peroneal artery. However, there is a hypovascular area approximately 2-6 cm above the calcaneus, making this region relatively prone to poor healing after trauma.[13] The sural nerve and tibial nerve mainly provide the innervation of this tendon. The sural nerve traverses from the posterior to the lateral aspect approximately 8-10 cm away from the calcaneal insertion point of the Achilles tendon.[14]

CLASSIFICATION

The classification for Achilles tendon rupture is based on the onset, location, and type of the rupture. Acute Achilles tendon rupture is defined as when an Achilles tendon has been ruptured for less than 6 weeks. If the onset of the rupture has passed 6 weeks, then it is called chronic ATR.[1] For chronic ATR, some classification systems have been developed to access the type of defect, especially asses the gap between the ruptured tendon and the best management for it. Myerson's and Kuwada's classifications are the two main classifications used worldwide. In Myerson's classification, the type of tear is divided into three types. If the defect is 1-2 cm long, it is classified as type I and the best management is with end-to-end repair and posterior compartment fasciotomy. In type II, the defect is 2-5 cm long, and the best management is with V-Y lengthening with or without tendon transfer. When the defect is greater than 5 cm, it is classified as type III, and the recommended treatment is with area tendon transfer alone or combined with V-Y advancement and augmentation. Based on Kuwada's classification, chronic ATR is further classified into four types. Type I (Partial tear) can be treated with conservative management, Type II (Complete tear less than 3 cm defect) can be treated with end-to-end repair, Type III (3-6 cm defect) can be treated with debridement and tendon transfer with or without tendon transfer, and for type IV (defect greater than 6 cm) can be treated with debridement and tendon graft with or without augmentation.[15]

Achilles tendon rupture can also be further categorized depending on its anatomic location. The musculotendinous junction occurs in 12.1% of all ATR cases, the midportion of Achilles occurs in 83% of all ATR cases, and the insertion of the calcaneus bone occurs in 4.6% of all ATR cases.[15] Based on the type of rupture, ATR can be divided into partial and total rupture. Partial rupture is defined as when there is

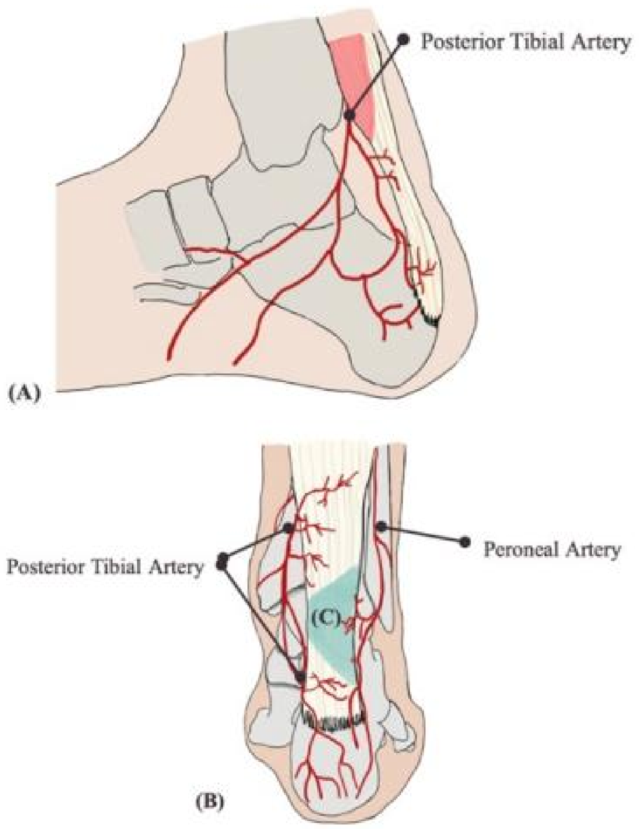

Figure 1. Vascularisation of the Achilles Tendon
A) Showing the posterior tibialis artery that supplies both the proximal, distal, and medial part of the Achilles Tendon; B) Showing the peroneal artery that supplies the middle and lateral part of the Achilles Tendon; C) Showing the "watershed zone" or area of hypovascularity approximately 2-6 cm above the Calcaneus Bone.[14]

Table 1. Myerson's Classification for Achilles Tendon rupture and Recommended Procedure

Type	Size of Defect (cm)	Recommended Procedure
I	1-2	End-to-end repair and posterior compartment fasciotomy
II	2-5	V-Y lengthening with or without tendon transfer
III	>5	Tendon transfer alone or combined with V-Y advancement and augmentation

Table 2. Kuwada's Classification for Chronic Achilles Tendon Rupture

Type	Defect	Recommended Procedure
I	Partial Tear	Conservative treatment
II	Complete tear (< 3 cm defect)	End-to-end repair
III	Complete tear (3-6 cm defect)	Debridement and tendon transfer with or without tendon graft
IV	Complete tear (> 6 cm defect)	Debridement and tendon graft with or without augmentation

partial discontinuation of the Achilles structure integrity, meanwhile, complete rupture is when there is complete discontinuation and complete separation of the Achilles tendon.[2,15]

EPIDEMIOLOGY

Based on recent studies, the peak age incidence of ATR is 30-49 years old and is dominated by males. The ratio of men and female rupture rates is 1:2 to 12:1. Besides that, sports activities caused 75% of all ATR cases, and the left Achilles was ruptured more commonly than the right, probably reflecting right-side dominance with the left leg pushing off.[15]

The average incidence of ATR varies between 7 and 40 per 100.000 person-years. Based on a recent population-based study in Finland with a range of data between 1997-2019, there is an increasing incidence of ATR from 17.3 to 32.3 incidence per 100.000 person-years.[15,20] Recent studies in the United States population show that sports activities were the most common cause of rupture, and the incidence was higher in people younger than 55 years. Based on the type of sports, basketball was the most involved sport followed by tennis and football.[21] There are no available studies about the incidence of Achilles Rupture in the Indonesian population.

ETIOLOGY AND RISK FACTORS

Several risk factors such as aging, obesity, episodic athlete, high-impact sports, use of antibiotics, and systemic factors contribute to the occurrence of ATR. Aging is believed to reduce regeneration capacity and

(A)

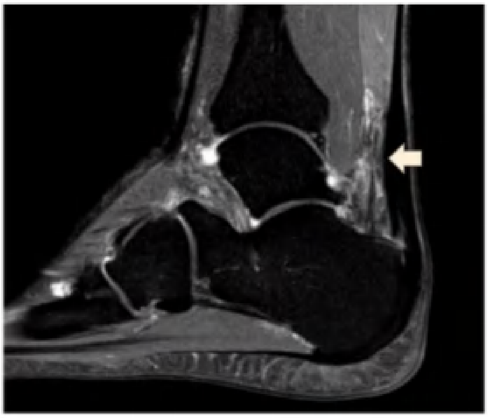

Figure 2A. MRI images of a case presented by Gatz., et al. showed a partial rupture Achilles tendon (Kuwada's classification type I) (White arrow).[16]

(B)

Figure 2B. MRI image of a case presented by Haghverdian., et al. Showed a chronic and complete right Achilles tendon rupture with a 2 cm gap. This case is included in Kuwada's classification type II (complete tear < 3 cm defect) and Myerson's classification type I (complete tear 1-2 cm defect).[17]

(C)

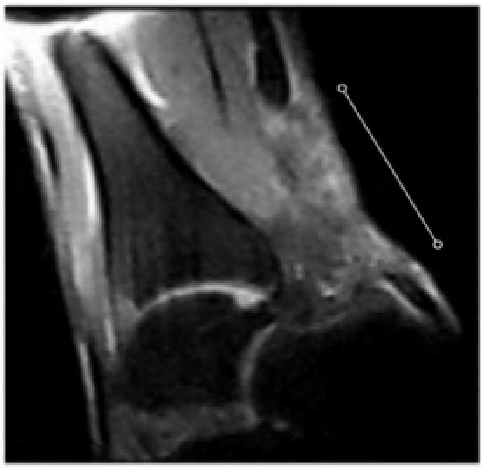

Figure 2C. MRI image of a case presented by Lin., et al. Showed a chronic and complete Achilles tendon rupture with a 9 cm gap. This case is included in Kuwada's classification type IV (complete tear with > 6 cm defect) and Myerson's classification type III (complete tear > 5 cm defect).[18]

(D)

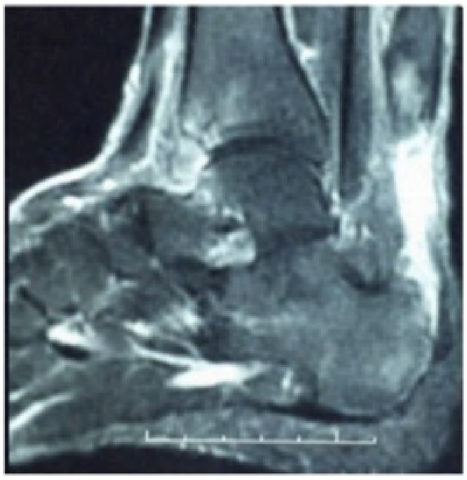

Figure 2D. MRI image of a case presented by Sadek., et al. Showed a chronic and complete right Achilles tendon rupture with a 2,4 cm gap. This case is included in Kuwada's classification type II (complete tear < 3 cm defect) and Myerson's classification type II (complete tear 2-5 cm defect).[19]

increase susceptibility to tendon injuries.[22] Tendons consist of Tendon Stem/Progenitor Cells (TSPCs) which play a crucial role in the maintenance, regeneration, and repair of tendons. As the aging process advances, TSPCs progressively lose their capacity for self-renewal and sustaining their population, resulting in depletion. Additionally, there is a reduction in collagen fibril size, accompanied by the fragmentation and disorganization of collagen fibers. This decline in collagen contributes to the disturbance in tendon tensile strength and viscoelasticity.[23]

There is still much debate regarding the relationship between obesity and ATR. A study states that obesity increases the risk of upper extremity tendon tear but does not have a correlation with lower extremity tendon rupture.[24] Despite this, fat accumulation within the tendon can lead to a disruption in its integrity. Fat deposition can also lead to muscle dysfunction, indirectly affecting tendon function.[25]

Achilles tendon injuries commonly occur in individuals who infrequently engage in physical activity, often referred to as "weekend warriors." This is caused by the sudden increase in intensity in the Achilles tendon when engaging in sports abruptly.[26] Furthermore, ATR commonly occurs in individuals involved in high-impact sports like badminton, volleyball, and football.[1] Despite the robustness of the Achilles tendon, repetitive exposure to high-energy loads during sports accelerates degenerative changes, leading to elongation and fatigue failure.[2]

Several studies indicate that the use of fluoroquinolone antibiotics can cause pathological lesions in tendons. In some cases, long-term use may even result in complete tendon rupture and significant subsequent disability. The exact mechanism is not yet precisely understood, but it is believed that fluoroquinolones can cause ischemia, degradation of tendon matrix, and degradation of the adverse alteration of tenocyte activity.[27] Other systemic conditions such as diabetes and chronic kidney disease, hyperthyroidism, rheumatoid arthritis, and systemic lupus erythematosus can also affect the structural integrity of tendons and increase the risk of rupture.[26]

PATHOPHYSIOLOGY

The pathophysiology of Achilles tendon rupture involves mechanical, structural, and biomechanical factors. Essentially, the Achilles tendon is the strongest tendon and can twist 90 degrees in both medial and lateral directions. However, despite its strength, the tendon can rupture due to excessive tensile load. Structural changes, including collagen fiber degeneration, lead to a decrease in tensile strength, increasing the risk of rupture. Additionally, Achilles tendons exposed to chronic stress or repeated microtrauma may undergo degeneration, further elevating the likelihood of rupture.[28]

CLINICAL EVALUATION

The most common patient profile for ATR is a male in his third or fourth decade of life who plays sports either occasionally or is an active athlete. The classical symptoms of a patient with ATR are a sudden painful blow with associated swelling in the posterior ankle. In some cases, the patient usually hears a "popping" or "snapping" sound when the injury occurs. The mechanism of injury is usually related to sudden or explosive movement related to sports activity with the ankle in a forced dorsoflexion position. After the injury, the patient also complained of an inability to bear weight and a weakness with push-off during gait or weakness when the ankle is forced to a plantarflexion position. Besides the mechanism of injury, it is important to assess if there is a history of minor or repetitive trauma to the Achilles tendon and if there are any risk factors associated with the rupture.[29]

On physical examination, the examiner usually finds external bruising and swelling in the posterior part of the ankle. It is important to thoroughly assess and compare both the affected and unaffected sides. It is also essential to perform a thorough neurovascular examination, with particular attention paid to the sural nerve.[29]

In assessing patients with suspected ATR, certain signs and tests can be helpful for an accurate diagnosis. The most common test is the Calf Squeeze Test (Thompson's Test or Simmond's Test). This test was performed with the patient in a prone position and both feet hanging over the edge of the bed. In normal or intact Achilles squeezing the calf will result in a plantar flexion of the ankle. If the Achilles is completely ruptured, there will be no apparent plantar flexion and this indicates a positive test.[29] The Matle's test, also called as knee-flexion test, was also one of the common tests performed. Matle's test is performed with the patient lying in a prone position and the patient is asked to flex the knee 90 degrees. The examiner will assess the neutral position of the ankle. Normally, the resting position of the ankle is slight plantarflexion. Dorsoflexion of the ankle at resting position suggests a torn tendon.[30] Apart from that, a single leg heel raise test can also be performed. In this test, the examiner will ask the patient to stand on the suspected leg with the heel raised. Unable to perform this test suggests a torn tendon.[31] Besides these tests, one of the most common and crucial clinical examinations that can be performed in ATR is a palpable gap. The examiner will palpate the Achilles tendon and try to feel the gap or discontinuation of the tendon. However, this method is less accurate in acute ATR when pain and swelling are present. Some literature suggests that performing this examination under anesthesia increases its sensitivity.[32]

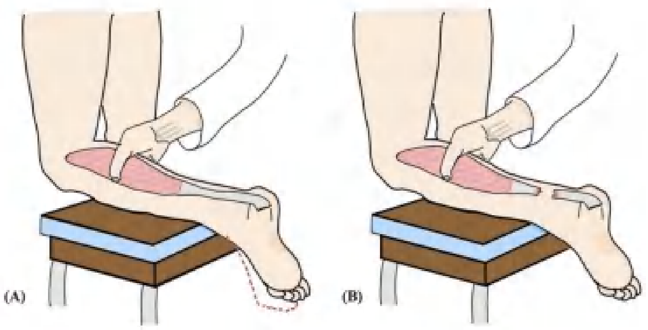

Figure 3A,B: Thompson Test - (A) Showing a normal or intact Achilles Tendon. As a result, squeezing the calf triggers ankle movements (plantar flexion). (B) The absence of ankle movement (plantar flexion) suggests a ruptured tendon.[29]

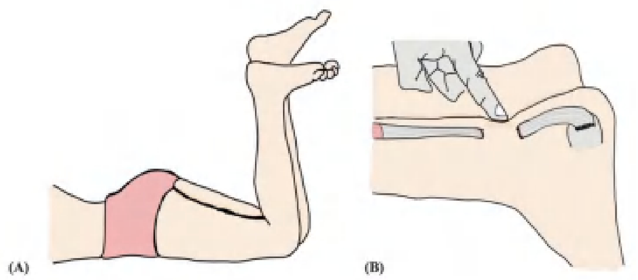

Figure 4A,B: (A) Matle's test, dorsoflexion of the left foot in a neutral position demonstrating a ruptured tendon when compared to the right side (slightly plantarflexion).[30]; (B) Showing a palpable gap or discontinuation of the tendon suggesting a torn Achilles tendon.[32]

DIAGNOSTIC STUDIES

The diagnosis of Achilles Tendon Rupture is predominately clinical. There are no routine imaging modalities needed. Imaging is useful when there is either doubt within clinical examination or to assess the gap and reducibility of the torn tendon. One of the best and most clinically used imaging modalities is ultrasound. The use of X-rays in ATR may be useful to exclude other differential diagnoses such as fractures. However, in X-rays, some signs may be helpful in the diagnosis of ATR. Obliteration of Kager's Fat Pad is one of the signs that may indicate an Achilles rupture. Kager's Fat Pad was a triangle seen on X-ray and is formed by three main structures: the flexor hallucis longus tendon, the superior part of os calcaneus, and the Achilles tendon. Obliteration or loss of the posterior border of the Kager's Fat Pad in lateral ankle X-ray may indicate a torn Achilles Tendon. Another sign that indicated a torn Achilles tendon is the Toygar's Sign. This sign involves the measurement of the angle of the posterior skin surface seen on the lateral projection. The Toygar angle below 150 degrees suggests an Achilles tendon is torn.[33]

Ultrasound was the main imaging modality used in Achilles Rupture. Ultrasound is the preferred option as it is cheaper and widely available, but it is operator-dependent. Besides that, the main strength of ultrasound lies in its ability to assess the gap between torn tendons, fibrosis, and hematoma formation within the tendon gap, and to evaluate the reducibility of the torn tendon in various positions, mainly plantar flexion. If the gap between the tendon ends is more than 1 cm on passive plantar flexion, some studies recommend operative treatment.[33]

TREATMENT

Achilles Tendon Rupture can be treated conservatively or surgically. Non-surgical or conservative management for ATR involves a short period of immobilization in a boot with early motion and progressive weight bearing. Patients typically undergo a cast placement in a plantarflexion position for the first 4 weeks, followed by a neutral position for the next 2-4 weeks. If surgical treatment is chosen, options include open repair, minimally invasive, and percutaneous repair techniques.[34] In open repair, a 6-8 cm incision is made in the posteromedial area, followed by dissections until the 2 ends of the ruptured tendon are identified. After that, debridement is performed, and stitching is done using vicryl sutures to secure the ends together. The paratenon layer is also stitched to reduce postoperative wound complications. Subsequently, layer-by-layer closure is performed, and the extremity is splinted in maximum plantar flexion.[35] Meanwhile, in minimally invasive repair, only an incision of 3-4 cm is made, and in percutaneous repair, mini-incisions are performed in the medial and lateral areas to insert instruments.[36] The commonly utilized open Achilles repair techniques comprise the Krackow and Bunnell suture techniques. Several minimally invasive approaches have been developed for the treatment of ATR. These include the Ma and Griffiths repair, the Webb and Bannister repair, the Achillon device, the Tenolig device, and the PARS repair, alongside other adapted percutaneous techniques.[37]

OUTCOME COMPARISON BETWEEN OPERATIVE AND NONOPERATIVE METHODS

Recent studies have shown similar outcomes in terms of clinical scores and patient satisfaction between the two methods. Table 3 describes recent meta-analyses regarding the comparison of operative and nonoperative treatment of ATR. Overall, studies have found that the likelihood of re-rupture is lower in those who underwent surgical treatment.[6,38–40] However, in the meta-analysis conducted by Yassie et al., it was found that the obtained risk difference is relatively small, specifically at 1.6%.[6] Dexter Seow et al. analyzed multiple meta-analyses comparing re-rupture rates in groups undergoing open surgery versus those opting for minimally invasive surgery or percutaneous repair. Their findings revealed no significant differences in the incidence of re-rupture among these three groups.[38]

Despite the lower re-rupture rate, it has been found that complication rates other than re-ruptures are significantly higher in those undergoing surgical intervention. Complications that typically occur following ATR interventions include infection, scar adhesion to the underlying tendon, sural nerve injury, and deep vein thrombosis (DVT). Across all four meta-analyses, it was observed that the overall complication rate was lower in the conservative group. However, most studies primarily compare surgical and conservative treatments broadly, without delving into the specific subtypes of surgical interventions, which can lead to misinterpretation. Various surgical procedures come with distinct risks and complications; for instance, open surgical interventions have a higher risk of infection, while minimally invasive surgery may have a lower infection rate but a higher risk of iatrogenic injuries, and after conservative treatment, DVT may be more prominent due to longer immobilization.[6,38–40]

Currently, the most interesting aspect for decision making is the patient's postoperative functional ability. Functional ability can be assessed through the patient's ability to return to activity/work/sports, ankle range of motion, and by utilizing the ATRS (Achilles Tendon Total Rupture Score) functional scoring system. In several meta-analyses, similar functional ability recovery was observed between the surgical and conservative treatment groups, whether in return to activity/work/sports, ankle range of motion, and ATRS scoring.[6,38–40]

In particular, return to activity (RTA) is a critical matter in treating ATR. On average, only around 72.5% of athletes can return to play after rehabilitation following ATR, with an average duration of 10.6 months.[41,42] This is concerning given that such a return is highly anticipated by nearly all individuals, particularly athletes. Interestingly, RTA outcomes may differ depending on the patient's lifestyle. When treating the athletic or active community, operative and functional rehabilitation may be preferred to enhance and expedite the outcomes. Whereas a sedentary person with limited functional outcome expectations may prefer nonoperative treatment. Some studies suggest that operative treatment and functional rehabilitation had a significant difference in plantar flexion strength at a higher or faster velocity than non-operative treatment. High-speed isokinetic strength may be of substantial importance for jumping and sprinting athletes.[43] Another study suggests that surgical fixation and early functional rehabilitation may be beneficial in expediting patients' return to work in active or athlete communities. A study conducted by Renninger et.al, investigating active-duty military members with ATR, showed that patients that undergo operative treatment returned to duty on average 1,5 months earlier than non-operative patients. These findings were sustained by a meta-analysis study conducted by Grassi et.al, which showed that patients that undergo surgical treatment returned to work on average 19 days earlier compared to conservative treatment.[44]

REHABILITATION

Rehabilitation plays a crucial role in the treatment of ATR, whether following conservative or surgical treatment. In the past, patients who underwent conservative treatment were not allowed to engage in movements and weight-bearing as early as those who underwent surgical treatment. However, recent studies indicate that early rehabilitation can lead to better outcomes, as it can reduce re-rupture rates.[5] Weightbearing can allow fibroblasts and collagen fibers to fill the tendon gaps, enhancing tendon strength. It can also increase plantar flexor activity which helps the healing process.[45]

The reported rates of re-rupture and complications after conservative treatments were not significantly different between earlier and later rehabilitation.[6,38–40] However, one particular meta-analysis strongly supported early rehabilitation, especially in the comparison between cast with orthosis and cast alone.[38] Another study also indicates that although early weightbearing did not show significant differences in terms of endurance and strength as assessed by the heel-rise work test, re-rupture rate, or return to activity/sport, there were significant differences observed in health-related quality of life. Meanwhile, early rehabilitation post-surgery has shown better outcomes. A systematic review of 12 studies categorized early rehabilitation into three categories: full weightbearing, early ankle mobilization, and a combination of both, and found that all categories demonstrated a higher satisfaction level.[42] This is further supported by a meta-analysis which found that early weightbearing could reduce both minor and major complication rates. Early rehabilitation also provides advantages in terms of patients' functional ability.[38] Various meta-analyses examining the clinical outcomes of ATR treatments indicated that early rehabilitation enhanced functionality to a greater extent and facilitated an earlier return to work and sports compared to late rehabilitation involving prolonged immobilization.[46]

REGENERATIVE THERAPY

In recent years, regenerative therapy using biological materials in orthopedic sports medicine, notably platelet-rich plasma (PRP), has surged. PRP offers advantages such as easy preparation, minimal patient burden, and relative safety.[46] Platelet-Rich Plasma therapy in the treatment of achilles tendon rupture primarily involves its potential to enhance and accelerate the healing process and is often used in conjunction with other treatments such as physical therapy, immobilization, or surgery. Rich in growth

Table 3. Recent Meta-analyses Comparing Surgical and Conservative Treatments for Achilles Tendon Rupture

Author	Year	Type of Study	Sample	Type of Interventions	Conclusion
Dexter Seow, et al.[38]	2023	Systematic review of overlapping meta-analyses. There were 16 meta-analyses that discussed the comparison of surgical versus conservative treatment.	There was a total of 27.240 participants with possible overlap.	Non-surgical treatment: Cast or/and orthosis Surgical treatment: Open repair or minimally invasive surgery	Significantly lower re-rupture rates were reported with surgical treatment compared to conservative treatment. However, conservative treatment was preferred due to lower complication rates.
Guorong She, et al.[40]	2021	Meta-analysis, 13 RCTs were included	There was a total of 1.164 participants (79,98% male) with an age range of 18-63 years. Participants were divided into two major groups: those who received non-surgical treatment (48,2%) and those who underwent surgery (51,8%).	Non-surgical treatment: Cast immobilization or functional bracing Surgical treatment: Open or minimally invasive surgery	Surgical treatment showed a significant reduction in re-rupture rate. However, the complication rates other than re-rupture (DVT, adhesion of scars, sural nerve injury, superficial, and deep infection) were significantly lower in conservative treatment. There was no significant difference between surgical and conservative treatment in returning to sports and ATRS functional score.
Yasser Reda et al.[39]	2020	Systematic review and meta-analysis, 9 RCTs were included	There was a total of 822 participants (76,76% male) aged over 18 years. The participants were categorized into two major groups: those who received conservative treatment (49.6%) and those who underwent surgical intervention (50.4%).	Non-surgical treatment: Cast immobilization and/or functional bracing. Surgical interventions: Open repair, minimally invasive techniques, or percutaneous methods.	Surgical intervention has a lower significant re-rupture rate compared to non-surgical treatment; however, surgical treatment carries a higher risk of experiencing wound complications.
Yassine Ochen, et al.[6]	2019	Systematic review and meta-analysis, 29 studies (10 RCTs and 19 observational studies) were included	There was a total of 15.862 participants (74% male) with an age range of 17-86 years. Participants were divided into two major groups: those who received non-operative treatment (40,9%) and those who underwent surgery (59,1%).	Non-operative treatments: Cast immobilization or functional bracing. Operative treatment: Open repair or minimally invasive surgery	Operative treatment of ATR reduces the risks of re-rupture compared with nonoperative treatment, however, it has a higher risk of complications.

factors like TGF-b, VEGF, PDGF, IGF, and bFGF, PRP aids tissue repair and accelerates healing. The use of PRP can be considered to expedite healing by promoting tissue regeneration and reducing inflammation during the early stages following an acute Achilles tendon rupture. Post-surgical application of PRP at the repair site may enhance healing outcomes, potentially decreasing recovery time and increasing tissue strength. In cases where there is poor healing in chronic Achilles tendon rupture, PRP can be used to stimulate healing in the damaged tissue. Additionally, when PRP is used in conjunction with conservative treatments such as immobilization or physical therapy, it can enhance the overall efficacy of the rehabilitation program. However, there is currently no standardized protocol for PRP preparation and application, which results in inconsistent clinical outcomes. Therefore, PRP indications and uses for Achilles tendon healing remain to be fully explored.[47] While some clinical studies have explored its effectiveness in treating ATRs, conclusive evidence remains limited. Shota Morimoto et al. reported a case study where a patient was able to return to sport only 3 months after receiving an intra-tissue injection of freeze-dried platelet-derived factor concentrate along with early rehabilitation following operative treatment. Considering this case, it is important to evaluate the potential of early rehabilitation, specifically mechanical loading, in aiding and speeding up tendon tissue healing when combined with growth factors like an intra-tissue injection of FD-PFC.[46]

Conclusion

Achilles tendon rupture is an emerging problem due to young populations increasing awareness of regular exercise. The operative treatment is also modified to be as minimally invasive as possible. Despite the lower re-rupture rate with surgical treatment, recent evidence showed that conservative treatment yields comparable patient's satisfaction. Current studies are primarily focused on re-rupture rates, while other outcomes such as complication rate, functional ability recovery, and patient's satisfaction should be taken into consideration when deciding on treatment. Consideration of the patient and the types of activity in everyday life is also crucial in treating ATR. In athletes or active communities, the surgical and functional rehabilitation option may be wise due to an earlier return to work rate and stronger plantar flexion ability. Moreover, it is also essential to conduct research that can compare outcomes based on other considerations such as comorbidities and systemic conditions that may influence the results.

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Review Article

Outcome Comparison Between Percutaneous Vertebroplasty Versus Conservative Treatment in Osteoporotic Vertebral Compression Fracture: A Systematic Review and Meta Analysis

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Abstract

Introduction:
Osteoporotic vertebral compression fractures (OVCFs) are common in older adults and cause chronic back discomfort and kyphotic deformity. Percutaneous vertebroplasty (PVP) is preferred over conservative treatment (CT) for pain relief and quality of life improvement. However, there are ongoing debates about PVP's effectiveness and safety, with some suggesting it should only be available to patients who have exhausted other non-invasive options.

Methods:
A systematic review was conducted following the principles outlined in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). A thorough literature search was conducted to get a complete, peer-reviewed manuscript in English that compares the outcomes of vertebroplasty versus conservative therapy in osteoporotic compression fractures. We conducted a comprehensive search on PubMed, Google Scholar, and Cochrane Library. This systematic study aims to compare the therapeutic efficacy of vertebroplasty versus conservative therapy.

Results:
The electronic investigation identified 236 entries from various databases, screening them for eligibility, assessing duplicates, and eliminating duplicates, resulting in 9 studies for qualitative and quantitative synthesis. The heterogeneity across studies was examined throughout the I2 statistic described as follows: low, 25% to 50%; moderate 50% to 75%; or high>75%. There is no significant difference found in 1 week and 3 months of pain relief in these two groups in pain relief (mean difference 0.73 (-0.52, 1.96); 95% CI, P = 0,25); (mean difference -0.76 (-2.02, 0.49); 95% CI, =0.23). we found no statistically significant difference between those two groups favoring the PVP group in terms of quality-of-life outcome (mean difference -0.76 (-2.02, 0.49); 95% CI, P < 0.23); (mean difference 1.75 (-0.87, 4.38); 95% CI, P < 0.19). PVP has no association with new adjacent vertebral fractures. (M-H, Fixed, 95% CI -0.07 (-0.17, 0.03); I2 = 0%, P = 0.16).

Conclusion:
Comparatively, percutaneous vertebroplasty was determined to be more effective in alleviating pain and enhancing quality of life, without posing an elevated risk of nearby vertebral fracture as compared to the CT group. Therefore, it is necessary to conduct a more extensive investigation to determine which patients with osteoporotic vertebral compression fractures (OVCFs) are most likely to experience a positive outcome following percutaneous vertebroplasty (PVP) with little risk of sequelae.

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Introduction

Osteoporotic vertebral compression fracture (OVCFs) commonly occurs in the elderly, which usually causes chronic back pain, and progressive kyphotic deformity with sagitta imbalance, it also decreases quality of life and survival.[1]

There is extensive literature suggesting that treatment such as percutaneous vertebroplasty (PVP) is favored to relieve pain and improve quality of life compared to conservative treatment,emt (CT) such as (e.g., oral analgesics, rehabilitation exercise, bisphosphonates, orthotics, and multimodal therapy).[2,3]

However, debates clinging in this topic comparing PVP and CT in an osteoporotic vertebral compression fracture. Some have suggested that PVP should only be offered to patients after conservative treatment has failed.[4] Some studies also suggested that the PVP did not incur more pain relief than the conservative group.[5]

Therefore this systematic review and meta-analysis of randomized controlled trials (RCTs) aims to evaluate the efficacy and safety in PVP and CT for OVCFs.

Materials & Method

Search Strategy

A systematic review was conducted in accordance to Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Figure 1). A comprehensive literature search was performed to gather a full-length, peer-reviewed paper in English on the comparison of outcomes between vertebroplasty and conservative treatment in osteoporotic compression fracture. We searched PubMed, Google Scholar, and Cochrane Library. The focus in this systematic review is to compare treatment between vertebroplasty and conservative treatment. Keywords in the search matched the MeSH rule and term used are ("Percutaneous Vertebroplasty"), AND ("Conservative Treatment"), AND ("Osteoporotic Vertebral Compression Fracture").

Inclusion Criteria

The inclusion criteria were any studies about 1) osteoporotic vertebral compression fractures; 2) percutaneous vertebroplasty versus conservative treatment; 3) pain relief outcomes, quality of life outcome, and the rate of adjacent vertebral fractures; and 4) RCTs design. The outcomes assessed using the forest plot include pain relief, quality of life using EuroQol and Roland-Morris Disability Questionnaire, and new adjacent vertebral fractures rate.

Quality Evaluation

Assessment of study quality and risk of bias assessed using criteria developed by the Oxford Center for Evidence-based Medicine, perspicacity defined by the Grades of Recommendation Assessment, Development and Evaluation (GRADE) Working Group, and sanction made by the Agency for Healthcare Research and Quality (AHRQ). The class of evidence is categorized into "class I" for good quality RCT, "class II" for moderate to poor quality RCT and good quality cohort, "class III" for moderate or poor-quality cohorts and case-control studies, "class IV" for the case series.

Results

Literature Search, Study Selection, and Study Characteristics

The electronic research resulted in 236 records from various databases. After the process of identification, screening, eligibility, duplication elimination, and exclusion, the remaining 9 studies were included in qualitative and quantitative synthesis. The remaining articles were excluded due to a lack of mean and standard deviation data and did not meet the inclusion and exclusion criteria.

Statistical Analysis

We utilized the Review Manager version 5.3 software (RevMan; The Cochrane Collaboration Oxford, England) to perform all statistical analyses. Based on the heterogeneity of the current study, we performed a sensitivity analysis to further assess the overall results. The heterogeneity across studies was examined through the I^2 statistic describing as follows: low, 25% to 50%; moderate 50% to 75%; or high>75%. We applied the fixed-effect models to calculate the total MDs/ORs when low heterogeneity was seen in studies. In other cases, we used the random effects model. Studies with a P values less than .05 were thought to have statistical significance. Forest plots showed the findings of our meta-analysis.

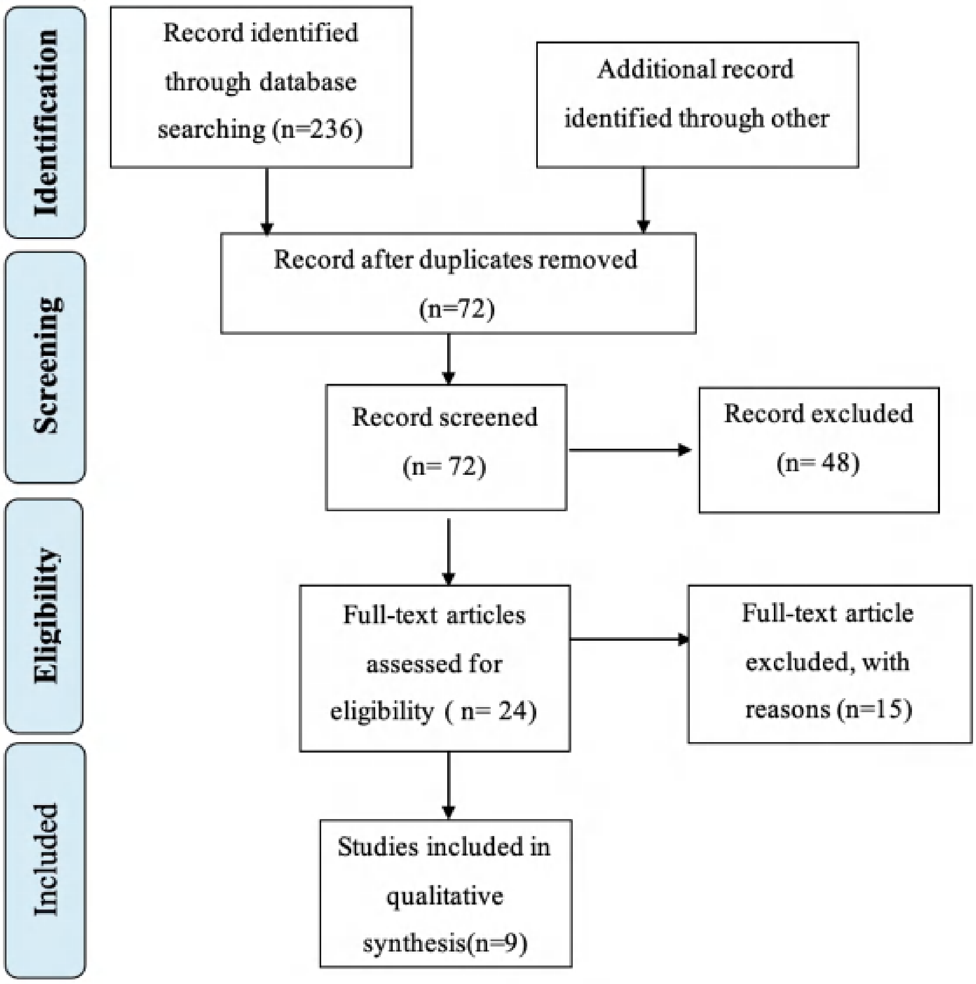

Figure 1. Flow diagram based on PRISMA Guideline describing the strategy for conducting this study.

Table 1. List of studies included

No	Reference	Journal	Study Design	Level of Evidence
1	Klazen, et al, 2010	The Lancet	Prospective randomized trial	II
2	Farrokhi *et al*, 2011	Journal Neurosurgery Spine	Randomized controlled trial	II
3	Comstock *et al*, 2013	Neuroradiology	Randomized controlled trial	II
4	Firanescu *et al*, 2022	British Medical Journal	Randomized controlled clinical trial	II
5	Clark *et al*, 2016	The Lancet	Randomized Multicenter Placebo Controlled Trial	II
6	Buchbinder *et al*, 2009	The New England Journal of Medicine	Randomized Multicenter Placebo Controlled Trial	III
7	Hnasen *et al*, 2016	Global Spine Journal	Double blind Placebo-controlled triam	III
8	Chen *et al*, 2014	Journal of Clinical Neuroscience	Randomized Controlled trial	I
9	Kroon *et al, 2014*	Journal of Bone and Mineral Research	Randomized controlled trial	I

Table 2. Characteristic of patient

No	Reference	Total Sample Size	Treatment Protocol					Mean Age (SD)					Gender (Male/Female Ratio)				
			PV	OMT	Sham Procedure	Control Procedure	Conservative Treatment	PV	OMT	Sham Procedure	Control Procedure	Conservative Treatment	PV	OMT	Sham Procedure	Control Procedure	Conservative Treatment
1	Klazen, et al. 2010	202	101	-	-	-	101	75.2 (9.8)	-	-	-	75.4 (8.4)	-	-	-	-	-
2	Farrokhi et al. 2011	82	40	42	-	-	-	72 (59–90)	74 (55–86)	-	-	-	10/30	12/30	-	-	-
3	Comstock et al. 2013	131	68	-	-	63	-	-	-	-	-	-	-	-	-	-	-
4	Firanescu et al. 2018	180	91	-	89	-	-	74.7 (10.7)	-	76.9 (8.1)	-	-	24/67	-	23/66		-
5	Clark et al. 2016	120	61	-	-	-	59	80	-	-	-	81	13/48	-	-	-	19/40
6	Buchbinder et al. 2009	78	38	-	-	-	40	74.2± 14.0	-	-	-	78.9±9.5	7/31	-	-	-	9/31
7	Hnasen et al. 2016	46	22	-	-	-	24	70.6	-	-	-	69.03.00	4/18	-	-	-	2/22
8	Chen et al. 2014	96	46	-	-	-	50	64.63+ 9.10	-	-	-	66.49+9.11	14/32	-	-	-	13/30
9	Kroon et al. 2014	78	29	-	28	-	21	76.7+ 9.4	-	77.7+0.2	-	77.2+9.2	23 female	-	24 female	-	15 female

PV= Percutaneous Vertebroplasty; OMT=Optimal Medical Therapy

Table 3. Outcome Characteristics

No	Reference	Study Comparison	Follow up Duration	Clinical Outcomes	Complications
1	Klazen, et al, 2010	To compare vertebroplasty and conservative treatment in acute osteoporotic vertebral compression fractures	12 months	VAS	-
2	Farrokhi et al, 2011	To asses the short and long-term effect of PV on pain relief and QOL in comparison with OMT in patients with osteoporotic VCFs	15 months	VAS, Oswetry LBP disability scale	Cement extravasation
3	Comstock et al, 2013	To evaluate 1-year outcomes of the investigational vertebroplasty safety and efficacy trial (INVEST) to investigate the effectiveness of percutaneous vertebroplasty in the treatment of osteoporotic vertebral compression fractures	12 months	RDQ score Average pain intensity	-
4	Firanescu et al, 2018	To asses whether percutaneous vertebroplasty results in more pain relief than a sham procedure in patients with acute osteoporotic compression fractures of the vertebral body	12 months	VAS, QUALEFO, RMDQ	-
5	Clark et al, 2016	To measured safety and efficacy vertebroplasty for acute painful osteoporotic (VAPOUR) in patients with poorly controlled pain and osteoporotic spinal fractures of less than 6 weeks' duration	6 months	NRS pain score, RDQ score, VAS pain score, QUALEFFO score, EQ-5D score, Analgesic use	-
6	Buchbinder et al, 2009	To compare outcome treatment by vertebroplasty for one or two painful osteoporotic vertebral fractures patients that were of less than 12 months' duration and unhealed.	6 months	Pain score, QUALEFFO total score, AQoL score, EQ-5D score, Perceived pain	Multiple drug allergies, Adjacent new fractur, Osteomyelitis
7	Hansen et al, 2016	investigate the clinical effects of PVP compared with a SHAM procedure when treateing acute osteoporotic VCFs	3 months	VAS, QUALEFFO, RMDQ	-
8	Chen et al, 2014	Compare the efficacy of PVP with that of CT in terms of pain and functional outcome in patients with chronic compression fractures and persistent severe pain	1 week, 1 months, 3 months, 6 months, 12 months	VAS, ODI, RMDQ	-
9	Kroon et al, 2014	to report clinical outcome in pain and functional outcomes related to cement volume and cement leakage in 12 months and 24 months	12 months. 24 months	AS, QUALEFFO, AQoL, RDQ, EQ5	-

Table 4. Characteristic of Outcome of studies

No	Reference	Outcome Measure					
1	Klazen, et al 2010	**VAS**					
		Vertebroplasty			Conservative Treatment		
		1 day: 3·7 [SD 2·4] 1 week: 3·5 [2·5] 1 month: 2·5 [2·5] 3 months: 2·5 [2·7] 6 months: 2·3 [2·7] 1 year: 2·2 [2·7]			1 day: 6·7 [2·1] 1 week: 5·6 [2·5] 1 month: 4·9 [2·6] 3 months: 3·9 [2·8] 6 months: 3·9 [2·9] 1 year: 3·8 [2·8]		
2	Farrokhi et al, 2011	**VAS**			**Oswetry LBP**		
		PV	OMT		PV	OMT	
		Baseline: 8.4 ± 1.6 1 wk: 3.3 + 1.5 2 mos: 3.2 + 2.2 6 mos: 2.2 + 2.1 12 mos: 2.2 + 2.1 24 mos: 2.8 + 2.0 36 mos: 1.8 + 1.7	Baseline: 7.2 ± 1.7 1 wk: 6.4 + 2.1 2 mos: 6.1 + 2.1 6 mos: 4.1 + 1.5 12 mos: 4.1 + 1.8 24 mos: 3.7 + 2.0 36 mos: 3.7 + 2.5		Baseline: 52.2 ± 2.4 1 wk: 30.1 + 3.0 2 mos: 15.0 + 2.2 6 mos: 10.0 + 2.0 12 mos: 8.0 + 3.2 24 mos: 8.0 + 2.2 36 mos: 8.0 + 1.7	Baseline: 52.2 2.4 1 wk: 30.1 + 3.0 2 mos: 15.0 + 2.2 6 mos: 10.0 + 2.0 12 mos: 8.0 + 3.2 24 mos: 8.0 + 2.2	
3	Comstock *et al*, 2013	**RDQ**			**Average pain intensity**		
		Vertebroplasty	Control procedure		Vertebroplasty	Control procedure	
		1 month : 11.97 ± 6.32 3 months : 10.84 ± 5.68 6 months : 9.44 ± 6.12 12 months : 10.19 ± 6.46	1 month : 12.97 ± 6.38 3 months : 11.89 ± 6.37 6 months : 11.38 ± 6.35 12 months : 11.89 ± 6.24		1 month : 3.85 ± 2.91 3 months : 3.55 ± 2.81 6 months : 3.67 ± 2.98 12 months : 3.52 ± 2.89	1 month : 4.57 ± 2.97 3 months : 4.26 ± 2.85 6 months : 4.43 ± 2.89 12 months : 4.50 ± 2.70	
4	Firanescu *et al*, 2018	**VAS**		**QUALEFFO**		**RMDQ**	
		PV	Sham	PV	Sham	PV	Sham
		Baseline: 7.72 (0.2) 1 day: 5.24 (-0.43) 1 wk: 4.38 (-0.11) 1 mo: 3.32 (0.41) 3 mos: 2.69 (0.21) 6 mos: 3.02 (0.39) 12 mos: 2.72 (0.45)	Baseline: 7.92 (0.2) 1 day: 4.82 (-0.43) 1 wk: 4.27 (-0.11) 1 mo: 3.73 (0.41) 3 mos: 2.90 (0.21) 6 mos: 3.41 (0.39) 12 mos: 3.17 (0.45)	Baseline: 68.4 (17.1)	Baseline: 69.7 (17.9)	Baseline: 18 (4.5)	Baseline: 17.8 (4.7)
5	Clark *et al*, 2016	**Reduction in NRS pain score**	**Reduction in RDQ score**	**VAS pain score**	**QUALEFFO score**	**EQ-5D score**	**Analgesic use**
		Vertebroplasty: 3 days: 3·5 (2·6) 14 days: 4·2 (2·7) 1 month: 4·6 (3·0) 3 months: 5·4 (3·5) 6 months: 6·1 (3·3) Placebo: 3 days: 1·8 (2·3) 14 days: 3·0 (3·0) 1 month: 3·2 (2·7) 3 months: 4·1 (3·1) 6 months: 4·8 (3·1)	Vertebroplasty: 3 days: 4·5 (6·2) 14 days: 5·9 (5·8) 1 month: 6·9 (6·0) 3 months: 9·6 (7·7) 6 months: 11·7 (6·5) Placebo: 3 days: 2·9 (4·4) 14 days: 4·1 (6·3) 1 month: 4·3 (5·6) 3 months6·4 (7·0) 6 months: 7·4 (6·9)	Vertebroplasty (patient reported): 14 days: 39 (28) 6 months: 23 (26) (researcher observed): 14 days: 25 (23) 6 months: 14 (21) Placebo: (patient reported): 14 days: 49 (28) 6 months: 34 (27) (researcher observed): 14 days: 39 (29) 6 months: 19 (20)	Vertebroplasty: 14 days: 49 (13) 1 month: 49 (17) 6 months: 38 (15) Placebo: 14 days: 55 (14) 1 month: 52 (15) 6 months: 45 (16)	Vertebroplasty: 3 days: 0·69 (0·11) 14 days: 0·69 (0·10) 1 month: 0·75 (0·11) 3 months: 0·75 (0·12) 6 months: 0·80 (0·11) Placebo: 3 days: 0·65 (0·09) 14 days: 0·69 (0·10) 1 month: 0·75 (0·11) 3 months: 0·75 (0·12) 6 months: 0·80 (0·11)	Vertebroplasty: 3 days: 57 (97%) 14 days: 49 (88%) 1 month: 41 (75%) 3 months: 34 (64%) 6 months: 29 (58%) Placebo: 3 days: 56 (98%) 14 days: 52 (91%) 1 month: 50 (88%) 3 months: 44 (83%) 6 months: 39 (76%)
6	Buchbinder *et al*, 2009	**Pain score**	**RDQ score**	**AQoL score**	**QUALEFFO score**	**EQ–5D score**	**Perceived pain**
		Vertebroplasty: 1 week: (Overall): 1.5±2.5 (At rest): 0.8±3.0 (In bed at night): 0.9±2.7 1 months: (Overall): 2.3±2.6 (At rest): 1.2±4.0 (In bed at night): 0.5±3.3 3 month: (Overall): 2.6±2.9 (At rest): 1.4±3.4 (In bed at night): 1.6±2.9 6 months: (Overall): 2.4±3.3 (At rest): 2.0±3.2 (In bed at night): 1.5±3.6 Plasebo: 1 week: (Overall): 2.1±2.8 (At rest): 1.3±3.9 (In bed at night): 0.4±2.8 1 months: (Overall): 1.7±3.3 (At rest): 1.2±4.0 (In bed at night): 0.5±3.3 3 month: (Overall): 1.9±3.3 (At rest): 1.5±3.7 (In bed at night): 0.8±3.4 6 months: (Overall): 2.1±3.3 (At rest): 0.9±3.2 (In bed at night): 1.6±3.6	Vertebroplasty: 1 week: 1.8±5.0 1 months: 4.4±6.6 3 month: 3.7±5.4 6 months: 4.1±5.8 Plasebo: 1 week: 4.0±6.8 1 months: 3.1±6.8 3 month: 5.3±7.2 6 months: 3.7±5.8	Vertebroplasty: 1 week: 0.0±0.2 1 months: 0.0±0.2 3 month: 3.7±5.4 6 months: 0.0±0.3 Plasebo: 1 week: 0.0±0.2 1 months: 0.1±0.3 3 month: 0.1±0.3 6 months: 0.1±0.3	Vertebroplasty: 1 week: −0.5±7.4 1 months: 2.8±9.3 3 month: 6.0±9.6 6 months: 6.4±13.4 Plasebo: 1 week: 3.6±9.2 1 months: 2.4±12.3 3 month: 6.1±13.7 6 months: 6.1±13.4	Vertebroplasty: 1 week: 0.1±0.3 1 months: 0.1±0.3 3 month: 0.2±0.3 6 months: 0.2±0.4 Plasebo: 1 week: 0.1±0.3 1 months: 0.1±0.3 3 month: 0.2±0.4 6 months: 0.2±0.4	Vertebroplasty: 1 week: (Better): 6 (16) (No change): 26 (70) (Worse): 5 (14) 1 months: (Better): 12 (34) (No change): 21 (60) (Worse): 2 (6) 3 month: (Better): 14 (39) (No change): 19 (53) (Worse): 3 (8) 6 months: (Better): 16 (46) (No change): 12 (34) (Worse): 7 (20) Plasebo: 1 week: (Better): 13 (35) (No change): 23 (62) (Worse): 1 (3) 1 months: (Better): 9 (24) (No change): 20 (53) (Worse): 9 (24) 3 month: (Better): 12 (32) (No change): 18 (49) (Worse): 7 (19) 6 months: (Better): 15 (42) (No change): 16 (44) (Worse): 5 (14)
7	Hansen *et al*, 2016	**Pain score**		**RMDQ**		**QUALEFFO**	
		baseline VAS PVP: 5.3+0.4 baseline VAS CT: 4.6+0.46		-		-	
8	Chen *et al*, 2014	**VAS**		**ODI**		**RMDQ**	
		1 week PVP: 3.4+05 1week CT: 5.0+0.7 1 months PVP: 2.8+0.4 1months CT: 4.0+0.6 3 months PVP: 2.5+0.5 3 months CT: 3.9+0.7 6 months PVP: 2.6+0.6 6 months CT: 4.0+0.8 1 year PVP: 2.5+0.5 1 year CT: 4.1+0.8		1 week PVP: 30.3+3.2 1week CT: 44.5+3.9 1 months PVP: 20.4+3.1 1months CT: 35.4+2.9 3 months PVP: 16.6+1.6 3 months CT: 30.0+2.4 6 months PVP: 15.5+1.1 6 months CT: 31.3+3.5 1 year PVP: 15.0+1.3 1 year CT: 32.1+4.5		1 week PVP: 17 1week CT: 43 1 months PVP: 13 1months CT: 33 3 months PVP: 7 3 months CT: 26 6 months PVP: 6 6 months CT: 24 1 year PVP: 7 1 year CT: 28	
9	Kroon et al, 2014	**Pain Score**	**QUALEFFO**	**AQoL**	**RDQ**	**EQ5D**	
		12 months in VP group: 2.4+2.7 12 months in sham procedure: 1.9+2.8 24 months in PVP group: 3.0+3.1 24 months in sham procedure: 1.9+.3.0	12 months in VP groups: 6.7+12.2 12 months in sham procedure: 8.8+13.3 24 months in PVP group: 5.9+10.7 24 months in sham procedure: 4.6+15.0	12 months in VP groups: 0.1+0.3 12 months in sham procedure: 0.2.-0.3 24 months in PVP group: 0.1+0.3 24 months in sham procedure: 0.1+0.3	12 months in VP groups: 2.0+5.7 12 months in sham procedure: 2.6+6.9 24 months in PVP group: 2.6+7.0 24 months in sham procedure: 2.7+5.6	12 months in VP groups: 0.2+0.4 12 months in sham procedure: 0.2+0.4 24 months in PVP group: 0.2+0.4 24 months in sham procedure: 0.2+0.4	

Pain Relief Outcome

We performed a subgroup analysis to evaluate pain relief between PVP and CT in osteoporotic vertebral compression fracture in 1 week,1 month and 3 months. There is no significant difference found in 1 week and 3 months pain relief these two groups in pain relief (mean difference 0.73 (-0.52, 1.96) ; 95% CI, P = 0,25); (mean difference -0.76 (-2.02, 0.49); 95% CI, =0.23), therefore in 1 month we found statistically significant difference in pain relief. [6–12]

Quality of life outcome

We performed a subgroup analysis to evaluate quality of life using EuroQol and RMDQ to compare PVP and CT groups. In these studies, the PVP group showed better outcomes in EuroQol, but different in RMDQ showing slightly favored to CT group. Hence, we found no statistically significant difference in between those two groups favoring the PVP group in term of quality of life outcome (mean difference -0.76 (-2.02, 0.49); 95% CI, P < 0.23); (mean difference 1.75 (-0.87, 4.38); 95% CI, P < 0.19)[13]

Study or Subgroup	PVP Mean	PVP SD	PVP Total	CT Mean	CT SD	CT Total	Weight	Mean Difference IV, Random, 95% CI	Year
Farokhi 2011	5.1	2.5	37	2.1	2.8	37	18.7%	3.00 [1.79, 4.21]	2011
Chen 2014	3.1	0.5	46	1.4	0.7	43	22.4%	1.70 [1.45, 1.95]	2014
Hansen 2016	1.357	2.18	22	1.387	2.18	24	18.4%	-0.03 [-1.29, 1.23]	2016
Clark 2016	-4.2	2.7	55	-3	3	57	19.5%	-1.20 [-2.26, -0.14]	2016
Firanescu 2018	4.38	2.52	90	4.27	2.48	86	21.0%	0.11 [-0.63, 0.85]	2018
Total (95% CI)			**250**			**247**	**100.0%**	**0.73 [-0.52, 1.97]**	

Heterogeneity: Tau² = 1.79; Chi² = 51.99, df = 4 (P < 0.00001); I² = 92%
Test for overall effect: Z = 1.14 (P = 0.25)

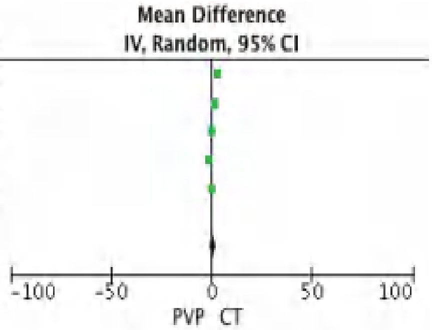

Figure 2. Pooled analysis of pain relief outcome between PVP and CT in 1

Study or Subgroup	PVP Mean	PVP SD	PVP Total	CT Mean	CT SD	CT Total	Weight	Mean Difference IV, Random, 95% CI	Year
Klazen 2010	3.7	0.4	46	2.4	0.6	44	37.2%	1.30 [1.09, 1.51]	2010
Comstock 2013	3.01	3.16	63	2.56	3.11	56	27.4%	0.45 [-0.68, 1.58]	2013
Chen 2014	5.3	1.6	96	2.6	1.6	92	35.5%	2.70 [2.24, 3.16]	2014
Total (95% CI)			**205**			**192**	**100.0%**	**1.56 [0.43, 2.69]**	

Heterogeneity: Tau² = 0.88; Chi² = 33.16, df = 2 (P < 0.00001); I² = 94%
Test for overall effect: Z = 2.71 (P = 0.007)

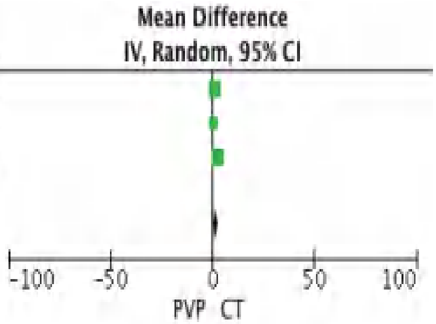

Figure 3. Pooled analysis of pain relief outcome between PVP and CT in 1 week

Study or Subgroup	PVP Mean	PVP SD	PVP Total	CT Mean	CT SD	CT Total	Weight	Mean Difference IV, Random, 95% CI	Year
Farokhi 2011	3.2	2.2	40	6.1	2.1	42	20.7%	-2.90 [-3.83, -1.97]	2011
Comstock 2013	3.31	3	63	2.85	2.97	56	19.9%	0.46 [-0.61, 1.53]	2013
Hansen 2016	0.864	2.13	22	0.688	2.13	24	19.0%	0.18 [-1.06, 1.41]	2016
Clark 2016	-5.4	3.5	53	-4.1	3.1	52	18.9%	-1.30 [-2.56, -0.04]	2016
Firanescu 2018	2.69	2.5	87	2.9	2.55	84	21.5%	-0.21 [-0.97, 0.55]	2018
Total (95% CI)			**265**			**258**	**100.0%**	**-0.76 [-2.02, 0.49]**	

Heterogeneity: Tau² = 1.76; Chi² = 30.14, df = 4 (P < 0.00001); I² = 87%
Test for overall effect: Z = 1.19 (P = 0.23)

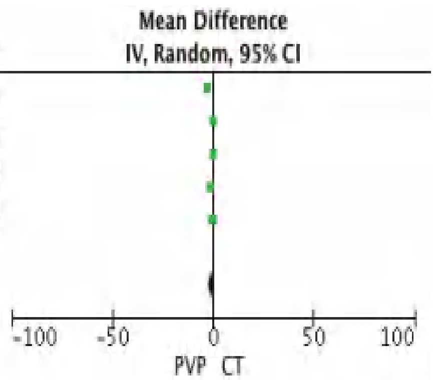

Figure 4. Pooled analysis of pain relief outcome between PVP and CT in 3 months

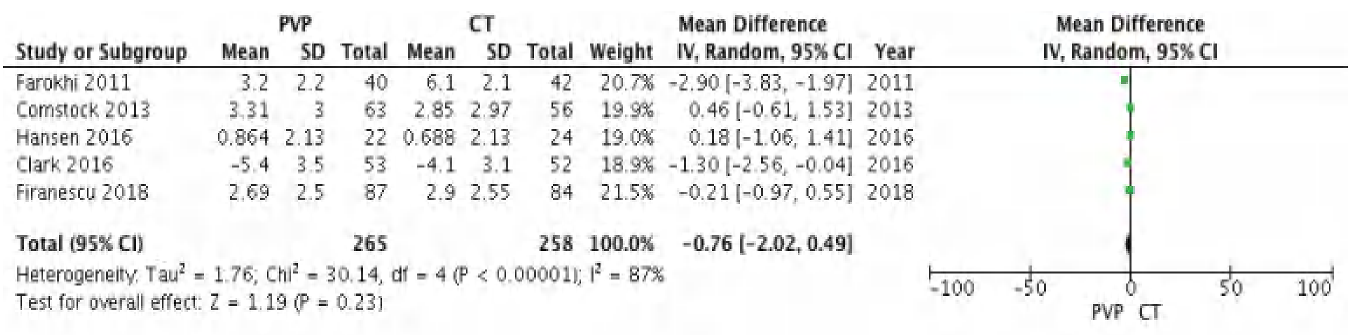

Figure 5. Pooled analysis of EuroQol outcome between PVP and CT groups

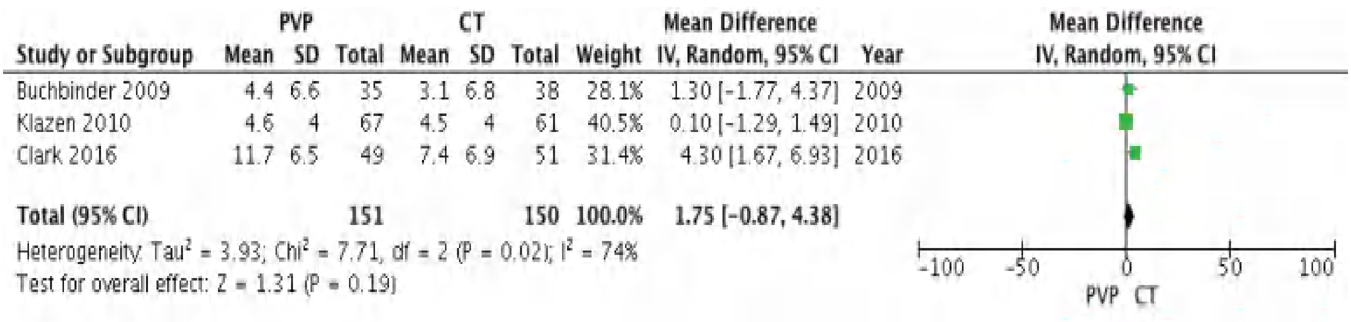

Figure 6. Pooled analysis of Roland Morris Questionaire outcome between PVP and CT groups

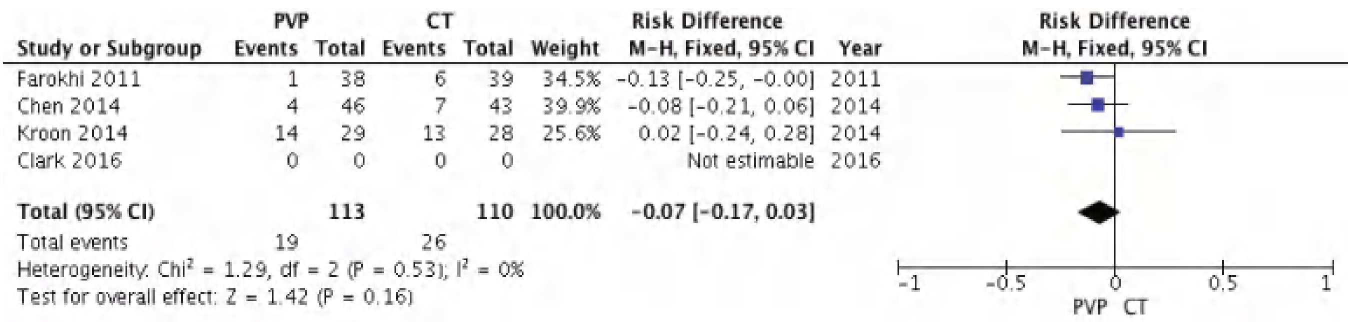

Figure 7. Pooled analysis of EuroQol outcome between PVP and CT groups

New adjacent vertebral fracture outcome

We also performed a subgroup analysis to evaluate new adjacent vertebral fractures comparing methods between PVP and CT groups. In these studies, the PVP group showed no statistically significant difference between CT groups. It may show that PVP has no association to new adjacent vertebral fractures. (M-H, Fixed, 95% CI -0.07 (-0.17, 0.03); $I^2 = 0\%$, P = 0.16).

Osteoporotic vertebral compression fractures (OVCFs) usually occur in the elderly and are associated with chronic back pain, functional disability, decreased quality of life, progressive kyphotic deformity, and increased risk of adjacent vertebral fractures that can lead to mortality. Recommended treatment for OVCFs is CT, including orthosis, pain intervention using medication, bisphosphonates, bed rest, and activity modification. Although OVCFs also can be treated using PVP, which was introduced in 1987. [14–16] These methods consist of injection of PMMA (polymethylmethacrylate) within the vertebral body via a percutaneous approach.[17]

Both PVP and CT have advantages and disadvantages which still give debates regarding the best option therapy for OVCFs. This study is designed to compare both groups and assess efficacy in patients with OVCFs. The pain relief studies assessed the outcomes using Visual Analogue Scale (VAS). From the pooled data we found a statistically significant result regarding outcomes of pain relief for patients treated with PVP compared to CT at 1 week and not statistically significant at 3 months, although it was not statistically significant many of the patient's reports of satisfactory results in PVP group after the procedure this was regarding quality of life. We pooled the data and got statistically significant differences showing improvement in quality of life in the PVP group compared to the CT group.

In PVP the mechanism of pain relief remains unknown, this may possibly be achieved in at least 2 known ways, which were mechanical stabilization reduced microfractures of the site applied to nociceptive endings within the bone, also thermal necrosis or chemo toxicity of intraosseous pain receptors. [17,18]

Based on a previous study, injection of cement via PVP gave effective stabilization at the site of the vertebral fracture level and may relieve pain and improve daily activity. [6] Early mobilization may only be seen in the VP group rather than in the CT group.[19]

Early mobilization made the duration of bed rest much shorter than that in the CV group. Therefore, VP has greater potential to avoid various problems associated with prolonged bed rest, such as pneumonia, deep vein thrombosis, UTI, function of the musculoskeletal system, and progression of osteopenia. Also, usage of analgesics by the patients was less in the VP group compared to the CT group, resulting in a reduction rate of adverse effects. This maybe the reason that a better quality of life is seen in the PVP group than that in the CV group. With the improvement of pain relief and quality of life, PVP would be a better treatment of choice for the patients.

Adjacent vertebral fractures may cause acute and intense lumbar back pain, that will decrease the quality of life for osteoporotic patients. From our studies, we observed that the PVP group did not increase the incidence of adjacent vertebral fracture compared to the CT group. The possibility of this explanation may be caused by to associated number of vertebrae treated during VP procedure.

The main strength of our study is that we included updated and well-maintained studies that were designed as RCTs. More larger studies may also be needed to confirm the efficacy of PVP and CT for OVCF patients.

Conclusion

Summarizing our study, we conduct a systematic review and meta-analysis with evidence-based data comparing both groups (PVP and CT) in treating OVCF patients. Percutaneous vertebroplasty was found to be better in improving pain relief, and quality of life without giving an increased risk of adjacent vertebral fracture compared to the CT group. Hence, a further study is clearly required to identify which patients of OVCFs would likely get beneficial effects from PVP with low risk for complications.

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