

# The Philippine Journal of Orthopaedics

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## ORIGINAL ARTICLES

Pre-operative Neutrophil-Lymphocyte and Platelet-Lymphocyte Ratios as Predictors of Morbidity and Mortality in Diabetic Foot Infection Amputation Patients

Interprosthetic Joint Motion in Bipolar Partial Hip Arthroplasty after One-year Follow-up

Functional Outcomes of Patients with Ankylosed Elbow Managed with Fascia Lata Interposition Arthroplasty and Early Post-operative Active Motion Protocol: A Retrospective Study

Comparing Clinical Outcomes of Five-Strand Hamstring Tendon Autograft and Quadrupled Hamstring Tendon Autograft for Single Bundle Anterior Cruciate Ligament Reconstruction in Filipinos: An Ambi-directional Cohort Study

Outcomes of Patients with Tendinous Mallet Finger Injury Managed with DIPJ Extension Splinting vs Axial Pinning: A Descriptive Study

Non-invasive Removal of Tethered Surgical Drains Using Kirschner Wire with Ultrasound Guidance: An In-Vitro Experimental Study

Negative Pressure Wound Therapy versus Traditional Dressing in Posterior Spinal Surgery: A 10-year Retrospective Study

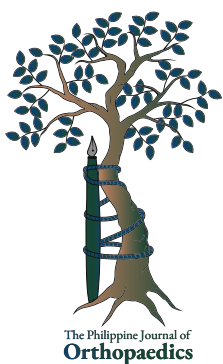
## SYSTEMATIC REVIEW

Meta-analysis of Randomized Controlled Trials: Comparing Standard versus Stump-preserving Techniques in Anterior Cruciate Ligament Reconstruction Using An Autologous Hamstring Graft

## CASE REPORTS

Management of a Polytrauma Patient with L4 Bony Fracture-Dislocation, Multi-Level L1-L3 Flexion-Distracton (Bony Chance) Injuries, Lateral Compression III Pelvic Injury, and Lower Extremity Fractures: A Case Report

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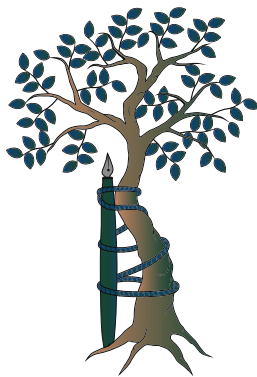
#### **ABOUT THE LOGO: THE TREE OF ANDRY**

Nicholas Andry coined the French term “orthopédie” which is derived from the Greek words “orthos” (correct or straight) and “paidion” (child). As implied in its etymology, “orthopédie” was first practiced treating childhood spinal and bone deformities.

The main elements of the logo are the tree of Andry; the Philippine Journal of Orthopaedics wordmark; and the fountain pen. The fountain pen, in replacement of the stake, represents how research has been the backbone of orthopaedic learning and practice.



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The **Philippine Journal of Orthopaedics**, the official journal of the **Philippine Orthopaedic Association, Inc.** is an open-access, English language, web-based, medical science journal published by the Association. The Journal is guided by the International Committee of Medical Journal Editors (ICMJE) **“Recommendations for the Conduct, Reporting, Editing, and Publication of Scholarly Work in Medical Journals.”**

The **Philippine Journal of Orthopaedics** shall advance the art and science of orthopaedics in the country by publishing high quality original clinical investigations, epidemiological studies, case reports, review articles, evaluations of diagnostic and surgical techniques, and the latest updates on management guidelines. The journal's target audience are local and international practitioners, clinicians, and other scientists, researchers. It shall accept manuscript submissions from consultants, fellows, residents, and other allied medical professions and specialties, not only from the Philippines but also from Asia and the rest of the world as long as these are within scope and relevant to the practice. Non-members of the Association may submit scientific manuscripts to the journal.



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Ever since the relaunch of the Philippine Journal of Orthopaedics in 2023, it has been with pride and joy that we present each and every publication. In 2023, we published one issue and in 2024 we were able to come up with two. For the year 2025 the PJO editorial board has decided to publish three! This is in line with the mission and vision of the Philippine Orthopaedic Association, which is to promote excellence in research.

In this edition there are seven interesting original articles, one systematic review, and two case reports. Submissions have been increasing and those selected are all worth reading.

We hope to publish more quality papers in the future and inspire more of our colleagues and residents to write and share their scientific findings with all of us. It is our duty as orthopedic surgeons to expand our knowledge and improve patient care.

We acknowledge the continued support of our sponsor, Uratex Philippines, in this worthwhile scientific endeavor.

Enjoy reading! We encourage you to let us know your opinions.

**Justinian Aquilino IV Cyril LI. Pimentel, MD, FPOA**

*President, Philippine Orthopaedic Association and ASEAN Orthopaedic Association*



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## Research Utilization in Clinical Practice



Research, when mentioned to the everyday clinician, has, in my observation, always evoked images of nerds in lab gowns tinkering with glassware or number-crunching geeks hunched over laptops or charts. The average orthopedic surgeon is strongly averse to it and may mention that they are not research-oriented, or that research is not their cup of tea. While it seems that only a few have been bitten by the research bug, everyone who practices medicine—and of course, orthopedics—should spare a moment to reflect on how every aspect of practice has been touched by research. Gone are the days when the medical practitioner relied on oral tradition and eminence-based pronouncements. Medicine is today the result of a billion steps—big and small—of medical research breakthroughs. From the discovery of penicillin to the development of the polio vaccine to computer-assisted orthopedic surgery to gene editing for sickle cell disease, many are the products of lab rats (real and metaphorical), clinicians and lateral thinkers—all in the name of research.

For those who think that the above examples are too esoteric to be relevant to clinic practice, let me cite a few examples of research whose impact is still felt today.

Wilhelm Röntgen discovered the x-ray in 1895<sup>1</sup> and won a Nobel Prize in Physics in 1902.<sup>2</sup> While a “plain” x-ray is considered a basic diagnostic tool that is taken for granted in modern orthopedic practice, I shudder to think what an orthopedist would do without it.

Dennis Smith<sup>3</sup> describes how he and John Charnley came up with the idea of using grout to fix the acetabular cup for a total hip replacement. This grout has since revolutionized the field of arthroplasty and beyond, under the misnomer bone cement.

Dr. Harold Kleinert demonstrated astute lateral thinking when he demonstrated that the key to successful flexor tendon repairs in zone 2 lay in early motion and hand therapy. The principles he laid forth in his controversial presentation at the ASSH convention back in 1967 are now the bedrock of flexor tendon repair of modern hand surgeons.<sup>4</sup>

Let me stop this stroll down history and bring us back to this volume of the Philippine Journal of Orthopaedics. In this edition, we present 10 articles for our clinicians to peruse and hopefully learn from. Will these create the same impact as the above examples? Maybe, maybe not; but I am confident that a careful study of these articles will give clinicians a chance to relate to the findings of our authors. After all, aren't lab gowns cousins to our white coats?

**Tammy L. Dela Rosa, MD, MMedSc**  
*Editor-in-Chief*

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## Pre-operative Neutrophil-Lymphocyte and Platelet-Lymphocyte Ratios as Predictors of Morbidity and Mortality in Diabetic Foot Infection Amputation Patients

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### ABSTRACT

**Background.** Diabetic foot infection is a complication of uncontrolled diabetes. Some cases require amputation to avoid the spread of infection; however, this can also lead to poor outcomes. Inflammatory markers, such as neutrophil-lymphocyte ratio (NLR) and platelet-lymphocyte ratio (PLR), have been explored as predictors of outcomes following amputation; however, only a few published studies are available.

**Objective.** The study aimed to determine the diagnostic value of pre-operative neutrophil-lymphocyte and platelet-lymphocyte ratios in predicting in-hospital morbidity and mortality among diabetic foot infection patients who underwent amputation in a tertiary government hospital.

**Methodology.** This retrospective cohort study included a total of 535 diabetic foot ulcer patients who underwent amputation at a tertiary government hospital. Data was collected via medical chart review. Complete blood count (CBC) parameters closest to the time of amputation were obtained to calculate the neutrophil-lymphocyte and platelet-lymphocyte ratios.

**Results.** Only 10.28% of patients experienced in-hospital morbidity and/or mortality. Based on Youden's index, the optimal cutoff points of neutrophil-lymphocyte and platelet-lymphocyte ratios were 7.27 and 32.40, respectively. Both markers showed 98% sensitivity in predicting the outcome. Specificity was 99% for the neutrophil-lymphocyte ratio and 93% for the platelet-lymphocyte ratio. Accuracy parameters remained high when morbidity and mortality were analyzed separately.

**Conclusion.** Neutrophil-lymphocyte and platelet-lymphocyte ratios accurately predict in-hospital morbidity and mortality among diabetic foot infection patients who underwent amputation. The low cost and wide availability of a CBC make NLR and PLR valuable options in low-resource settings. Future studies should explore these markers' utility in predicting long-term outcomes after amputation.

**Keywords.** neutrophil-lymphocyte ratio, platelet-lymphocyte ratio, diabetic foot infection, morbidity, mortality, re-operation

### INTRODUCTION

Diabetes mellitus (DM) is a chronic metabolic disease that remains a major public health concern worldwide. According to the World Health Organization (WHO), about 422 million people worldwide have diabetes.<sup>1</sup> In the Philippines, there were over 3,993,000 cases of diabetes in 2017, with a 6.3% prevalence of diabetes among adults.<sup>2</sup> The estimated prevalence of diabetes in adults aged 18 to 99 years was at approximately 9.3% and is predicted to rise to 10.9% by 2045.<sup>3</sup>

Foot infections are common in patients with diabetes. Lifetime incidence may be as high as 25% in all individuals with the diagnosis. They are more common in elderly patients with

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comorbidities. Males and females are affected equally.<sup>4,5</sup> In a tertiary government hospital, an average of 140 diabetic foot patients are admitted every year, of whom 50% undergo amputation.<sup>6</sup> One common long-term complication of poorly controlled diabetes is the development of diabetic foot ulcers secondary to neuropathy or angiopathy.<sup>7,8</sup> Foot ulcers are the leading cause of lower leg amputation among diabetic patients.<sup>9</sup> Furthermore, lower extremity amputation is one of the most feared outcomes as it is associated with a significantly higher 5-year mortality rate—2.5 times greater than that of a diabetic individual without foot ulcers.<sup>5,10</sup> Financial burden includes both direct and indirect costs, such as loss of earnings and burden on caregivers. Most amputations are progressive, meaning that the smallest possible amount of tissue is removed sequentially. Diabetic foot infection contributes to the global burden of disability and reduces patients' quality of life, making it a considerable public health problem.<sup>10</sup>

Neutrophil-lymphocyte ratio (NLR) and platelet-lymphocyte ratio (PLR) are useful novel biomarkers of systemic inflammation easily obtained from routine blood examinations. They are highly sensitive measures of inflammation in the fields of oncology, cardiology, nephrology, and autoimmune rheumatic diseases.<sup>11,12</sup> Recently, several studies have also reported their significance in predicting mortality in diabetic complications.<sup>13</sup> To date, local studies on NLR and PLR among diabetic foot infection patients are limited. Therefore, this study aims to be one of the first local studies to determine the diagnostic value of pre-operative NLR and PLR in predicting morbidity and mortality among diabetic foot infection patients who underwent amputation in a tertiary government hospital.

Many inflammatory markers have been linked to DM complications such as diabetic nephropathy. These include interleukin (IL)1, IL6, IL8, transforming growth factor beta 1 (TGF- $\beta$ 1), and tumor necrosis factor-alpha (TNF  $\alpha$ ), which are not routinely performed due to their complexity. As a result, NLR and PLR have emerged as novel surrogate markers and predictors of morbidity and/or mortality among diabetic patients with micro and macrovascular complications. Hence, this study aimed to determine whether NLR and PLR can predict the clinical outcomes of patients with diabetic foot ulcers who underwent amputation.

## METHODOLOGY

This study employed an analytic retrospective cohort study design. The participants were diabetic foot ulcer patients who underwent amputation at Jose R. Reyes Memorial Medical Center from January 2015 to January 2022. A simple random sampling design was used to select study participants. Open Epi Random Number Generator was used to generate random numbers.

Data were collected via medical chart review from January 2022 to January 2023.

## Inclusion criteria

- Age >18 years
- Pay and service patients
- Diagnosed with Type 2 Diabetes Mellitus
- Presented with diabetic foot ulcer on hospital admission and classified as Wagner 3 to 5
- Underwent lower extremity amputation (toe disarticulation, Ray amputation, Lisfranc amputation, Chopart amputation, Syme amputation, below-the-knee amputation, knee disarticulation, above-the-knee amputation, and hip disarticulation)

## Exclusion criteria

- Patients discharged against medical advice
- Outpatient department patients
- Patients with end-stage renal disease, severe pulmonary and liver disease, cerebrovascular disease, and cancer

Power Analysis and Sample Size (PASS) 15 software was used to calculate the minimum sample size required. Parameters were derived from a previously published study.<sup>13</sup> The sample size was computed separately for NLR and PLR:

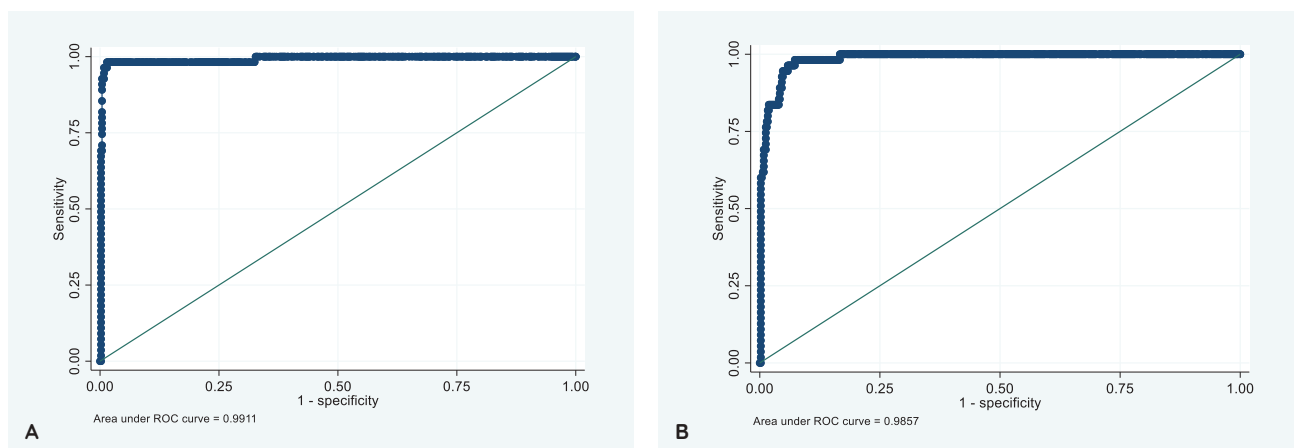
	Parameters	Sample size
<b>NLR</b>	OR = 5.43 Power = 80% Alpha = 0.05	233
<b>PLR</b>	OR = 3.08 Power = 80% Alpha = 0.05	533

The largest computed sample size, equal to 533, was used as the minimum sample size requirement for this study to achieve 80% statistical power.

Before study implementation, the researcher sought clearance from the hospital's Technical Review Committee and Institutional Ethics Review Board and permission from the Medical Records section.

Data from medical charts were recorded in a Data Abstraction Form from January 2022 to January 2023. The following variables were collected: demographic and clinical profiles, disease duration, comorbidities, smoking and alcohol status, laboratory results such as pre-operative complete blood count, FBS, HbA1c, ulcer classification, level of amputation, estimated intraoperative blood loss, and incidence of morbidity and mortality.

Data were encoded in MS Excel. Stata MP version 17 software was used for data processing and analysis. Continuous data were presented as interquartile range/IQR due to non-normal data distribution based on Shapiro Wilk's test and were analyzed using the Mann-Whitney U test. Categorical data were presented as frequency and percentage and were analyzed using the Chi-square test and Fisher's exact test.



**Figure 1.** ROC curve in predicting in-hospital morbidity/mortality: (A) NLR and (B) PLR.

Optimal cutoff points of NLR and PLR were determined based on Youden's index. Discriminative ability was based on the Area Under the Curve (AUC) of the Receiver Operating Characteristic (ROC) curve and interpreted as follows: 0.50 (no discrimination), 0.51–0.69 (poor), 0.70–0.80 (acceptable), 0.81–0.90 (excellent), and >0.90 (outstanding).<sup>14</sup> Two by two (2 x 2) tables were constructed, and the following diagnostic value parameters were calculated: accuracy, sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and likelihood ratios (LR).

The association of NLR and PLR (based on cutoff points) with morbidity and/or mortality was determined using logistic regression analysis. Simple logistic regression was used to identify potential confounding variables, with a cutoff of  $p < 0.20$ .<sup>14</sup> Potential confounders were entered into the full model and multiple logistic regression was performed. Model building was based on the change-in-estimate (CIE) criterion of 10%.  $P$  values  $\leq 0.05$  were considered statistically significant.

## RESULTS

A total of 535 diabetic foot infection patients who underwent amputation were included in the study, of whom 55 patients developed the outcome of interest (i.e., in-hospital morbidity and/or mortality). The incidence was 10.28% (95% CI: 7.97–13.16%). When the outcomes were analyzed separately, in-hospital morbidity was 6.17% (95% CI: 4.28–8.55%). The specific morbidities were post-surgery infection or wound complication ( $n = 15$ , 45%), need for re-amputation ( $n = 12$ , 36%), and hospital-acquired pneumonia ( $n = 6$ , 18%). Meanwhile, the incidence of in-hospital mortality was 4.67% (95% CI: 3.17–6.83%), and the median time to death was 3 days (IQR: 0–10; range: 0–51 days). Sixteen out of 25 deaths (64%) occurred within seven days post-amputation. Among survivors, the median length of stay from the date of amputation was eight days (IQR: 4–15; Range: 0–136 days). Among those who died, the median time to death from the date of amputation was three days (IQR: 0–10; Range: 0–51 days).

The median age was 57 years old (range: 25–89 years old), and most patients were male. About one-third of the patients had a normal BMI, and the median disease duration was 5 years (range: 1–50 years). The most common comorbidity was hypertension affecting about one-third of the patients. Most patients were non-smokers, had never consumed alcohol, and had low hemoglobin, high FBS, and high HbA1c levels. Most patients were classified as Wagner 4, and more than half underwent minor amputation. The most common specific levels of amputation were ray amputation (37%) and below-knee amputation (39%). Only five patients (1%) underwent bilateral amputation. The median NLR was 4.1 (range: 0.3–40.4) and the median PLR was 20 (range: 3.2–163.9).

A higher proportion of patients with morbidity or mortality were female, had hypertension, had kidney disease, and underwent above-knee amputation. The NLR, PLR, and median intraoperative blood loss were also significantly higher in patients with morbidity and mortality. In addition, the median hemoglobin level was significantly lower for overall outcome, but not when morbidity and mortality were analyzed separately.

The receiver operating characteristic (ROC) curves for both NLR and PLR showed outstanding discriminative ability in predicting in-hospital morbidity and/or mortality (Table 1). Based on Youden's index, the optimal cutoff points for NLR and PLR are presented in Table 2.

The discriminative ability of NLR was outstanding (Table 3). NLR also showed very high accuracy, sensitivity, specificity, and NPV when morbidity and mortality were analyzed separately (Table 4).

Likewise, PLR had outstanding discriminative ability (Table 5). PLR also showed high accuracy, sensitivity, specificity, and NPV when morbidity and mortality were analyzed separately (Table 6).

Subgroup analysis was also performed between patients who underwent major and minor amputations (Table 7).

**Table 1.** Demographic and clinical profile of diabetic foot infection patients who underwent amputation (n = 535)

	All patients (n = 535), n (%)	In-hospital morbidity/ mortality		P-value
		YES (n = 55), n (%)	NO (n = 480), n (%)	
<b>Age (in years), median</b>	57 [IQR: 50-64]	59 [IQR: 51-62]	57 [IQR: 50-64]	0.9555 <sup>a</sup>
<b>Sex</b>				
Male	338 (63)	27 (49)	311 (65)	0.022 <sup>ab</sup>
Female	197 (37)	28 (51)	169 (35)	
<b>Weight (in kg), median</b>	60 [IQR: 55-65]	60 [IQR: 55-65]	60 [IQR: 55-65.5]	0.5714 <sup>a</sup>
<b>Height (in cm), median</b>	160 [IQR: 157-165]	160 [IQR: 154-165]	160 [IQR: 157-166]	0.2241 <sup>a</sup>
<b>BMI (in kg/m<sup>2</sup>), median</b>	23.4 [IQR: 22-25]	23.4 [IQR: 21.4-25.4]	23.4 [IQR: 22-25]	0.9101 <sup>a</sup>
Normal	181 (34)	18 (33)	163 (34)	0.822 <sup>c</sup>
Underweight	19 (4)	3 (5)	16 (3)	
Overweight	202 (38)	19 (35)	183 (38)	
Pre-obese	109 (20)	12 (22)	97 (20)	
Obese	24 (4)	3 (5)	21 (4)	
<b>Disease duration (in years), median</b>	5 [IQR: 2-10]	5 [IQR: 2-10]	5 [IQR: 2-10]	0.7878 <sup>a</sup>
<b>Co-morbidities, %yes</b>				
Hypertension	184 (34)	28 (51)	156 (33)	0.006 <sup>ab</sup>
Kidney disease	54 (10)	10 (18)	44 (9)	0.036 <sup>ab</sup>
Heart disease	26 (5)	2 (4)	24 (5)	1.000 <sup>c</sup>
Vascular disease	35 (7)	7 (13)	28 (6)	0.076 <sup>c</sup>
Active skin infections	8 (2)	1 (2)	7 (1)	0.583 <sup>c</sup>
Anemia	19 (4)	2 (4)	17 (4)	1.000 <sup>c</sup>
Pneumonia	15 (3)	1 (2)	14 (3)	1.000 <sup>c</sup>
Pulmonary tuberculosis	10 (2)	1 (2)	9 (2)	1.0000 <sup>c</sup>
COVID-19	6 (1)	1 (2)	5 (1)	0.480 <sup>c</sup>
Others	10 (2)	2 (4)	8 (2)	0.274 <sup>c</sup>
<b>Smoking status</b>				
Non-smoker	348 (65)	37 (67)	311 (65)	0.741 <sup>b</sup>
Current smoker	121 (23)	13 (24)	108 (22)	
Past smoker	66 (12)	5 (9)	61 (13)	
<b>Alcohol consumption</b>				
Never consumed alcohol	314 (59)	33 (60)	281 (59)	0.195 <sup>b</sup>
Frequent drinker	43 (8)	7 (13)	36 (7)	
Occasional drinker	128 (23)	8 (14)	120 (25)	
Past drinker	50 (9)	7 (13)	43 (9)	
<b>Hemoglobin level (g/dL), median</b>	10.7 [IQR: 9.9-11.6]	10.3 [IQR: 9.5-11]	10.7 [IQR: 10-11.6]	0.0137 <sup>aa</sup>
Normal	81 (15)	5 (9)	76 (16)	0.306 <sup>c</sup>
Low	442 (83)	50 (91)	392 (82)	
High	9 (2)	0	9 (2)	
<b>FBS level (in mmol/L), median</b>	7.5 [IQR: 5.8-9.7]	8 [IQR: 6.3-10.8]	7.4 [IQR: 5.8-9.5]	0.0897 <sup>a</sup>
Normal	132 (25)	10 (18)	122 (25)	0.310 <sup>c</sup>
Low	11 (2)	0	11 (2)	
High	392 (73)	45 (82)	347 (72)	
<b>HbA1C level (in %), median</b>	8.6 [IQR: 7-10.9]	9.2 [IQR: 7.2-11.8]	8.5 [IQR: 6.9-10.8]	0.1621 <sup>a</sup>
Normal	37 (7)	6 (11)	31 (6)	0.255 <sup>c</sup>
High	498 (93)	49 (89)	449 (94)	
<b>Wagner classification</b>				
Wagner 3	160 (30)	10 (18)	150 (31)	0.122 <sup>b</sup>
Wagner 4	324 (61)	38 (69)	286 (60)	
Wagner 5	51 (10)	7 (13)	44 (9)	
<b>Level of amputation</b>				
Major	297 (56)	28 (51)	269 (56)	0.468 <sup>b</sup>
Minor	238 (44)	27 (49)	211 (44)	

**Table 1.** Demographic and clinical profile of diabetic foot infection patients who underwent amputation (n = 535) (continued)

	All patients (n = 535), n (%)	In-hospital morbidity/ mortality		P-value
		YES (n = 55), n (%)	NO (n = 480), n (%)	
<b>Specific level of amputation. % yes</b>				
Toe Disarticulation	92 (17)	10 (18)	82 (17)	0.838 <sup>b</sup>
Ray Amputation	197 (37)	17 (31)	180 (38)	0.337 <sup>b</sup>
Lisfranc Amputation	1 (1)	0	11 (1)	1.000 <sup>c</sup>
Chopart Amputation	1 (1)	0	1 (1)	1.000 <sup>c</sup>
Syme Amputation	9 (2)	1 (2)	8 (2)	1.000 <sup>c</sup>
Below the knee Amputation	211 (39)	21 (38)	190 (40)	0.840 <sup>b</sup>
Knee Disarticulation	0	0	0	-
Above the knee amputation	26 (5)	6 (11)	20 (4)	0.041 <sup>c</sup>
Hip Disarticulation	1 (1)	0	1 (1)	1.000 <sup>c</sup>
<b>Laterality</b>				
Unilateral	530 (99)	54 (98)	476 (99)	0.420 <sup>c</sup>
Bilateral	5 (1)	1 (2)	4 (1)	
<b>Estimated blood loss intra-op (in ml). median</b>				
NLR, median	200 [IQR: 100-300]	250 [IQR: 100-500]	160 [IQR: 100-300]	0.0165*
PLR, median	4.1 [IQR: 2.5-5.8]	9.3 [IQR: 8-13.2]	3.8 [IQR: 2.4-5.2]	<0.00001 <sup>a</sup>
	20 [IQR: 13.3-29.1]	44.4 [IQR: 38.1-60.1]	18.6 [IQR: 12.7-25.7]	<0.00001 <sup>a</sup>

<sup>a</sup>Mann Whitney U test was used; <sup>b</sup>Chi square test was used; <sup>c</sup>Fisher's Exact test was used.

**Table 2.** Optimal cutoff point of NLR and PLR based on Youden's index

	Cut-off point
NLR	>7.27
PLR	>32.40

**Table 3.** Diagnostic value of NLR in predicting in-hospital morbidity/mortality

	In-hospital morbidity/mortality		Total
	Yes	No	
NLR >7.27	54	7	61
NLR ≤7.27	1	473	474
Total	55	480	535
AUC (95% CI)	0.98 (0.97-1.00)		
Accuracy	98.50%		
Sensitivity	98.18%		
Specificity	98.54%		
Positive predictive value	88.52%		
Negative predictive value	99.79%		
Likelihood ratio +	67		
Likelihood ratio -	0.02		

**Table 4.** Diagnostic value of NLR in predicting in-hospital morbidity and mortality

	In-hospital mortality	In-hospital morbidity
AUC (95% CI)	0.96 (0.95-0.98)	0.96 (0.92-0.99)
Accuracy	93.27%	94.39%
Sensitivity	100%	96.97%
Specificity	92.94%	94.22%
Positive Predictive Value	40.98%	52.46%
Negative Predictive Value	100%	99.79%
Likelihood Ratio +	14.17	16.79
Likelihood Ratio -	0	0.03

**Table 5.** Diagnostic value of PLR in predicting in-hospital morbidity/mortality

	In-hospital morbidity/mortality		Total
	Yes	No	
PLR >32.40	54	35	89
PLR ≤32.40	1	445	446
Total	55	480	535
AUC (95% CI)	0.95 (0.93-0.98)		
Accuracy	93.27%		
Sensitivity	98.18%		
Specificity	92.71%		
Positive predictive value	88.52%		
Negative predictive value	99.79%		
Likelihood ratio +	13.46		
Likelihood ratio -	0.02		

**Table 6.** Diagnostic value of PLR in predicting in-hospital morbidity and mortality

	In-hospital mortality	In-hospital morbidity
AUC (95% CI)	0.94 (0.92-0.95)	0.93 (0.90-0.96)
Accuracy	88.04%	89.16%
Sensitivity	100%	96.97%
Specificity	87.45%	88.65%
Positive Predictive Value	28.09%	35.96%
Negative Predictive Value	100%	99.78%
Likelihood Ratio +	7.97	8.54
Likelihood Ratio -	0	0.03

**Table 7.** Diagnostic value of NLR and PLR in predicting in-hospital morbidity and mortality: major versus minor amputation<sup>a</sup>

	Major amputation (n = 238)		Minor amputation (n = 297)	
	NLR	PLR	NLR	PLR
<b>AUC (95% CI)</b>	1.00 (0.99–1.00)	0.95 (0.92–0.97)	0.97 (0.94–1.00)	0.96 (0.92–1.00)
<b>Accuracy</b>	99.16%	90.34%	97.98%	95.62%
<b>Sensitivity</b>	100%	100%	96.43%	96.43%
<b>Specificity</b>	99.05%	89.10%	98.14%	95.62%
<b>Positive Predictive Value</b>	93.10%	54%	84.38%	69.23%
<b>Negative Predictive Value</b>	100%	100%	99.62%	99.61%
<b>Likelihood Ratio +</b>	105.50	9.17	51.88	21.62
<b>Likelihood Ratio -</b>	0	0	0.04	0.04

**Table 8.** Association between NLR or PLR, and in-hospital morbidity or mortality (n = 535)

	Crude OR (95% CI)	P value	Adjusted OR (95% CI)	P value
<b>NLR</b>				
≤7.27	Ref	Ref	Ref	Ref
>7.27	2293.85 (388.64–13538.67)	<0.0001*	22797.51 (157.83–3292895)	<0.0001 <sup>a</sup>
<b>PLR</b>				
≤32.40	Ref	Ref	Ref	Ref
>32.40	455.96 (86.89–2392.75)	<0.0001*	320.14 (62.69–1634.81)	<0.0001 <sup>b</sup>

<sup>a</sup> Adjusted for the confounding effects of sex, hypertension, kidney disease, vascular disease, alcohol consumption, hemoglobin, FBS, HbA1c, Wagner classification, AKA, blood loss

<sup>b</sup> Adjusted for the confounding effects of hypertension, kidney disease, vascular disease, alcohol consumption, hemoglobin, FBS, blood loss

All parameters remained high in both groups. In addition, a perfect sensitivity in predicting in-hospital morbidity and mortality was obtained for both NLR and PLR among those who underwent major amputation.

Univariable analysis using simple logistic regression was performed to identify potential confounders (Appendices D and E). Using the established cutoffs, both NLR and PLR were significantly associated with in-hospital morbidity or mortality even when controlled for the effect of significant confounders (Table 8).

## DISCUSSION

A diabetic foot ulcer is one of the most dreaded complications of uncontrolled diabetes, given its impact on quality of life and the heightened risks of morbidity and mortality.<sup>15–17</sup> In some cases, amputation is necessary to avoid the spread of infection and prevent further tissue damage; however, amputation is also associated with poor patient outcomes. In recent years, few studies have explored the utility of inflammatory markers in predicting patient prognosis among individuals with diabetic foot ulcers, but most have focused on mortality. To the best of the researchers' knowledge, this is the first local study that examined the accuracy of NLR and PLR in predicting both in-hospital morbidity and mortality among diabetic foot infection patients who underwent amputation.

In-hospital mortality in the present study was 4.67%, comparable to published studies.<sup>18–20</sup> Meanwhile, studies reported one-month mortality estimates that ranged from

11 to 18%,<sup>20–22</sup> which rose with longer follow-up periods. Very few studies, however, examined the morbidity rate after amputation. In a study conducted in Tunisia, the morbidity rate after amputation was 9.5%, slightly higher than the present study, where only 6.17% developed complications.<sup>18</sup> Furthermore, out of the 535 patients in this study, 15 (3%) had wound complications, 12 (2%) required re-amputation, and 6 (1%) had hospital-acquired pneumonia. These estimates were lower compared to previous studies. In a Tunisian study, 8% had wound complications, while 5% required re-amputation. Meanwhile, in a local study conducted in PGH, 12% had hospital-acquired pneumonia.<sup>20</sup> Despite its rarity, in-hospital morbidity has been associated with higher mortality rates; thus, identifying patients at risk for these poor outcomes is warranted.<sup>18,20</sup>

Because of the expected low number of events, the authors created a composite measure for poor outcomes, defined as in-hospital morbidity and/or mortality. In this study, only 10.28% of patients had the outcome of interest, and those with the outcome exhibited higher NLR and PLR values than those without the outcome. Furthermore, the association of these markers remained statistically significant even when controlled for the effects of confounders. The study results were consistent with those of other studies, which reported that NLR and PLR are significantly associated with poorer patient outcomes after amputation.<sup>23</sup>

The role of these inflammatory markers in predicting patient prognosis has been recognized in various medical and surgical conditions. As markers of systemic inflammation, high levels

may indicate ongoing tissue damage, microangiopathy, and microvascular complications among diabetic patients, which may result in end-organ damage.<sup>24-26</sup> The increased release of neutrophils may lead to endothelial damage, while an increase in platelets heightens the release of inflammatory mediators and may lead to thrombosis and cardiac problems.<sup>27-29</sup> Meanwhile, lymphocytes decrease due to increased apoptosis of these cells during a heightened inflammatory process. These series of events then lead to poorer postoperative outcomes, including death.<sup>13,23</sup>

The present study also examined the validity of pre-operative NLR and PLR in predicting outcomes. Using a cutoff of 7.27, NLR showed high accuracy, sensitivity, and specificity levels in predicting in-hospital morbidity and/or mortality. Most studies focused only on mortality as the outcome. In this study, NLR still showed high accuracy measures—100% sensitivity and 93% specificity in predicting in-hospital mortality.

Previous studies utilized a lower cutoff and exhibited lower sensitivity and specificity. In a study done in Turkey among major amputation patients, a cutoff of 6.37 showed 93% sensitivity but only 52% specificity.<sup>30</sup> Another study from Turkey used a cutoff of 6.80 and yielded a sensitivity of 83% and specificity of 66%.<sup>31</sup> Other studies that used postoperative NLR also exhibited poorer diagnostic performance.<sup>13,23</sup>

Although PLR was found to be an independent predictor of mortality by previous studies, its diagnostic performance was poorer than NLR. A study from Turkey used a cutoff of 247.28 for pre-operative PLR, which showed poor discriminative ability (AUC = 0.55) with 51% sensitivity, and 64% specificity.<sup>23</sup> Postoperative PLR also showed poor performance in published studies with sensitivity ranging from 73–74% and specificity of 44–47%.<sup>13,30</sup> In contrast, the present study proved that pre-operative PLR >32.40 was an excellent measure to predict in-hospital morbidity and/or mortality. Furthermore, PLR showed 100% sensitivity and 87% specificity when focused on mortality alone.

In this study, several patient characteristics were also found to be associated with in-hospital morbidity and/or mortality, which warrants further examination in future studies. For instance, the present study showed that females were more likely to develop the outcome than males, consistent with other studies.<sup>18,21,31,32</sup> Women are more likely to have cardiovascular complications due to diabetes than men, possibly explaining the higher probability of death among females.<sup>33</sup> In addition, one study concluded that females have poorer health status at the time of amputation since they are more likely to delay the procedure than males.<sup>34</sup>

Based on the univariable analysis, hypertension, kidney disease, and vascular disease were all significantly associated with the outcome of interest. In a study done in Tunisia, complications and death were more likely to occur in patients with hypertension than those without hypertension.<sup>18</sup>

Previous studies also observed higher mortality among patients with renal impairment, including increased BUN and creatinine, and decreased eGFR.<sup>13,20,32,35,36</sup> Aside from diabetes, comorbidities increase the likelihood of poorer outcomes. Vascular disease, especially peripheral artery disease, is a known risk factor for poor patient outcomes.<sup>37,38</sup> Renal impairment may also enhance cardiovascular risk factors, including hypertension, insulin resistance, oxidative stress, endothelial dysfunction, and inflammation which may result in poorer postoperative outcomes.<sup>39</sup> These comorbidities likely contribute to elevating inflammatory markers.<sup>40</sup>

Patients who developed the outcome also had lower hemoglobin levels and higher intraoperative blood loss. In a previous study from Brazil, the authors concluded that lower hemoglobin level was associated with mortality among those who underwent amputation.<sup>41</sup> Similar to a local study, patients who underwent intraoperative blood transfusion had higher mortality rates.<sup>20</sup>

Across all specific amputation levels, only above-knee amputation was significantly associated with a higher probability of the outcome, similar to previous studies.<sup>20,41</sup> However, Gocer et al. argued that mortality is not really due to the level of amputation. Instead, a higher level of amputation is a marker of the overall progression of the disease; thus, worse outcomes are expected from these patients.

One of the strengths of this study is its large population of diabetic patients who underwent amputation. The present study provides valuable evidence regarding the role of NLR and PLR in predicting patient postoperative outcomes. Most studies have focused only on major amputations and mortality outcomes.

The study has several limitations. First, the main outcomes of this study were in-hospital morbidity and mortality. However, as a government hospital, the length of hospital stay may have been affected by various factors (i.e., financial constraints), which then affected the detection of in-hospital morbidity and mortality. Moreover, mortality is known to increase over time after amputation;<sup>22,36</sup> It will also be worth examining if the inflammatory markers can predict long-term outcomes. Second, the study included patients from a single setting; therefore, the results have limited generalizability. The characteristics and outcomes of patients admitted to a tertiary government hospital may differ from those in other institutions. Third, NLR and PLR were computed based on the CBC result closest before the time of amputation. Although CBC collection is usually done within a week of the surgery, the variation in the timing of blood collection could have affected the study results. Lastly, due to the retrospective nature of this study, only routinely collected data were included in the analysis. An extensive literature review was performed to identify potential confounders, but not all could be controlled if they were not recorded in the charts. Residual confounding is, therefore, possible.

## CONCLUSION

The rate of in-hospital morbidity and/or mortality was 10.28% among diabetic foot infection patients who underwent amputation in the chosen institution. Both NLR and PLR performed well in predicting in-hospital morbidity and mortality, demonstrating high discriminative ability, sensitivity, and specificity, even when major and minor amputations were analyzed separately. These markers are inexpensive and easily obtainable; thus, they are particularly helpful and useful, especially in low-resource settings. Future studies should explore the utility of these markers in predicting long-term outcomes after amputation or in predicting standardized assessments of outcomes at specific time points (e.g., 30-day morbidity and mortality), as the length of hospital stay can vary greatly between patients.

## STATEMENT OF AUTHORSHIP

Both authors certified fulfillment of ICMJE authorship criteria.

## AUTHOR DISCLOSURE

Both authors declared no conflict of interest.

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## Interprosthetic Joint Motion in Bipolar Partial Hip Arthroplasty after One-year Follow-up

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### ABSTRACT

**Background.** Partial hip arthroplasty is the treatment of choice for displaced proximal femoral fractures in the elderly. The bipolar prosthesis was developed to lessen the acetabular erosion encountered with the unipolar prosthesis. However, bipolar prostheses lose their motion between the inner or outer articulation (interprosthetic joint motion) after three months, rendering them biomechanically like unipolar prostheses. Meanwhile, other literature has shown that the interprosthetic joint is mobile radiographically up to one year after the surgery.

**Objective.** This study evaluated and quantified the interprosthetic joint motion (motion between the outer and inner articulations) of bipolar prostheses one year after partial hip arthroplasty for proximal femoral fractures in a tertiary hospital. We also investigated the effect of adding the hip measurement in adduction.

**Methodology.** This retrospective cohort study measured the motion of the outer and inner articulations of locally available bipolar prostheses and the interprosthetic joint movement using one-year postoperative radiographs of patients who underwent bipolar partial hip arthroplasty for femoral fractures in a tertiary hospital from 2019 to 2021. Immediate and one-year post-operative AP radiographs in neutral, maximum hip abduction, and maximum hip adduction were measured and compared. The interprosthetic joint motion was calculated from the difference in pelvic-head angles and pelvic-shaft angles.

**Results.** Twelve patients were included in the study. The interprosthetic joint in bipolar prosthesis was still mobile even after one year in 75% of patients ( $p = 0.0001$ ). Adding hip adduction measurements resulted in a significantly higher mean of 74.69 degrees as compared to only 34.67 degrees ( $p = 0.0006$ ).

**Conclusion.** Most patients retained a mobile interprosthetic joint at one year post-op. Hip adduction radiographs gave additional information on the total interprosthetic joint motion. At both time points studied, the inner head articulation contributed more to the interprosthetic joint motion. All five locally available implant systems used showed good motion after one year.

**Keywords.** partial hip arthroplasty, hemiarthroplasty, femoral neck fracture, hip fracture, interprosthetic joint motion, bipolar prosthesis

### INTRODUCTION

Partial hip arthroplasty is the treatment of choice for completely displaced femoral neck fractures and special cases of intertrochanteric fractures in elderly patients. James Bateman developed a bipolar prosthesis in 1974 to solve issues that arose with the unipolar prosthesis.<sup>1</sup> The bipolar prosthesis is a modular system with two articulations and a moveable intermediate shell between the head of the femoral prosthesis and the acetabulum. This allows motion to occur between the articulations, lessening shear stresses between the metal shell on the acetabulum, decreasing erosion, and avoiding protrusion.<sup>2-4</sup> This has been demonstrated radiographically by Bochner et al. and others.<sup>5,6</sup>

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Randomized control studies and observational studies showed conflicting outcomes between the two prostheses.<sup>7-9</sup> The bipolar prosthesis has been reported to either result in fewer dislocations, better hip range of motion, and improved quality of life,<sup>2,10-16</sup> or have no significant effect, in addition to yielding similar pain scores, functional hip scores, acetabular erosion incidence, and reoperation rate.<sup>17</sup> The bipolar prosthesis has been reported to lose motion at either the inner or outer articulation, behaving like a unipolar prosthesis by three months postoperatively.<sup>18-20</sup> This may selectively occur depending on the size of the outer femoral head and the duration of follow-up.<sup>21</sup>

**OBJECTIVE**

This study aimed to radiographically evaluate the motion of the outer and inner articulations of the locally available bipolar prosthesis and quantify the interprosthetic joint movement using radiographs over a one-year follow-up period in patients who underwent partial hip arthroplasty for proximal femoral fractures in a tertiary hospital. This study included a new measurement: maximum hip adduction.

**METHODOLOGY**

**Research design**

This retrospective cohort study monitored the motion of the outer and inner articulations of the locally available bipolar prosthesis and the interprosthetic joint movement using radiographs over a one-year follow-up period in patients who underwent bipolar partial hip arthroplasty for proximal femoral fractures in a tertiary hospital from 2019 to 2021.

**Data collection methods**

Routine immediate and one-year post-operative hip radiographs were taken in supine anteroposterior (AP) views in neutral, maximum hip abduction, and maximum hip adduction. True neutral AP views were taken with both legs 15 degrees internally rotated. Maximum hip abduction views were taken with the maximum tolerated abduction done by the patient. Maximum hip adduction views, not included in Bochner’s original study, were taken with the maximum tolerated adduction done by the patient. All radiographic images used a computerized radiography system and were stored digitally in the Picture Archiving and Communication System (PACS). Consent was secured from the chairman of the Department of Radiology of the involved tertiary hospital and the chairman of the orthopaedic specialty clinic before accessing the images digitally.

Data was encoded using Microsoft Excel on a password-encrypted computer accessed only by the primary investigator. All measurements and encoding was done by the primary investigator.

**Outcome**

Interprosthetic joint motion in bipolar partial hip arthroplasty was assessed radiologically as originally described by Bochner.<sup>6</sup> Measurements were taken from hip AP radiographic views in neutral, maximum hip abduction, and maximum hip adduction.

The pelvic-head angle was the angle formed between the pelvic line and a line drawn along the center of the long axis of the femoral stem. The pelvic-shaft angle was the angle formed between the pelvic line (drawn tangential to the inferior margin of the ischial tuberosities) and a line drawn tangential to the inferior margin of the outer head. Angle A was the difference in the pelvic-head angle between the hip AP neutral (A1) and maximum hip abduction (A2) radiographs. Angle B was the difference in the pelvic-shaft angle between the hip AP neutral (B1) and maximum hip abduction (B2) radiographs. Angle C was the difference in the pelvic-head angle between the hip AP neutral and maximum hip adduction (B1) radiographs. Angle D was the difference in the pelvic-shaft angle between the hip AP neutral and maximum hip adduction (B3) radiographs (Figures 1, 2 & 3).

Interprosthetic motion in abduction (X) was calculated as the difference between Angle A and B. Interprosthetic motion in adduction (Y) was calculated as the difference between Angles C and D. The total interprosthetic joint motion (W) was the sum of X and Y.<sup>22</sup>

Angles A & C (AC) pertained to the total motion contributed by the outer head articulating with the acetabulum. Angles B & D (BD) pertained to the total motion of the prosthesis relative to the acetabulum (Figures 1, 2 & 3). The % interprosthetic motion (W%) was calculated as  $W \div \text{Angle BD}$ , representing the contribution of the inner head articulating with the outer shell to total prosthetic motion.

Measurement	Calculation	Interpretation
Angle A	A1-A2	outer shell motion in abduction
Angle B	B1-B2	shaft motion in abduction
Angle C	A1-A3	outer shell motion in adduction
Angle D	B1-B3	shaft motion in adduction
X	B-A	interprosthetic motion in abduction
Y	C-D	interprosthetic motion in adduction
W	X + Y	total interprosthetic motion
Angle AC	A + C	total outer shell motion relative to the pelvis
Angle BD	B + D	total shaft and prosthetic motion relative to the pelvis
W%	$W \div \text{Angle BD}$	the proportion of interprosthetic motion of total prosthetic motion or % interprosthetic motion

**Sample size**

The study included 12 patients. At a 95% confidence level and an 80% test power, the minimum detectable difference at one year was set at 30%.

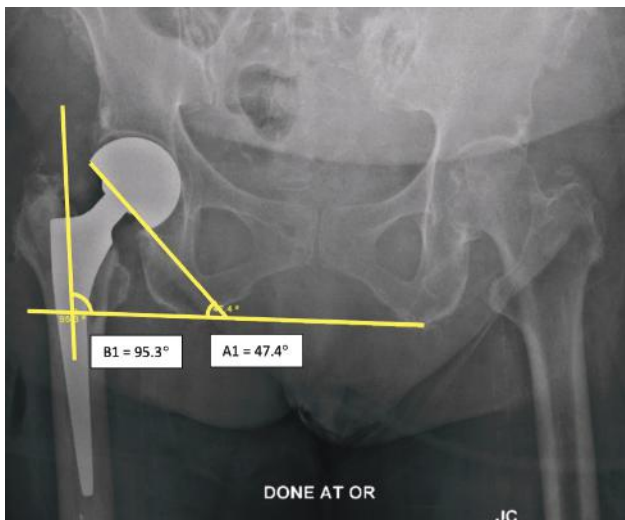


Figure 1. Hip neutral AP x-ray.

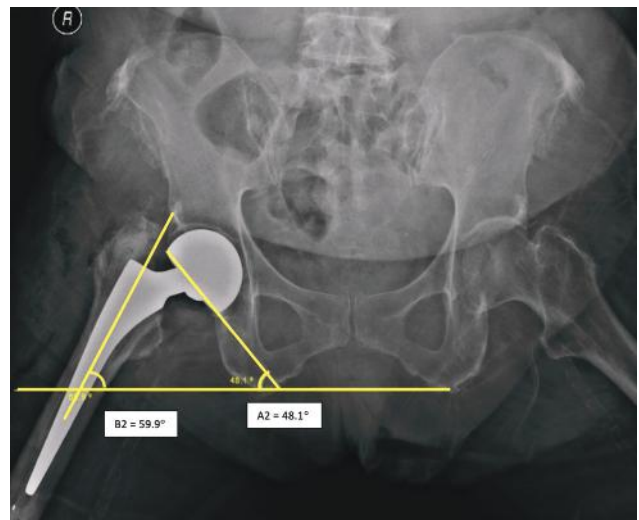


Figure 2. Hip maximum abduction AP x-ray.

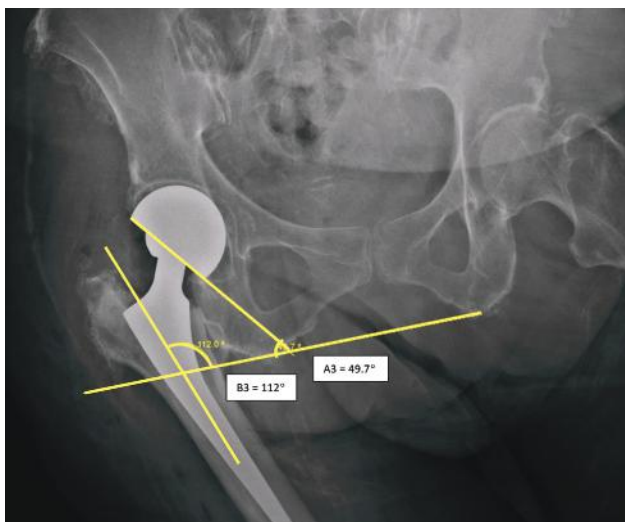


Figure 3. Hip maximum adduction AP x-ray.

In Figure 1, the Pelvic-head angle (A1) is 47.4° and the Pelvic-shaft angle (B1) is 95.3°. In Figure 2, the Pelvic-head angle (A2) is 48.1° and the Pelvic-shaft angle (B2) is 59.9°. In Figure 3, the Pelvic-head angle (A3) is 49.7° and the Pelvic-shaft angle (B3) is 112°. Angle A = 0.7°, difference between A1 and A2. Angle B = 35.4°, difference between B1 and B2. Angle C = 2.3°, difference between A1 and A3. Angle D = 16.7°, difference between B1 and B3. Angle BD is 52.1°. The interprosthetic joint motion in abduction (X) is 34.7°. The interprosthetic joint motion in adduction (Y) is 14.4°. The total interprosthetic joint motion (W) is 49.1° which is 94% of 62.1°. These radiographs were taken from actual patients of the co-author; this specific patient was not included in the study.

## Statistical analysis

Data were encoded in Microsoft Excel, and then edited and analyzed using STATA15. Categorical data were presented in frequencies and percentages, and compared using Paired Student's T-test and McNemar's Test. The rate of interprosthetic joint motion was presented using means and standard deviations. A z-test was used to compare the proportion of patients with bipolar motion to those with unipolar motion at one year post-operatively.

## Ethical considerations

The study adhered to the ethical considerations and principles set out in relevant guidelines, including the Declaration of Helsinki, WHO guidelines, International Conference on Harmonization-Good Clinical Practice, and National Ethics Guidelines for Health Research.

This study was reviewed and approved by the Makati Medical Center Institutional Review Board (IRB). The IRB also stated that no informed consent from patients were needed since the radiographs were routinely done even before the study was started. However, we asked for consent from the chairmen of the Department of Radiology of the involved tertiary hospital and the orthopaedic specialty clinic for access to the imaging.

## RESULTS

From 2019 to 2021, 48 patients underwent bipolar partial hip arthroplasty in the selected tertiary hospital. Thirty-six patients were excluded from the study: nine patients had concomitant injuries, one patient had a peri-implant femoral fracture, two patients expired due to medical reasons, and 24 patients were lost to follow-up (went home to their provinces, refused follow-up during the COVID-19 lockdown, etc.). Only 12 patients met the criteria and were included in our study.

Most were females (91.67%). Ages ranged from 67 to 95 years old, with a mean age of  $77.4 \pm 7.8$  years old. All patients included in the study had femoral neck fractures (Table 2).

There were significant differences ( $p < 0.05$ ) between immediate and one-year post-operative values of pelvic-shaft angle in hip abduction (B2;  $p = 0.0020$ ), pelvic-head angle in hip adduction (A3;  $p = 0.0437$ ), A1 and A2 (angle A;  $p = 0.0189$ ), B1 and B2 (angle B;  $p = 0.0037$ ), interprosthetic joint motion in abduction (X;  $p = 0.0029$ ), total interprosthetic joint motion (W;  $p = 0.0066$ ), and percentage of total interprosthetic joint motion (Z%;  $p = 0.0055$ ).

A functioning bipolar joint must demonstrate % interprosthetic joint motion (W%) of 25% or more, demonstrating a mobile inner shell relative to the outer shell. Nine (75%) of our patients

demonstrated this at one-year post-op, significantly more than the number of patients with W%  $< 25\%$  ( $z = 259.79$ ,  $p = 0.0001$ ). No significant difference was seen when comparing the two time points (immediate vs. one-year post-op,  $p = 0.3173$ ) (Table 4). When comparing our new measurement (measuring both abduction and adduction) with the original measurement (abduction only), we found a significant increase in the mobility recorded ( $p = 0.0006$ ) (Table 5).

One year post-operatively, seven out of 12 patients (58.3%) demonstrated more total prosthetic motion than interprosthetic motion (Table 6). Five different implant systems were documented. While all systems had cases retaining bipolar interprosthetic motion at one year post-op, the three cases with unipolar motion were attributed to AK Medical ( $n = 2$ , 17%) and U2 Hip ( $n = 1$ , 8%).

Most (75%) patients still had mobile bipolar interprosthetic joints even after one year. Half (50%) also retained interprosthetic movement on abduction and 58.3% retained movement on adduction. Small amounts of motion, less than 5 degrees, would have been missed in seven patients if adduction had not been documented. These results show that hip adduction radiographs can give additional information on the total interprosthetic joint motion in bipolar prostheses.

**DISCUSSION**

Bochner initially determined interprosthetic joint motion from neutral pelvic AP and maximum hip abduction radiographs.<sup>6</sup> But on this study, we included hip adduction. There was a significant difference in the number of patients (75%) whose bipolar interprosthetic joints were still mobile (W%  $\geq 25\%$ ) compared with those whose joints were static (W%  $< 25\%$ ) even after one year ( $p = 0.0001$ ). This contrasts with the varying outcomes in the literature. Verberne found that mobility was already lost at three months (interprosthetic joint motion was 16.9%).<sup>18</sup> Rai reported that interprosthetic joint motion was 33.74% at three months, 25.66% at 1.5 years, and was steady at 20% for six years.<sup>5</sup>

**Table 1.** Inclusion and exclusion criteria

Inclusion Criteria	Exclusion Criteria
<ul style="list-style-type: none"> <li>60 years old and above</li> <li>Male and female</li> <li>Femoral neck and intertrochanteric fractures</li> <li>All patients of the department who had bipolar partial hip arthroplasty from 2019-2021 (multi-surgeon)</li> <li>With records of radiographic images at a tertiary hospital Picture Archiving and Communication System (PACS) and/or Philippine Orthopaedic Institute (POI) Radiology Department</li> <li>Previous community ambulator</li> </ul>	<ul style="list-style-type: none"> <li>Younger than 60 years old</li> <li>Episode of hip dislocation postoperatively</li> <li>Mental disability</li> <li>Osteoarthritis</li> <li>Other hip injuries besides femoral neck and intertrochanteric fractures</li> <li>Lost to follow-up</li> </ul>

**Table 2.** Patient characteristics

Variables	n	Mean $\pm$ SD; Frequency %
<b>Total number of patients</b>	12	
Male	1	8.33%
Female	11	91.67%
<b>Type of fracture</b>		
Femoral neck	12	100%
Intertrochanteric	0	0
<b>Age</b>		77.4 $\pm$ 7.8 years (Range 67-95)

**Table 3.** Comparison of immediate and one-year post-operative radiographic parameters

		Immediate, degrees (mean $\pm$ SD)	One year, degrees (mean $\pm$ SD)	P-value
<b>AP neutral xray</b>	<b>A1</b> (Pelvic-head angle)	37.5 $\pm$ 9.9	30.4 $\pm$ 20.3	0.1745
	<b>B1</b> (Pelvic-shaft angle)	92.0 $\pm$ 2.3	92.2 $\pm$ 3.3	0.8391
<b>Maximum abduction xrays</b>	<b>A2</b> (Pelvic-head angle)	44.2 $\pm$ 10.9	46.3 $\pm$ 26.8	0.7586
	<b>B2</b> (Pelvic-shaft angle)	66.6 $\pm$ 9.8	75.2 $\pm$ 9.5	<b>0.0020</b>
<b>Maximum adduction xrays</b>	<b>A3</b> (Pelvic-head angle)	33.8 $\pm$ 10.9	22.8 $\pm$ 19.8	<b>0.0437</b>
	<b>B3</b> (Pelvic-shaft angle)	99.3 $\pm$ 6.6	100.2 $\pm$ 4.6	0.5599
	<b>Angle A</b> (A1-A2)	6.7 $\pm$ 7.6	15.9 $\pm$ 10.6	<b>0.0189</b>
	<b>Angle B</b> (B1-B2)	25.3 $\pm$ 10.6	17.0 $\pm$ 8.3	<b>0.0037</b>
	<b>Angle C</b> (A1-A3)	5.2 $\pm$ 3.6	7.6 $\pm$ 4.2	0.1573
	<b>Angle D</b> (B1-B3)	7.6 $\pm$ 5.3	8.1 $\pm$ 2.8	0.7401
	<b>X</b> (neutral-abduction)	18.8 $\pm$ 9.7	6.5 $\pm$ 6.0	<b>0.0029</b>
	<b>Y</b> (neutral-adduction)	4.8 $\pm$ 4.9	3.9 $\pm$ 2.9	0.6320
	<b>W</b> (shaft movement)	23.6 $\pm$ 12.4	10.4 $\pm$ 6.0	<b>0.0066</b>
	<b>W%</b> (interprosthetic joint motion)	67.1 $\pm$ 24.2	36.1 $\pm$ 19.3	<b>0.0055</b>

\* Bold p-values showed a significant difference between the immediate and one-year follow-up.

**Table 4.** Proportion of interprosthetic joint motion immediately and one year post-operatively

	The proportion of interprosthetic joint motion of total prosthetic motion one year post-operative			Comparing immediate vs one-year postoperative		
	Values	Z value	p-value	Immediate Post Op	1 Year Post Op	p-value
<25%	3 (25%)	259.79	<b>0.0001</b>	1 (8.3%)	3 (25%)	0.3173
≥25%	9 (75%)			11 (91.7%)	9 (75%)	

\* Bold p-values showed significant difference between patients with <25% and those with >25%

We recorded more patients with % interprosthetic motion ≥25% when hip adduction measurements were included (58.3%) as compared to when excluded (50%,  $p = 0.0006$ ) (Table 5). This is the first study to include hip adduction. We did this to measure a bigger plane of motion, to determine if including adduction makes a significant difference, and to mitigate errors in radiologic measurement. According to Brady, there is a 3 to 5% rate of error and discrepancies in radiologic measurements, consisting of both human and system errors.<sup>23</sup> This error rate may mask small values, leading to erroneous measurements in interprosthetic joint motion.

We also compared the changes in interprosthetic motion over time. The inner head articulation was found to contribute more to overall motion in 91.67% of patients immediately post-op, and 58.3% one year post-op.

This is also the first study to report on the interprosthetic joint motion of locally available bipolar implants. Implant systems were chosen based on surgeon preference. According to our data, all five systems had cases with good interprosthetic joint motion at one year post-op. The three cases with W%

<25% were attributed to two systems. One possible reason is that hip abduction and adduction radiographs were only performed as tolerated by the patient.

The proposed advantage of bipolar over unipolar prostheses is reduced acetabular erosion, attributed to less motion between the metal shell and the acetabulum.<sup>2-4,10,12</sup> This is effective as long as motion is maintained in both articulations during the patient's lifetime.

### Scope and limitations

Our sample size was small due to the paucity of patients who met the inclusion criteria. This was due to the unavailability of radiographs and poor follow-up during the two years of lockdown related to the COVID-19 pandemic. The length of follow-up was limited to one year. Long-term outcomes would be beneficial in assessing the longevity of bipolar interprosthetic motion.

This study only measured the interprosthetic joint motion of bipolar hip prostheses. We also recommend assessing other outcomes and consequences of the amount of joint motion. Measurements were done on 2D plain radiographs which may be affected by positioning and radiologist technique. Radiographs were static and non-weight bearing, which could also have affected motion and measurements. Only one investigator performed the measurements and no intraclass correlation was done.

**Table 5.** Value of adding Y (hip adduction measurements)

	Mean	SD	Difference	p-value
<i>X only</i>	34.67	33.84	40.03	<b>0.0006</b>
<i>X+Y</i>	74.69	37.06		

\* Bold p-value shows a significant difference between measurements using hip abduction measurements only compared to using hip abduction and adduction measurements

**Table 6.** Comparison of inner and outer head articulation immediate post-operative and at least 1 year post-operative

Patient Initials	System	Immediate post-op		One year post-op			
		Angle AC	Angle BD	X%	Y%	Angle AC	Angle BD
<b>AC</b>	AK Medical	38	52.3	24	<b>60'</b>	<b>43.7''</b>	43.6
<b>AS</b>	<b>AK Medical</b>	6.8	34.5	2.1	8.4	<b>21''</b>	20.7
<b>SO</b>	AK Medical	3	52.1	<b>48'</b>	8	<b>50''</b>	31.1
<b>LA</b>	Chunli	6.5	27.4	<b>72'</b>	<b>40'</b>	<b>21.5''</b>	13.5
<b>ES</b>	AK Medical	6.6	36.1	11.3	55	24.4	<b>28.3''</b>
<b>MB</b>	U2 Hip	6.9	21	<b>27'</b>	<b>78'</b>	<b>20''</b>	17
<b>RD</b>	<b>AK Medical</b>	14.7	37.7	5.5	9.2	34.7	<b>37.1''</b>
<b>HC</b>	LCU	16.2	23.8	<b>83'</b>	0	9	<b>19''</b>
<b>FA</b>	AK Medical	9.8	31.1	<b>37.5'</b>	<b>83'</b>	11	<b>22''</b>
<b>EM</b>	Just Medical	19	19	7	<b>54.5'</b>	19	<b>24''</b>
<b>LL</b>	<b>U2 Hip</b>	5.5	42.3	0	<b>62.5'</b>	16	<b>21''</b>
<b>MF</b>	Chunli	3.4	18.5	<b>98.6'</b>	21.7	12.2	<b>23.7''</b>

\* Highlighted in bold are the implant systems with a % interprosthetic joint motion of <25% at one-year post-op.

† Bold values represent interprosthetic joint motion in abduction (X%) and adduction (Y%) ≥25%.

†† Bold values represent whether total outer shell motion (Angle AC) or total prosthetic motion (Angle BD) was higher for each case.

## CONCLUSION

Most patients retained a mobile interprosthetic joint at one year post-op. Hip adduction radiographs gave additional information on the total interprosthetic joint motion. At both time points studied, the inner head articulation contributed more to the interprosthetic joint motion.

This is also the first study to report on locally available bipolar implants. All five implant systems had cases that showed good motion after one year, despite three cases of <25% interprosthetic joint motion being attributed to two of these systems.

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## STATEMENT OF AUTHORSHIP

All authors certified fulfillment of ICMJE authorship criteria.

## AUTHOR DISCLOSURE

The authors declared no conflict of interest.

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None.

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## Functional Outcomes of Patients with Ankylosed Elbow Managed with Fascia Lata Interposition Arthroplasty and Early Post-operative Active Motion Protocol: A Retrospective Study

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### ABSTRACT

**Background.** Interposition arthroplasty is a non-prosthetic-requiring surgery that restores motion in young patients with ankylosed elbows who are not amenable to total elbow arthroplasty, elbow arthrodesis, or resection arthroplasty. This procedure usually requires extensive soft tissue stripping to free the elbow joint, an interposition graft, and post-operative immobilization.

**Objective.** This study determined the functional outcomes of patients who underwent interposition arthroplasty of the elbow with early post-operative active motion exercise protocol, foregoing external fixation.

**Methodology.** The study retrospectively reviewed charts of patients treated by a single surgeon for ankylosed elbows from 2017 to 2023 in a tertiary institution. All patients initiated early overhead active motion exercises as early as 24–48 hours post-surgery without any external fixation. Pre-operative and last follow-up functional outcomes were determined using the Mayo Elbow Performance and Fil-DASH scores.

**Results.** The study included six patients with a mean age of 44 (24–61). Mayo Elbow Performance improved by a mean of 23% and Fil-DASH scores improved by a mean of 92%. Patients' average arc of motion was 65° at a mean follow-up of 20 months. All elbows were stable and painless throughout the arc of motion.

**Conclusion.** Interposition arthroplasty using tensor fascia lata graft combined with early overhead active motion is a viable surgical option for pain relief and improvement of motion in patients with elbow ankylosis who are candidates for either total elbow arthroplasty or arthrodesis.

**Keywords.** arthritis, elbow, post-traumatic, interposition, arthroplasty, ankylosis

### INTRODUCTION

Interposition arthroplasty is a non-prosthetic-requiring surgery that restores motion in young patients with ankylosed elbows who are not amenable to total elbow arthroplasty, elbow arthrodesis, or resection arthroplasty.

This usually requires extensive soft tissue stripping to free the elbow joint, and an interposition graft coupled with post-operative contractions in the form of a hinged external fixator,<sup>1</sup> or dynamic joint distractor.<sup>2</sup>

Despite knowing that early motion aids in improving function, motion is usually delayed depending on the surgeon's preference, the patient's specific condition, and the type of post-operative immobilization used.

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This study determined the functional outcome of patients who underwent interposition arthroplasty of the elbow without post-operative external fixation, combined with early (24–48 hours) post-operative overhead active motion exercise protocol.

### Rationale and review of related literature

Most activities performed with the arm depend on a 100° functional arc of motion of elbow extension and flexion (30–130°), and another 100° arc of motion for pronation and supination.<sup>1</sup> A 50° loss in the arc of motion can lead to an 80% loss of function.<sup>2</sup> This is most especially true for the ankylosed elbow with little to no arc of motion.

Surgical management options for elbow ankylosis include open or arthroscopic releases, interposition arthroplasty, elbow arthrodesis, and elbow arthroplasty.<sup>2</sup>

Arthrodesis is mainly performed for severe joint destruction, most commonly due to post-traumatic arthritis, instability, or infection.<sup>3</sup> Arthrodesis becomes problematic in older patients or those being treated for chronic infection since fusion is difficult to achieve when the bone stock is deficient. More importantly, fusion has a high complication rate and is functionally disabling.<sup>4–6</sup>

Total elbow arthroplasty longevity has yet to be proven and is primarily indicated for inflammatory elbow arthritis or conversion of a failed interposition arthroplasty in elderly patients.<sup>7</sup> Some drawbacks are the infection rate and the inability to bear weight on this implant system.

Interposition arthroplasty, introduced by Murphy in 1905,<sup>8</sup> is a viable option for patients with severe elbow arthritis or ankylosis. The triceps aponeuroses are detached, and the ulno-humeral joint dislocated and cleared of osteophytes before interposing biologic tissue such as autologous tensor fascia lata or an Achilles tendon allograft to cover the bone ends.<sup>9,10</sup> Extensive soft tissue stripping will allow the surgeon to perform this procedure with ease while compromising stability, hence the need to reinforce with an external fixation post-operatively. This procedure relieves pain and improves the total arc of motion while maintaining the native elbow joint.<sup>1,2</sup>

Positioning the arms overhead converts gravity from a distracting to a stabilizing force.<sup>11,12</sup> The overhead and supine position minimizes the effect of gravity, decreases posteriorly directed forces, and allows the triceps to function as an elbow stabilizer by avoiding abduction and internal rotation. This position eliminates the gravitational varus and extension-distraction force without affecting the integrity of the lateral ulnar collateral ligament (LUCL), allowing the surgeon to move the elbow without fear of dislocation.

No other study initiated early active motion within 24–48 hours after interposition arthroplasty of the elbow. The

surgeon in this study minimized soft tissue releases while interposing soft tissue in the ulno-humeral joint, eliminating the need for post-operative external fixation, and allowing overhead active elbow motion exercise as early as 24–48 hours after surgery.

### METHODOLOGY

#### Study design and participants

This study was approved by the Ethics Review Board of V. Luna Medical Center and conducted according to the Declaration of Helsinki. The medical records of patients diagnosed with ankylosed elbows who were surgically managed with interposition arthroplasty with early post-operative active motion protocol over five years were reviewed.

#### Surgical technique

A single orthopedic surgeon with subspecialty training in hand and reconstructive microsurgery performed the surgeries. Each patient was positioned in lateral decubitus with the affected side up. A bump was placed anterior to the arm with the forearm hanging off the edge of the bed (Figure 1). The distal humerus was exposed using the posterior triceps-sparing approach. The lateral ulnar collateral ligament (LUCL) and capsule were released to posteromedially dislocate the elbow (Figure 2). The medial collateral ligament (MCL) and the ulnar nerve were isolated and protected.

Attention was then focused on the lateral thigh, where an incision was made to harvest the full-thickness central portion of the tensor fascia lata graft, ensuring a sufficient graft size of at least 8 x 5 cm (Figure 3A and B). After careful hemostasis, the dermis was closed directly over the gap without a drain using thick 1-0 absorbable sutures. The fascia lata graft was folded over the eburnated surface of the distal humerus and anchored to the intact remnant periosteum on the lateral and medial sides of the distal humerus using 4-0 absorbable sutures (Figure 4).

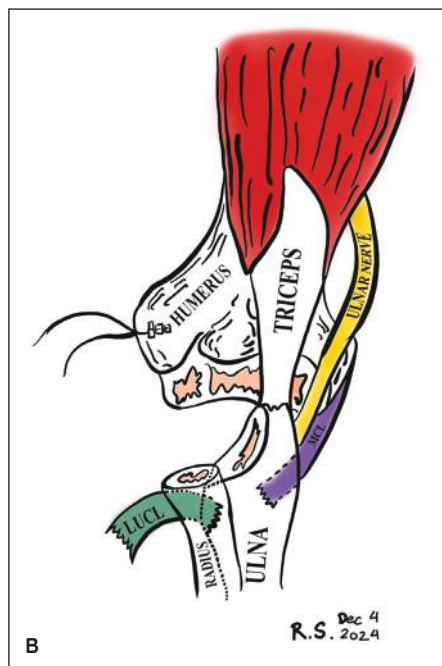
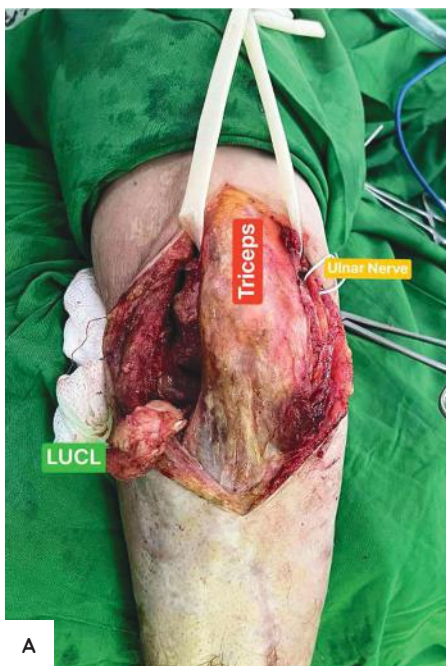
The elbow was then surgically reduced and the LUCL was repaired using a 4.5mm suture anchor (Figures 5A and B). The wound was closed over a drain. An arm sling was used to immobilize the elbow. No external fixation was used for all patients.

#### Postoperative care and rehabilitation

As early as 24–48 hours after surgery, each patient performed overhead active elbow range of motion exercises while reclining at a 45° angle. The shoulder was flexed forward to 90° in adduction and neutral rotation. The elbow was allowed to flex with gravity. Active-assisted forearm pronation and supination, and flexion and extension were performed as tolerated (Figures 6A and B). Shoulder internal rotation and abduction were avoided to minimize gravitational varus strain.<sup>12</sup>



**Figure 1.** Patient position in lateral decubitus with the affected side up.



**Figure 2.** (A) Posterior Triceps sparing approach showing the release of LUCL to allow capsulectomy and Ulna-Humeral joint release and posteromedial dislocation. The MCL is retained. (B) Schematic representation of the surgical technique used by the authors showing the eburnated articulating surfaces of the elbow joint after posteromedial surgical dislocation of the ulna with retention of the anterior bundle of the MCL. Also shown are the ulnar nerve protected and isolated after release, and the suture anchor in place for later repair of the LUCL.

At the end of the third week, active-assisted elbow and forearm rotation exercises were allowed in gravity-dependent sitting or standing positions.

At six weeks post-surgery, patients were allowed to do range-of-motion exercises with the elbow independent of gravity.

### Outcome analysis

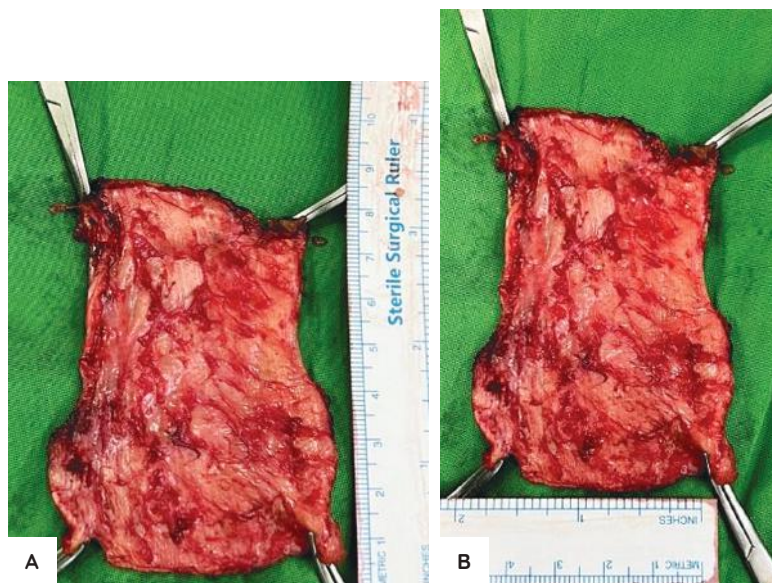
At each patient's last follow-up, functional outcomes were determined using the Mayo Elbow Performance Score (MEPS) and the Filipino Disabilities of the Arm, Shoulder and Hand (DASH) scores.

The maximum MEPS is 100 points: 45 points for no pain, 20 points for  $>100^\circ$  of motion, 10 points for joint stability, and 25 points for the capacity to perform selected daily activities. The results are categorized as excellent (90–100 points), good (75–89 points), fair (60–74 points), or poor ( $<60$  points).<sup>13</sup>

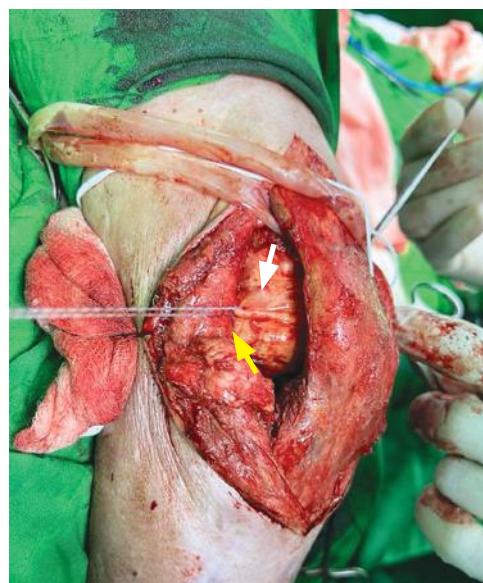
The DASH score was originally published in the *American Journal of Industrial Medicine* in 1996 by Hudak and later translated to Filipino (Fil-DASH) by Estrella. It is a standardized assessment of the impact on the function of a variety of musculoskeletal diseases and injuries of the upper extremities. It is a validated 30-item subjective questionnaire in which the response options are presented as 5-point Likert scales. A higher numerical result directly correlates with difficulty and limitation in performing activities of daily living, work, and sports.<sup>14,15</sup>

### RESULTS

The study identified six patients with elbow ankylosis who underwent fascia lata interposition arthroplasty in a tertiary medical center over five years. The mean age of the participants was 44 years (range: 24–61), with an average follow-up period of 20 months (Table 1). Most were post-traumatic in etiology (83.3%).



**Figure 3. (A)** Tensor fascia lata graft harvested 8 cm in length, based on the eburnated surface of the distal humerus. **(B)** Tensor fascia lata graft harvested measuring 5 cm in width.



**Figure 4.** Fascia lata graft (white arrow) anchored to retained periosteal remnants of the eburnated surface of the distal humerus on both lateral and medial sides. Yellow arrow shows suture anchor in place for repair.



**Figure 5. (A)** The LUCL was repaired (white arrow) at its origin using 4.5 mm suture anchor. The ulnar nerve transposed superficial to the fascia lata graft (blue arrow). **(B)** Post-operative radiograph with suture anchor in place for LUCL repair (white arrow).

There was a 23% improvement in mean MEPS from 21.67° pre-operatively to 92.5° (Figure 7 and Table 2) with an average arc of motion at 65°.

The mean Fil-DASH scores improved by 92% from 69.34 pre-operatively to 4.9 at 24 months follow-up (Figure 8).

At the last follow-up, pain scores were rated as mild to none. All patients report subjective satisfactory outcomes. There were no post-surgical complications, such as surgical site infection, heterotrophic ossification, or residual instability.

Although a painless crepitus was noted during the range of motion, this gradually disappeared after two years.

**DISCUSSION**

This study describes a surgical approach for elbow ankylosis that involves minimal soft tissue releases, allowing for soft tissue interposition in the ulno-humeral joint. This technique eliminates the need for post-operative external fixation and enables overhead active elbow motion exercises as early as 24–48 hours after surgery.

**Table 1.** Patient demographics

Patient Number	Patient Initials	Sex	Age (years)	Handedness	Etiology	Follow-up (months)
1	RA	Male	61	Right	Post-traumatic	24
2	ADV	Male	32	Right	Post-traumatic	30
3	DA	Male	29	Right	Post-traumatic	24
4	LT	Female	24	Right	Post-traumatic	24
5	GF	Male	61	Right	Post-traumatic	6
6	DB	Male	56	Right	Tuberculous	12
<b>Mean</b>			<b>44</b>			<b>20</b>

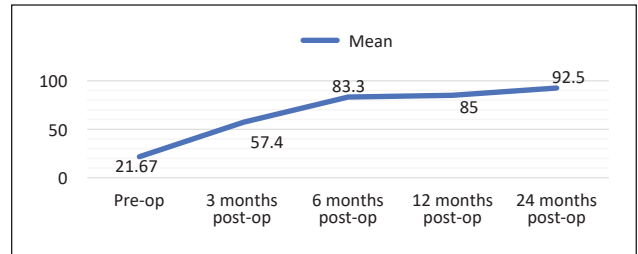
**Table 2.** Mean Mayo Elbow Performance Score (MEPS)

MEPS	Pre-op	3 months-post-op	6 months post-op	12 months post-op	24 months
<b>Pain</b>	2.50	22.5	32.5	40	41.25
<b>Motion</b>	5.00	13.3	15.8	15	16.25
<b>Stability</b>	7.50	8.3	10.0	10	10.00
<b>Daily Function</b>	6.67	13.3	25.0	25	25.00
<b>Total</b>	<b>21.67</b>	<b>57.4</b>	<b>83.3</b>	<b>85</b>	<b>92.50</b>

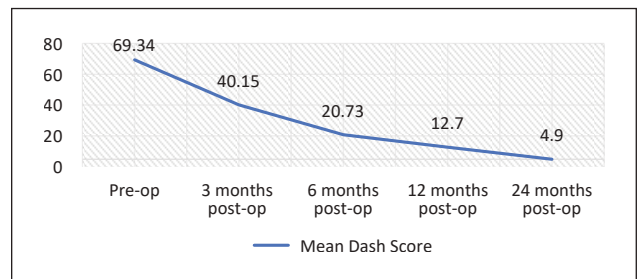


**Figure 6.** (A) Early overhead exercises initiated within 48 hours post-surgery showing gravity dependent position of elbow flexion. (B) Active-assisted range of motion exercises is performed from gravity dependent elbow flexion to elbow extension.

The following techniques helped us achieve an early active range of motion: first, the triceps was spared so that active elbow extension could be initiated immediately, in contrast to a study by Charalambous and Morrey where the triceps aponeurosis was detached and reattached after clearing out the ulno-humeral joint of osteophytes.<sup>3</sup> Second, only the LUCL was detached to dislocate the joint postero-medially and insert the fascia lata graft. The anterior bundle of the MCL was retained, in contrast to Chen’s study which removed and then reconstructed all soft tissue attachments.<sup>9</sup> Third, no external fixation or dynamic distractor was applied, in contrast to studies by Miyazaki et al. and Cheng.<sup>1,2</sup> Fourth, active overhead motion protocol for elbow dislocations as described by Schreiber was initiated 1–2 days post-operatively.<sup>12</sup> This maneuver utilizes the dynamic stability to the elbow provided by the actively contracting triceps against gravity. Retaining the MCL with a repaired LUCL can allow early overhead motion without strain, like starting a dart thrower motion exercise after a scapholunate ligament repair.<sup>16</sup>



**Figure 7.** Mean MEPS.



**Figure 8.** Mean Fil-DASH Score.

Functional outcomes are also generally satisfactory even without using post-operative devices. Cheng used an elbow distractor for three to four weeks to separate the articular surfaces and to protect the fascial graft. Nine of their 13 patients (69%) had satisfactory relief from pain and eight (62%) had excellent or good MEPS results at a mean follow-up of 63 months, while four required revision to total elbow arthroplasty at a mean of 30 months.<sup>2</sup> In our study, 6 patients (100%) had satisfactory pain relief, and 5 (83%) had an excellent MEPS at their last follow-up and none of these patients were converted to total elbow arthroplasty at a mean follow-up of 20 months. Although our follow-up period is shorter, our patients could bear weight on the reconstructed elbow during activities such as push-ups and weightlifting. This is significant, given that patients who undergo total

elbow arthroplasty typically face a lifetime weight restriction of 15 lbs. While we noted a 92% improvement in the Fil-DASH score at the last follow-up, no other related studies measured DASH scores in their functional outcome.<sup>1,2,6</sup>

All our patients had painless crepitus during range of motion that disappeared by the 24<sup>th</sup> month post-surgery. None of the previous authors mentioned this in their study, most probably because they delayed motion.

The study is limited due to the rare diagnosis and indication (i.e., elbow arthroplasty in the young population). This study was still able to demonstrate excellent results in terms of MEPS and Fil-DASH scores.

## CONCLUSION

Interposition arthroplasty using tensor fascia lata graft combined with early overhead active motion protocol is a viable surgical option for pain relief and improvement of motion in an ankylosed elbow. In the local setting, in addition to minimizing cost by eliminating the need for any temporary joint fixator, this can be an excellent option for primary arthroplasty. It allows patients to engage in early post-operative rehabilitation while preserving the native elbow joint. Furthermore, it can be successfully converted to a total elbow arthroplasty if indicated subsequently.

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This research is dedicated to all battle casualties of the Armed Forces of the Philippines, especially those who were discharged from service due to upper extremity disabilities, and also to the fallen during the Marawi Siege of 2017.

## STATEMENT OF AUTHORSHIP

All authors certified fulfillment of ICMJE authorship criteria.

## AUTHOR DISCLOSURE

The authors declared no conflict of interest.

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None.

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## Comparing Clinical Outcomes of Five-Strand Hamstring Tendon Autograft and Quadrupled Hamstring Tendon Autograft for Single Bundle Anterior Cruciate Ligament Reconstruction in Filipinos: An Ambi-directional Cohort Study

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### ABSTRACT

**Background.** Anterior cruciate ligament (ACL) tears are common, especially in athletes, and are often treated with hamstring tendon autografts using a single-bundle technique. Graft diameter is crucial, with evidence showing that larger grafts reduce failure risk. Asian populations typically have smaller graft diameters. This study compares the clinical outcomes of the five-strand versus the quadrupled technique in a Filipino Asian population to assess potential benefits in graft thickness and knee stability.

**Objective.** To compare the functional outcomes, graft sizes, failure rates, and time to return to sports between five-strand and quadrupled hamstring tendon autografts in ACL reconstruction.

**Methodology.** This ambi-directional cohort study involved Asian Filipino patients aged 18–50 with unilateral ACL tears who underwent single-bundle ACL reconstruction with either quadrupled or five-strand hamstring autografts between January 2022 and August 2023. Data on graft dimensions, IKDC scores, and time to return to sports were collected pre- and postoperatively. The analysis included descriptive statistics, Fisher's exact test, t-tests, and ANOVA, with significance at  $p < 0.05$ .

**Results.** The study included 18 patients, showing no significant differences in demographic characteristics such as age (24.78 vs. 27.67 years,  $p = 0.202$ ), height (1.71 vs. 1.64 meters,  $p = 0.146$ ), weight (84.43 vs. 74.98 kg,  $p = 0.252$ ) body mass index (28.95 vs. 27.98 kg/m<sup>2</sup>,  $p = 0.714$ ), or average return to sports (10.63 vs. 11.83 months,  $p = 0.642$ ). There was no significant difference in thicknesses ( $p = 0.089$ ) and lengths ( $p = 0.885$ ) of the graft. IKDC scores showed no significant differences between the two groups in pre- or postoperative outcomes at six months and one year. Complications were minimal, with no significant difference found.

**Conclusion.** Both the five-strand and quadrupled techniques demonstrated similar demographics, graft dimensions, and clinical outcomes, indicating comparable functional results and safety profiles.

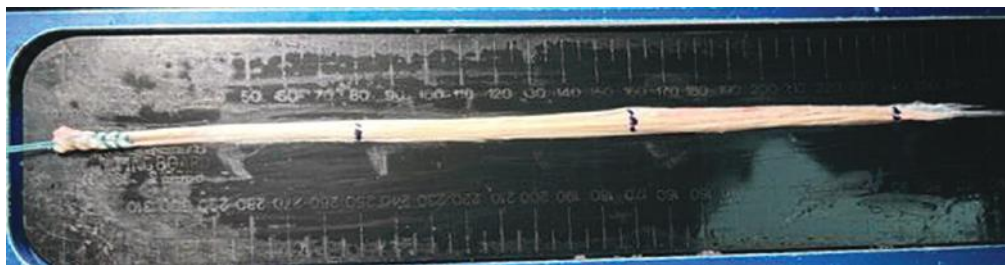
**Keywords.** anterior cruciate ligament, reconstruction, hamstring tendon autograft, five-strand tendon autograft, single-bundle technique, outcomes

### INTRODUCTION

The quadrupled hamstring tendon graft has become the graft of choice in anterior cruciate ligament (ACL) reconstruction because of its biomechanical properties that mimic or even outperform the native ACL, the ease of harvesting, good clinical outcomes, and minimal donor site morbidity.<sup>1-3</sup> The quadrupled configuration is obtained by folding the gracilis and semitendinosus tendons once.<sup>4</sup> Multiple and thicker strands correlate with higher graft strength and lower risk of graft revision.<sup>5,6</sup> The estimated risk of graft failure is at 1.8% to 10.4%,<sup>7,8</sup> which is decreased by 0.82 to 0.86 times with every 0.5 mm increase in graft diameter between 7.0 and 10.0 mm.<sup>9,10</sup> The Asian hamstring autografts are usually smaller than their Caucasian counterparts—around 7 mm for females and 8 mm for males.<sup>11</sup> Tang et al. found that a target graft diameter

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**Figure 1.** Semitendinosus tendon marked into three parts for a five-strand hamstring auto graft.

of 8 mm or more decreases the risk of graft failure and that race may help predict graft failure in ACL reconstruction.<sup>12</sup>

In a Multicenter Orthopaedic Outcomes Network (MOON) cohort study of more than 250 patients, patient-reported outcomes were better with larger-diameter hamstring grafts. Specifically, 5.2-, 3.3-, and 2.0-point increases in KOOS Sports, Pain, and Activities of Daily Living scores, respectively, were observed for every 1 mm increase in graft diameter, with a 3.4-point increase in the subjective International Knee Documentation Committee (IKDC) score.<sup>13</sup> Generally, a thicker graft is a goal for every ACL reconstruction case.

Despite the promising outcomes of the hamstring tendon autograft, an important drawback is its variability in diameter.<sup>14</sup> Several techniques have been described to increase the hamstring autograft diameter when presented with a less than 8.0 mm diameter graft. In the five-strand hamstring tendon autograft, the longer semitendinosus tendon is folded into three equal parts (Figure 1) while the gracilis tendon is folded in half once. This technique has been known to increase the graft diameter by an average of 1–2 mm according to Lavery et al.<sup>15</sup>

Few studies discuss the clinical outcomes of the five-strand hamstring tendon autograft. Calvo et al. found that a five-strand graft was clinically comparable with a four-strand graft in terms of re-rupture rates and clinical outcomes (both grafts being >8 mm). Krishna et al.'s cohort study also concludes that when faced with an undersized graft, the five-strand graft technique is useful in increasing the graft diameter providing a good and valid option comparable to the standard quadrupled technique.<sup>16</sup>

The goal is to restore the stability of the knee, expediting return to sports while minimizing the risk of re-rupture, translating to a high functional clinical outcome. The study aimed to compare the clinical outcomes of the five-stranded hamstring autograft in a Filipino population versus the quadrupled hamstring tendon autograft for single-bundle reconstruction for patients with anterior cruciate ligament tears.

## METHODOLOGY

### Study design

This was an ambidirectional cohort study.

### Study setting

This study was done at Chong Hua Hospital, Fuente Osmeña, Don Mariano Cui St., Cebu City, Philippines.

### Study population

#### Inclusion criteria

This study included Filipino patients ages 18–50 years old with unilateral complete anterior cruciate ligament tears; who underwent a primary single-bundle reconstruction using hamstring tendon autografts; from January 2022 to August 2023; where a meniscectomy or meniscal repair may or may not have been done; performed in Chong Hua Hospital; where either a quadrupled hamstring autograft or a five-strand hamstring autograft was harvested; where a cortical button was used for the femoral end and a bioabsorbable interference screw for the tibial end of the ACL graft; who consented to be included in the study; and completed at least one year of follow-up.

#### Exclusion criteria

This study did not include: bilateral ACL tear patients; patients with other ligamentous injuries such as PCL or collateral ligament injuries; those with previous surgeries on the operated knee; cases of ACL revision; and patients wherein the number of strands were not indicated or did not belong to a quadrupled or a five-strand autograft in the records.

### Sample size determination

Total sampling of patients meeting the inclusion and exclusion criteria.

### Research tool

The research tool that was used was the International Knee Documentation Committee Subjective Knee Form (IKDC).

### Data collection

The study was approved by the Chong Hua Hospital Institutional Review Board. Patients who fit the inclusion and exclusion criteria were appraised and gave their consent. Patients underwent anterior cruciate ligament reconstruction using hamstring grafts. If the harvested tendons were long enough to be folded to create a five-strand graft, patients were

assigned to the intervention group, while harvested tendons that were too short for a five-strand graft were assigned to the control group.

The surgeon harvested the hamstring autografts with care to maximize the tendon length. The tendons were transferred to the graft preparation table and stripped of excess muscles on the proximal end. For the five-strand technique, the surgeons must have harvested a total of 240 mm for the semitendinosus and 160 mm for the gracilis. Any excess length was cut off. The gracilis was folded once while the semitendinosus was folded into three equal parts, making it the same length as the folded gracilis. The target length was 80–90 mm (20 mm femoral tunnel graft, 30 mm intra-articular graft, and 30–40 mm tibial tunnel graft). The tendons were whipstitched together with the cortical button applied on one end.<sup>11</sup> The quadrupled autografts were prepared similarly, with the difference being that both the semitendinosus and the gracilis were each folded over once.

Patients who did not concomitantly undergo a meniscal repair were allowed immediate weight-bearing and range of motion. For patients with meniscal repairs, weight-bearing was delayed up to two weeks, and range of motion was delayed for four weeks. The rehabilitation regimen after this period was the same for all patients thereafter.

Demographic data, pre- and postoperative IKDC scores, harvested graft length and diameter, and intraoperative and postoperative adverse events were recorded. Six- and twelve-month follow-up outcomes were collected via interview, including IKDC scores and time required to return to sports.

### Data management and analysis

In this study, continuous variables were summarized using means and standard deviations, while nominal variables were summarized using frequencies and percentages. Fisher's exact test was used to compare nominal variables, and the t-test was used for continuous variables. One-way repeated measures ANOVA was used to compare matched or repeated measures.

When ANOVA results were significant, a conditional post hoc analysis was performed. The level of statistical significance was set at  $p < 0.05$ .

## RESULTS

A total of 18 patients were included in this study, nine cases each for the five-strand and the quadrupled groups. Demographic data revealed that the five-strand and quadrupled groups were well-matched across several characteristics, with no statistically significant differences observed for age, sex, height, weight, BMI, etiology of injury, and time to operation (Table 1). While more patients in the five-strand group had left-sided injuries (55.56%), compared to the quadrupled group (22.22%), this difference was not statistically significant ( $p = 0.335$ ).

The mean graft diameter in the five-strand group was 8.17 mm ( $SD = 0.87$ ), and 7.56 mm ( $SD = 0.53$ ) in the quadrupled group ( $p = 0.089$ ), with no statistically significant difference. The five-strand group's mean graft length was 85.00 mm ( $SD = 10.00$ ), while the quadrupled group's was 85.56 mm ( $SD = 5.27$ ), with no significant difference ( $p = 0.885$ ). The five-strand group displayed a wider range of sizes, with the most common dimensions (diameter x length) being 8 x 80 mm (33.33%), followed by 8 x 100 mm (22.22%). Other sizes such as 7 x 70 mm, 9 x 80 mm, 7.5 x 85 mm, and 10 x 90 mm were observed less frequently (each at 11.11%). In contrast, the quadrupled group showed a concentration in specific sizes, with 8 x 90 mm (33.33%) being the most common, while 7 x 80 mm and 7 x 90 mm were observed in 22.22%. There was no significant difference in graft diameter between the two groups ( $p = 0.066$ ) (Table 2).

Among patients with sports-related injuries, there was no significant difference in the average time to return to sports ( $p = 0.642$ ) (Table 3).

There were no significant differences in preoperative measures for IKDC Symptoms, Sports, Function, and Total scores (Table 4,  $p > 0.05$ ). However, significant changes were observed

**Table 1.** Patient demographics

	Five-strand Group (n = 9)	Quadrupled Group (n = 9)	p Value
<b>Age. (years)</b>	24.78 (3.15)	27.67 (5.70)	0.202
<b>Gender. n (%)</b>			
Male	7 (77.78)	6 (66.67)	1.000
Female	2 (22.22)	3 (33.33)	
<b>Height. (cm)</b>	1.71 (0.08)	1.64 (0.10)	0.146
<b>Weight. (kg)</b>	84.43 (22.31)	74.98 (8.39)	0.252
<b>Body Mass Index in kg/m<sup>2</sup></b>	28.95 (7.23)	27.98 (2.59)	0.714
<b>Time to Operation (months)</b>	20.33 (28.40)	29.22 (39.33)	0.590
<b>Laterality. n (%)</b>			
Left	5 (55.56)	2 (22.22)	0.335
Right	4 (44.44)	7 (77.78)	
<b>Type of Injury. n (%)</b>			
Non-sports	1 (11.11)	3 (33.33)	0.577
Sports	8 (88.89)	6 (66.67)	

Note: \* Significant at 0.05; Values are presented in mean (standard deviation) unless otherwise stated.

within each group over time. In the five-strand group, IKDC scores for symptoms, sports, and total IKDC significantly increased at six months post-operation, indicating an improvement in knee function and a reduction in symptoms shortly after the operation. Despite this initial increase, scores stabilize after one year. Conversely, in the quadrupled group, there was a significant increase in IKDC sports, function, and total scores at six months, reflecting improved ability to participate in sports while also indicating a general improvement in knee function and overall health. A significant increase in symptoms score was observed at one year, with the total score continuing to increase significantly, indicating ongoing

improvement. These findings highlight distinct patterns of change, with each group showing different trajectories in knee health and functionality following their respective interventions.

There were no cases of tunnel blowout, graft failure, or stiffness in either group (Table 5). One patient had instability (11.11%) in the five-strand group, while there were none in the quadrupled group ( $p = 1.00$ ). For miscellaneous complications, the five-strand group had one case of meniscus injury at 10 months postoperatively and another case of partial tear of the ACL at 15 months postoperatively; no

**Table 2.** Graft dimensions and measurements

	Five-strand Group (n = 9)	Quadrupled Group (n = 9)	p Value
<b>Average graft thickness</b>	8.17 (0.87)	7.56 (0.53)	0.089
<b>Average graft length</b>	85.00 (10.00)	85.56 (5.27)	0.885
<b>Dimensions of the graft (mm)</b>			
7 x 70	1 (11.11)	0 (0.00)	0.066
7 x 80	0 (0.00)	2 (22.22)	
7 x 90	0 (0.00)	2 (22.22)	
8 x 80	3 (33.33)	2 (22.22)	
8 x 90	0 (0.00)	3 (33.33)	
8 x 100	2 (22.22)	0 (0.00)	
9 x 80	1 (11.11)	0 (0.00)	
10 x 90	1 (11.11)	0 (0.00)	

Note: \* Significant at 0.05; values are presented in frequency (percentage).

**Table 3.** Time to return to sports (among patients with sports-related injuries, n = 14)

	Five-strand Group (n = 8)	Quadrupled Group (n = 6)	p Value
<b>Return to sports (months)</b>	10.63 (2.88)	11.83 (6.43)	0.642

Note: \* Significant at 0.05; Values are presented in mean (standard deviation) unless otherwise stated.

**Table 4.** Comparison of outcomes

	Five-strand group (n = 9)	Quadrupled group (n = 9)	Between groups comparison, p value
<b>Pre-operative scores</b>			
IKDC symptoms	23.44 (7.54) <sup>A</sup>	26.67 (4.42) <sup>A</sup>	0.285
IKDC sports	24.78 (9.43) <sup>A</sup>	26.33 (8.37) <sup>A</sup>	0.716
IKDC function	8.11 (1.54)	7.33 (2.18) <sup>A</sup>	0.395
Total	64.75 (19.75) <sup>A</sup>	69.35 (14.82) <sup>A</sup>	0.584
<b>Post-operative scores 6 months</b>			
IKDC symptoms	30.56 (6.39) <sup>B</sup>	29.22 (3.90) <sup>A</sup>	0.600
IKDC sports	36.56 (4.42) <sup>B</sup>	35.67 (5.77) <sup>B</sup>	0.718
IKDC function	8.89 (1.17)	8.89 (1.17) <sup>B</sup>	1.000
Total	87.36 (11.68) <sup>B</sup>	84.80 (9.97) <sup>B</sup>	0.625
<b>Post-operative scores 1 year</b>			
IKDC symptoms	33.78 (4.68) <sup>B</sup>	35.33 (2.18) <sup>B</sup>	0.380
IKDC sports	39.00 (1.66) <sup>B</sup>	39.44 (0.73) <sup>B</sup>	0.472
IKDC function	9.67 (0.71)	9.44 (1.01) <sup>B</sup>	0.597
Total	94.76 (7.80) <sup>B</sup>	96.81 (2.97) <sup>C</sup>	0.473
<b>Within group comparison</b>	<b>p value</b>	<b>p value</b>	
IKDC symptoms	<0.001 *	<0.001 *	
IKDC sports	<0.001 *	<0.001 *	
IKDC function	0.015 *	<0.001 *	
Total	<0.001 *	<0.001 *	

Note: \* Significant at 0.05; Values are presented in mean (standard deviation); different superscripts indicate significant differences in scores with the group; IKDC stands for International Knee Documentation Committee Subjective Knee Form.

**Table 5.** Complications

	Five-strand Group (n = 9)	Quadrupled Group (n = 9)	p Value
<i>Tunnel blowout</i>	0 (0.00)	0 (0.00)	1.000
<i>Graft failure</i>	0 (0.00)	0 (0.00)	1.000
<i>Stiffness</i>	0 (0.00)	0 (0.00)	1.000
<i>Instability</i>	1 (11.11)	0 (0.00)	1.000
<i>Others</i>	2 (22.22)	0 (0.00)	0.471

Note: \* Significant at 0.05; values are presented in frequency (percentage).

miscellaneous complications were observed in the quadrupled group ( $p = 0.471$ ). Overall, the rates of complications were low and comparable between the two groups.

## DISCUSSION

This study compared the clinical outcomes and demographic characteristics of two treatment groups: the five-strand and quadrupled hamstring tendon autograft groups. The primary focus was on graft thickness, clinical outcomes, and complication rates.

### Patient demographics and baseline characteristics

The groups were well-matched in terms of age, gender, height, weight, BMI, time to operation, laterality, and injury type, making these variables less likely to confound the outcomes.

#### *Graft dimensions*

Graft dimensions were similar between the five-strand and quadrupled groups. The five-strand group had a mean thickness of 8.17 mm (SD = 0.87) and length of 85.00 mm (SD = 10.00), while the quadrupled group had a mean thickness of 7.56 mm (SD = 0.53) and length of 85.56 mm (SD = 5.27), falling within the 7–8 mm range for Asian populations.<sup>1</sup> Differences in thickness ( $p = 0.089$ ) and length ( $p = 0.885$ ) between the two groups were not statistically significant. While the variability in graft sizes was not substantial ( $p = 0.066$ ), the five-strand group demonstrated a wider range of sizes while the quadrupled group showed concentration in specific sizes. We theorize that wide variability in graft thickness could influence the mechanical properties of the graft and potentially affect patient outcomes. However, since we found no statistically significant variability, it is unlikely to be a major confounder in this study.

### Clinical outcomes

The IKDC scores provide insights into knee function and recovery over time. Both groups showed significant improvements in symptoms, sports participation, and overall knee function at six months postoperative. However, the trajectory of recovery diverged in one year. The five-strand group saw stabilization in scores, suggesting a plateau in recovery after the initial improvement. In contrast, the quadrupled group continued to show significant gains, particularly in symptoms and overall health.

These findings highlight that while both graft types led to substantial improvements, the quadrupled group may have experienced continued benefits beyond the six-month mark. This could suggest that the quadrupled graft offered a more sustained improvement in knee function, although the clinical significance of these differences would need further exploration in larger studies. Overall, for both groups, we noted almost equivalent outcomes.

## Complications

Complication rates were low and comparable between the groups, with no significant differences in tunnel blowout, graft failure, stiffness, or other complications. There was one case of instability, one case of meniscus injury at 10 months, and a partial ACL tear at 15 months in the five-strand group, but no statistically significant difference was found when comparing these incidences with the quadrupled group. The low rate of complications suggests that both graft types are generally safe and well-tolerated. This supports the use of either technique in clinical practice, although individual patient factors and preferences should guide the choice of graft. We note that our follow-up period was short, which might not capture all possible complications.

The postoperative protocol for patients with isolated ACL reconstruction, or with meniscectomy followed standard practices of immediate weight-bearing and range of motion.<sup>17</sup> For those with ACL reconstruction and meniscal repair, the rehabilitation started with a protocol for isolated meniscal repairs. Adams recommends for ACL reconstruction with meniscal repair a period of no weight-bearing for four weeks, followed by a gradual reintroduction of weight-bearing over the next four weeks, with standard ACL reconstruction protocol resuming after eight weeks.<sup>17</sup> Accelerated protocols, including the 2018 Knee Pain and Mobility Impairments guidelines, recommend early progressive motion and weight-bearing, achieving full weight-bearing by six to eight weeks.<sup>18</sup> Our study employed an accelerated rehabilitation protocol while ensuring clinical milestones were met. After four weeks, the same protocol was followed for ACL reconstruction with meniscectomy, without meniscectomy, and with meniscal repair.

## CONCLUSION

Overall, this study finds that the five-strand and quadrupled groups are comparable in demographic and clinical characteristics, with no significant differences in baseline measures or complications. Both treatments resulted in significant improvements in knee function at six months, though the quadrupled group demonstrated a trend toward continued recovery beyond up to one year. Still, this difference is not statistically significant. While there may have been differences in graft thickness and recovery trajectories, they were not likely to substantially alter the overall safety and effectiveness profiles of the two treatments. Future research with larger sample sizes and longer follow-ups could provide

more definitive insights into the long-term benefits and optimal use of each graft type.

## RECOMMENDATIONS

The researchers would like to recommend the following for future studies: (1) a larger population size and/or a longer study period; (2) incorporating correlation between gender and graft dimensions; (3) a population focused on anterior cruciate ligament reconstruction only; and (4) more frequent intervals for outcome measures.

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## STATEMENT OF AUTHORSHIP

All authors certified fulfillment of ICMJE authorship criteria.

## AUTHORS DISCLOSURE

The authors declared no conflict of interest.

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## Outcomes of Patients with Tendinous Mallet Finger Injury Managed with DIPJ Extension Splinting vs Axial Pinning: A Descriptive Study

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### ABSTRACT

**Background.** Mallet finger, a common finger injury, results from damage to the distal extensor tendon, causing a flexion deformity at the distal interphalangeal joint. While conservative treatment with splinting is often effective, surgical intervention using Kirschner wire fixation may be necessary for complex cases or non-compliant patients.

**Objective.** This study compared the outcomes of two treatments for tendinous mallet finger: splinting and pinning. Researchers analyzed patient demographics, distal interphalangeal joint range of motion, clinical outcomes, and complication rates between the two groups.

**Methodology.** We retrospectively reviewed patients diagnosed with tendinous mallet finger injury managed conservatively or surgically from 2018 to 2022 in a tertiary hospital.

**Result.** Both surgical and conservative treatments were effective, as shown by the excellent total active motion scores and satisfactory qDASH (Disabilities of the Arm, Shoulder, and Hand) outcomes in both groups. However, when comparing the Miller and Crawford criteria, the surgical group consistently showed slightly better functional outcomes.

**Conclusion.** Both treatments yielded similar results for range of motion, extension lag, and flexion loss, making them equally effective. However, axial pinning may result in better subjective improvement and satisfaction.

**Keywords.** tendinous mallet finger injury, axial pinning, mallet finger splinting

### INTRODUCTION

Mallet finger injury is characterized by a discontinuity in the distal extensor tendon, causing delayed extension at the distal interphalangeal (DIP) joint with or without compensatory hyperextension at the proximal interphalangeal (PIP) joint. It is a common sports injury that happens when a straight digit tip is injured by an axial force, causing passive severe DIP hyperextension or hyperflexion.<sup>1,2</sup> The extensor tendon is damaged at the base of the distal phalanx, often involving a tendon rupture or bone avulsion.<sup>3,4</sup> This injury can result in a "drop finger" or "baseball finger" deformity.<sup>5,6</sup> The terminal extensor tendon may be torn due to crash injuries or lacerations in the dorsal area of the distal phalanx; most mallet injuries are closed.<sup>7</sup> This injury represents a substantial portion of tendinous injuries, with a global prevalence of 9.3% and comprising 5.6% of all hand and wrist tendinous injuries.<sup>8</sup>

Once diagnosed, restoring strong DIP joint extension is crucial to avoid a swan neck deformity. Most closed mallet finger injuries are treated conservatively with finger splints. Patients unable to tolerate splints have been advised to undergo surgical treatment using Kirschner wire fixation,<sup>9</sup> which some authors deem excessively invasive.

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This study compared outcomes of non-bony mallet finger injuries treated with either conservative splinting or surgical Kirschner wire fixation, including post-treatment range of motion in the DIP joint, Miller,<sup>10</sup> and Crawford<sup>11</sup> criteria outcomes, Filipino Quick Disabilities of the Arm, Shoulder, and Hand (qDASH)<sup>12,13</sup> questionnaire outcomes, and the incidence of complications.

## METHODOLOGY

### Study design

Retrospective Cohort Study

### Study population

We conducted a four-year retrospective analysis of all patients diagnosed with tendinous acute mallet finger injuries. Protocol approval was obtained from the Technical Review Board and Independent Ethics Committee, De La Salle University Medical Center (DLSUMC). Data of patients treated from January 2018 to December 2022 were collected from the records of the DLSUMC operating room and clinics. Patients were diagnosed through clinical assessment and radiographic evaluation.

#### Inclusion criteria

Eligible patients included those with a flexible DIP joint, with or without subluxations, and without associated fractures, who were treated with either splinting or K-wire fixation. Patients should have also completed their management regimen, had the splint or K-wire removed at eight weeks, completed their one-year follow-up, and completed the Filipino qDASH questionnaire.

#### Exclusion criteria

Patients were excluded if they were non-compliant with treatment or follow-up (Figure 1).

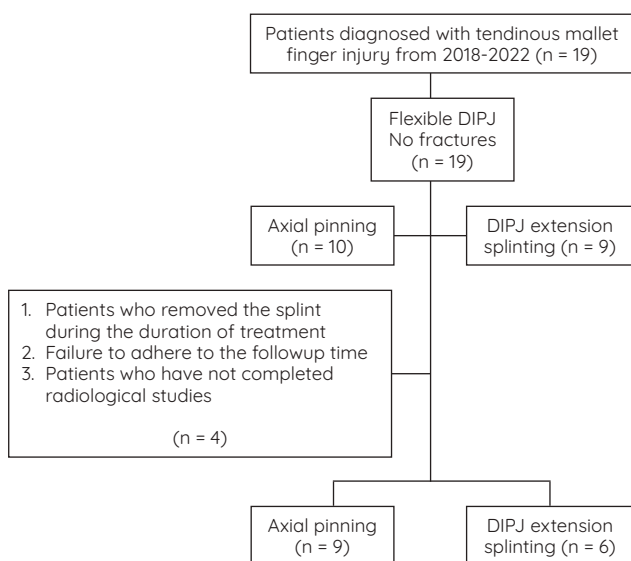


Figure 1. Flow diagram of study participants.

No randomization was done to assign patients to either group. Surgical treatment involved axial pinning with a Kirschner wire at the DLSUMC's operating room complex, verified by postoperative x-rays. Conservative treatment consisted of DIP joint extension splinting, with a repeat x-ray after one week to confirm that reduction was maintained. Both groups of patients followed up at the outpatient department or senior author's clinic. X-rays were repeated at eight weeks, 12 weeks and one year post-treatment. Outcomes were assessed by orthopedic surgery residents and the consultant. Clinical outcomes were assessed at the final examination at one year post-treatment. The final range of motion was measured using a digital goniometer. Clinical outcomes were measured using the Miller criteria (Table 1), the Crawford criteria (Table 2), and the Filipino qDASH. Any treatment complications such as skin maceration, ulcerations, pin loosening, pin tract infection, and nail deformity were recorded.

### Surgical technique: axial pinning

All surgeries were done under digital block anesthesia. With the DIPJ extended, a 0.045 in K-wire was inserted centrally through the tip of the distal phalanx, advanced proximally to its base, penetrating the DIPJ, then advanced through the head of the middle phalanx up to its base without PIPJ penetration. Intraoperative fluoroscopy was used to confirm K-wire placement. The exposed end of the K-wire was trimmed and buried underneath the skin. Standard absorbent dressing was applied without suturing or splinting (Figure 2).

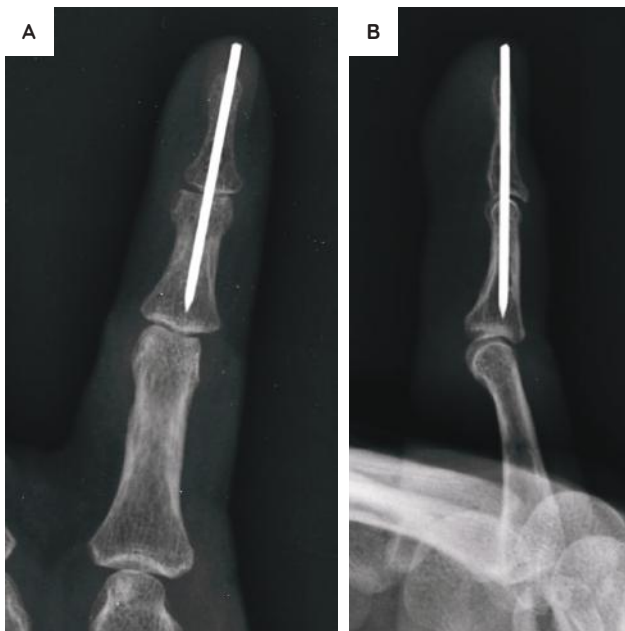
The pins were removed at the day surgery complex after eight weeks. Under digital block anesthesia, a small incision was made over the skin where the pin was palpable. The pin was gently rotated and pulled out, and sterile dressings were applied to the wound.

Table 1. Miller's Criteria for Assessing Extensor Tendon Function. Evaluates extensor tendon function based on active extension lag and flexion deficit at the DIP joint

Results	Total extension lag (degrees)	Total flexion loss (degrees)
Excellent	0	0
Good	≤10	≤20
Fair	11-45	21-45
Poor	≥45	≥45

Table 2. Crawford Criteria. Grades outcomes based on DIP joint flexion-extension loss and pain

Grade	Characteristics of distal interphalangeal joint
Excellent	Full extension Full flexion No pain
Good	Extension deficit 0-10 degrees Full flexion No pain
Fair	Extension deficit 10-25 degrees Any flexion loss No pain
Poor	Extension deficit >24 degrees Persistent pain



**Figure 2.** Kirschner wire fixation. **(A)** Anteroposterior radiograph. The K-wire was inserted axially in a retrograde fashion. Tricortical: pin penetrating the tip and base of distal phalanx and head of middle phalanx. **(B)** Lateral radiograph. The DIP joint was fixed in extension.



**Figure 3.** Conservative management. The padded tongue depressor was cut to length and applied distal to the proximal interphalangeal joint to keep the DIPJ extended. The splint was secured with sticking plaster.

### Conservative management: volar/dorsal splint

A padded tongue depressor cut to the appropriate length was applied spanning the middle phalanx to the fingertip, immobilizing the distal interphalangeal joint (DIPJ) in extension. This was maintained with an adhesive plaster for eight weeks (Figure 3). If the DIP joint had been allowed to flex during that time, the patient was categorized as non-compliant.

Gentle range of motion exercises for the DIP joint were initiated after the removal of the splint or pin.

## RESULTS

Nineteen patients were diagnosed with tendinous mallet finger injuries from January 2018 to December 2022. Ten underwent axial pinning, while nine underwent splinting. Four patients were non-compliant with treatment or postoperative x-rays or were lost to follow-up, leaving nine patients in the axial pinning group, and six in the splinting group (Figure 1). The

mean age of the overall cohort was  $35.8 \pm 9.97$  years. The surgical group had a higher proportion of males (66.67%) compared to the conservative group (50%). The right hand was more commonly affected, 77.78% in the surgical group and 66.67% in the conservative group. Injuries were relatively equally distributed between the small, ring, middle, and index fingers across both groups. In the surgical group, the small and ring fingers were most commonly affected (44.44% and 33.33%, respectively). In the conservative group, the ring and middle fingers were equally affected (33.33%), and the small finger was less frequently involved (16.67%) (Table 3).

At one year follow-up, these were the outcomes and complications noted (Tables 4 and 5).

- **Total Extension Lag:** The conservative group demonstrated a mean of  $8.08 (\pm 3.89)$  degrees of extension lag, while the surgical group demonstrated  $6.67 (\pm 2.91)$  degrees.
- **Total Flexion Loss:** Similarly, the conservative group had a mean flexion loss of  $4.25 (\pm 1.1)$  degrees, while the surgical group had a mean of  $3.48 (\pm 1.0)$  degrees.
- **Total Active Motion (TAM):** Both groups achieved excellent TAM scores, with 100% of patients in both groups reaching satisfactory total active motion.
- **Miller and Crawford Criteria:** All patients in the surgical group (100%) achieved a "good" outcome according to both criteria, whereas half (50%) of patients in the conservative group had a "fair" outcome.
- **qDASH Score:** Both groups had satisfactory functional outcomes, with the surgical group scoring a mean of  $22.47 (\pm 2.40)$  while the conservative group scored a mean of  $20.45 (\pm 3.22)$ .
- **Radiographic Findings and Complications:** All patients in both groups had unremarkable radiographic findings, and no complications (skin-related complications, infection, arthritis) were reported in either group.

## DISCUSSION

Mallet injuries, as defined by the Doyle classification, present in various forms: they can be closed injuries, either with or without an associated avulsion fracture, or open injuries, which may involve tendon or soft tissue damage, sometimes in conjunction with fractures.<sup>14</sup> Failure to restore DIP joint extension may lead to complications such as a swan neck deformity, a condition characterized by hyperextension of the PIP joint with concurrent DIP joint flexion.<sup>15,16</sup>

Conservative management, predominantly through six to eight weeks of DIPJ extension splinting, remains the standard for treating most closed mallet injuries. However, patient compliance is a common challenge with this approach. Wearing a splint continuously for the recommended duration can be uncomfortable. Skin-related complications, including necrosis, maceration, and ulceration, can arise due to the pressure and moisture buildup under the splint, especially when patients fail to maintain proper hygiene or allow the skin to air out regularly.<sup>16-21</sup>

**Table 3.** Demographic profile of the patients

	Total (n=15)	Surgical (n=9, 60%)	Conservative (n=6, 40%)
	Frequency (%); Mean ± SD		
<b>Age, years</b>	35.8 ± 9.97	34.44 ± 11.70	37.83 ± 7.17
<b>Sex</b>			
Male	9 (60)	6 (66.67)	3 (50)
Female	6 (40)	3 (33.33)	3 (50)
<b>Affected hand</b>			
Right	11 (73.33)	7 (77.78)	4 (66.67)
Left	4 (26.67)	2 (22.22)	2 (33.33)
<b>Affected finger</b>			
Small finger	5 (33.33)	4 (44.44)	1 (16.67)
Ring finger	5 (33.33)	3 (33.33)	2 (33.33)
Middle finger	4 (26.67)	2 (22.22)	2 (33.33)
Index finger	1 (6.67)	0	1 (16.67)

**Table 4.** One-year follow-up

	Total (n=15)	Surgical (n=9, 60%)	Conservative (n=6, 40%)
	Frequency (%); Mean ± SD		
<b>Total extension lag</b>	7.23 ± 3.28	6.67 ± 2.91	8.08 ± 3.89
<b>Total flexion loss</b>	3.79 ± 1.08	3.48 ± 1	4.25 ± 1.1
<b>Total active motion (TAM)</b>	164 ± 3.48	164.86 ± 3.26	162.67 ± 3.67
Excellent	15 (100)	9 (100)	6 (100)
<b>Miller criteria</b>			
Fair	3 (20)	0	3 (50)
Good	12 (80)	9 (100)	3 (50)
<b>Crawford criteria</b>			
Fair	3 (20)	0	3 (50)
Good	12 (80)	9 (100)	3 (50)
<b>qDASH (Filipino)</b>	21.66 ± 2.83	22.47 ± 2.40	20.45 ± 3.22
Satisfactory	15 (100)	9 (100)	6 (100)
<b>Unremarkable Radiographic findings</b>	15 (100)	9 (100)	6 (100)
<b>Complication</b>			
Absent	15 (100)	9 (100)	6 (100)
Present	0	0	0

**Table 5.** Demographics, clinical and radiological values of the study population (A) Surgical and (B) Conservative

A. Surgical (k-wire)														
Patient	Age	Gender	Affected hand	Affected finger	Final (1 year post-treatment)									
					Total extension lag	Total flexion loss	Total active motion (TAM)	Millers criteria	Crawford criteria	qDASH (Filipino)	Radiographic findings	Complications		
1	52	female	right	small finger	8.9	2.6	163.5	excellent	good	good	22.72	satisfactory	unremarkable	none
2	24	male	left	small finger	0.4	2.1	172.5	excellent	good	good	20.45	satisfactory	unremarkable	none
3	16	female	right	middle finger	7.0	4.9	163.1	excellent	good	good	18.18	satisfactory	unremarkable	none
4	24	male	left	small finger	9.0	2.1	163.9	excellent	good	good	22.72	satisfactory	unremarkable	none
5	29	male	right	ring finger	8.2	3.7	163.1	excellent	good	good	25.00	satisfactory	unremarkable	none
6	44	female	right	ring finger	4.0	4.0	167.0	excellent	good	good	20.45	satisfactory	unremarkable	none
7	41	male	right	middle finger	9.0	4.4	161.6	excellent	good	good	25.00	satisfactory	unremarkable	none
8	41	male	right	ring finger	5.5	4.0	165.5	excellent	good	good	25.00	satisfactory	unremarkable	none
9	39	male	right	small finger	8.0	3.5	163.5	excellent	good	good	22.72	satisfactory	unremarkable	none

B. Conservative (splinting)														
Patient	Age	Gender	Affected hand	Affected finger	Final (1 year post-treatment)									
					Total extension lag	Total flexion loss	Total active motion (TAM)	Millers criteria	Crawford criteria	qDASH (Filipino)	Radiographic findings	Complications		
1	36	female	right	middle finger	5.3	4.6	165.1	excellent	good	good	20.45	satisfactory	unremarkable	none
2	25	female	right	index finger	5.2	5.8	164.0	excellent	good	good	15.90	satisfactory	unremarkable	none
3	40	female	left	middle finger	11.7	3.7	159.6	excellent	fair	fair	22.72	satisfactory	unremarkable	none
4	46	male	left	ring finger	12.4	2.9	159.7	excellent	fair	fair	18.18	satisfactory	unremarkable	none
5	42	male	right	ring finger	3.4	3.4	168.2	excellent	good	good	20.45	satisfactory	unremarkable	none
6	38	male	right	small finger	10.5	5.1	159.4	excellent	fair	fair	25.00	satisfactory	unremarkable	none

For patients unable to adhere to the demands of splinting due to occupational demands, K-wire fixation is often recommended. After the six to eight-week immobilization period, part-time splinting for an additional 2 to 4 weeks may follow, allowing for a more gradual transition to full mobility. K-wire fixation stabilizes the joint without violating the tendon, thereby maintaining the structural integrity of the extensor mechanism while promoting proper joint alignment during the healing process.<sup>16-21</sup>

Despite its advantages, K-wire fixation has complications. Issues range from short-term joint stiffness and septic arthritis to long-term osteoarthritis.<sup>22</sup> Osteoarthritis can develop from the disruption of the articular surface during pin insertion, altering joint mechanics and causing articular degeneration. Surgery carries inherent risks of infection, K-wire loosening, and pain at the insertion site. If infection extends to the bone, the resulting osteomyelitis requires extensive treatment, including prolonged antibiotic therapy or additional surgeries.<sup>23-30</sup>

Casscells and Strange in 1957 first introduced transarticular fixation of the DIP joint using K-wires.<sup>31</sup> This method was paired with immobilization of the proximal interphalangeal (PIP) joint using a plaster cast to maintain joint stability for four weeks. Studies comparing surgical and non-surgical treatment for mallet fingers have varying results. While Auchincloss<sup>23</sup> and Renfree<sup>24</sup> found that surgery improved DIP joint extension, both concluded that clinical outcomes were similar to conservative treatment. Auchincloss suggested surgery might be better for delayed presentations, while Groebli<sup>32</sup> recommended splinting in such cases, reserving surgery for open injuries or persistent joint incongruity. Lubahn<sup>33</sup> favored surgery for subluxation or large fractures, citing improved extension and cosmesis, whereas Wehbe and Schneider<sup>34</sup> generally recommended non-surgical treatment regardless of subluxation or fracture size.

In our study, K-wire fixation was applied longitudinally through the DIP joint and buried beneath the skin without external splinting, streamlining recovery. One year postoperatively, the absence of rotational deformities demonstrated the technique's efficacy, especially for patients needing unrestricted hand use in their occupations.

A similar study by Nagura et al.<sup>35</sup> explored the use of a single K-wire inserted obliquely through the DIP joint. While the oblique approach may offer advantages, such as engaging more cortical bone to reduce the likelihood of wire loosening and easier extraction in the event of wire breakage, insertion is more difficult and is more likely to injure adjacent soft tissues. Axial K-wire placement technique remains a preferred option due to its simplicity and direct stabilization of the joint. In this study, pain and scarring at the wire insertion site were minimal, attributed to careful surgical technique and proper wound care.

Our surgical technique was intended to reduce common complications including infection, irritation, pain, and the risk of osteoarthritis from articular disruption. By centrally placing a single axial K-wire, the technique minimizes joint damage and mechanical irritation. This approach also reduces the need for multiple pins, which can exacerbate the risk of infection and other complications. By providing a stable fixation, this technique optimizes the healing process, offering a favorable balance between joint stabilization and functional recovery.

While both treatments are viable, surgical intervention for finger injuries resulted in slightly better subjective outcomes. All patients in the surgical group achieved a "good" outcome based on both the Miller and Crawford criteria in contrast to only half of the patients treated conservatively. The absence of complications in either group demonstrated the safety of both approaches.

## CONCLUSION

Both surgical and conservative treatments resulted in similar ranges of motion, and incidences of extension lag and flexion loss, suggesting that they were equally effective. However, axial pinning may result in greater overall improvement and satisfaction based on subjective measures. Treatment must be individualized based on clinical presentation and patient preferences, as both approaches have their merits depending on the desired outcomes.

## Limitations

The study was limited only to a single institution. The number of participants was limited by the total number of patients treated by the senior investigators during this period. Patients were not randomized to treatment groups. We also noted more dropouts from the conservative group. While the results may provide valuable insights into patient outcomes, they must be interpreted cautiously and might not be generalizable to other populations or practice settings.

## Recommendations and future research directions

Future research should involve multiple centers to increase the sample size and enhance the generalizability of the findings. A larger, more diverse patient population would provide greater statistical power and allow for subgroup analysis (e.g., by age, fracture type, or activity level). Moreover, while the current study assessed outcomes at one year, longer follow-up is crucial to evaluate the long-term efficacy and potential complications of both surgical and conservative treatments. This would help determine if the observed benefits of surgical treatment, particularly in terms of patient satisfaction, are sustained.

## STATEMENT OF AUTHORSHIP

All authors certified fulfillment of ICMJE authorship criteria.

## AUTHORS DISCLOSURE

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## Non-invasive Removal of Tethered Surgical Drains Using Kirschner Wire with Ultrasound Guidance: An In-Vitro Experimental Study

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### ABSTRACT

**Background.** Surgical drain retention is rare but can cause significant consequences if not addressed promptly. Few studies have investigated non-invasive methods to remove tethered drains. This study aimed to determine whether tethered drains could be removed using a Kirschner wire under ultrasound guidance.

**Methods.** The study was an experimental in-vitro study on pork loin specimens. Drain tubes (No. 10, No. 15) were placed subfascially with one suture stitch passing through the lumen of the drain tube (Vicryl 2-0, Vicryl 1-0). An ultrasound machine (Sonosite M Turbo) was used to locate the area of tethering. Kirschner wires (1.6 mm and 2.0 mm, threaded and smooth) were inserted and thrust multiple times intraluminally to cut the suture. There were eight possible combinations of wire type, drain diameter, and suture size with seven replicates per combination. Ultrasound accuracy was set at 0.5 cm from the tethering site, and durations were recorded with a cut-off value of five minutes.

**Results.** Ultrasound was able to locate the tethered site in 47 out of 56 attempts (83.93%). Most attempts (48 out of 56, 85.71%) were successful in cutting the tethered suture and removing the drain. The overall duration for drain removal was 1'35". Shorter durations were recorded for threaded compared to smooth Kirschner wires (1'34" vs 1'37"), for size No. 10 compared to No. 15 drains (1'20" vs 1'50"), and for Vicryl 2-0 compared to Vicryl 1-0 sutures (1'25" vs 1'45").

**Conclusion.** Using ultrasound to locate the area of tethering and using Kirschner wire intraluminally was an effective non-invasive way to remove tethered drains in pork loin specimens. This combined method can simplify drain removal and can be used as a first-line option before open removal.

**Keywords.** tethered drain, Kirschner wire, intraluminal, non-invasive, ultrasound

### INTRODUCTION

Surgical drains allow blood and other fluids to be removed from the surgical wound postoperatively.<sup>1</sup> While their use has been documented as early as Hippocrates, it remains controversial and highly dependent on the surgeon's preference. Advantages include reducing ecchymosis, hematoma, seroma (which are culture media for bacteria), and dressing changes,<sup>2</sup> while complications include retrograde infection, increased postoperative bleeding (paradoxically), and breakage or retention.<sup>3-5</sup> A retained drain (either broken or tethered) is rare, easily overlooked, and avoidable but can lead to serious complications.<sup>6</sup>

The incidence rate is unknown and likely underreported because of legal implications. The primary cause for a tethered drain is accidental suture fixation during wound closure. Post-operative drains are usually pulled out at bedside. Unfortunately, tethering is often discovered only

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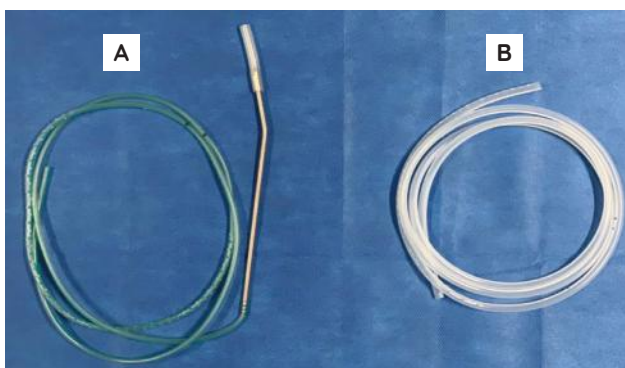
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upon attempting removal.<sup>7</sup> Most surgeons support surgical exploration for complete removal. However, the additional procedure places the patient at risk of anesthesia and surgery, causes anxiety for both patient and surgeon, and increases costs, infection rates, and postoperative pain.

To prevent reoperation, non-invasive methods to remove tethered drains have been attempted. Namyslowski was able to remove a retained Jackson-Pratt drain percutaneously by inserting, maneuvering, and inflating an angioplasty balloon over a hydrophilic-coated steerable guidewire.<sup>8</sup> Rue and Johnson removed silicone drains by applying gentle in-line traction while twisting the drain five to seven times.<sup>9</sup> Lazarides used the pointed tip of Kirschner wires intraluminally to cut the suture and remove the drain.<sup>10</sup> To date, this is the only paper describing the use of Kirschner wires to remove tethered drains. They reported a 100% success rate but did not mention the specimens used.

Percutaneously locating the tethering site is also a challenge. Traditionally, plain radiographs, computed tomography (CT) scans, and contrast-enhanced magnetic resonance imaging (MRI) have been used. Given that silicone and polyvinyl chloride (PVC) tubes are radiolucent, ultrasound can visualize their path within the body. Li et al. used ultrasound to indirectly visualize the site of tethering.<sup>11</sup> After locating the walls of the drain tube on the longitudinal view, the authors described the “sliding sign,” which was visualized as the drain tube sliding in the surrounding soft tissue with repeated gentle tugging of its free end. Moving the transducer proximally (or away from the free end of the drain tube), the authors identified the point where the sliding sign disappears, and the drain tube and soft tissue move as one during repeated tugging. This area was marked as the “vanishing point” and corresponded to the tethering site. Under ultrasound guidance, the authors were able to successfully remove the tethered drains in all three patients and were able to reproduce the same results in pork models.

Herein, we present a technique of tethered drain tube removal under ultrasound guidance using an intraluminal Kirschner wire. To the best of our knowledge, there has been no study combining the use of both Kirschner wire and ultrasound to remove tethered drains.



**Figure 1.** (A) Drain tube Fr. 10 (polyvinyl chloride; Biometrix); (B) Drain tube Fr. 15 (silicone; Cardinal Health).

## OBJECTIVES

### General objective

To demonstrate the efficacy of using Kirschner wire with ultrasound guidance as a non-invasive method to remove tethered drains.

### Specific objectives

1. To determine the success rate of ultrasound in locating the site of tethering
2. To measure the duration required to cut the suture and remove the drain
3. To determine the success rate in cutting the suture and removing the drain
4. To demonstrate the effect of the thickness of the suture, Kirschner wire type, and drain diameter on the success rate and duration required to cut the tethered drain

## METHODOLOGY

The protocol was approved by our institution's ethics review board (ERB).

### Design and patients

We conducted an in-vitro experimental study using boneless pork loin specimens (each measuring 20 x 5 x 5 cm [L x W x H]), instead of cadaveric or actual patients. Pork models were used because they are simple and cost-effective models and have similar anatomic structures and echogenicity to human tissue.<sup>11</sup>

### Sample size determination

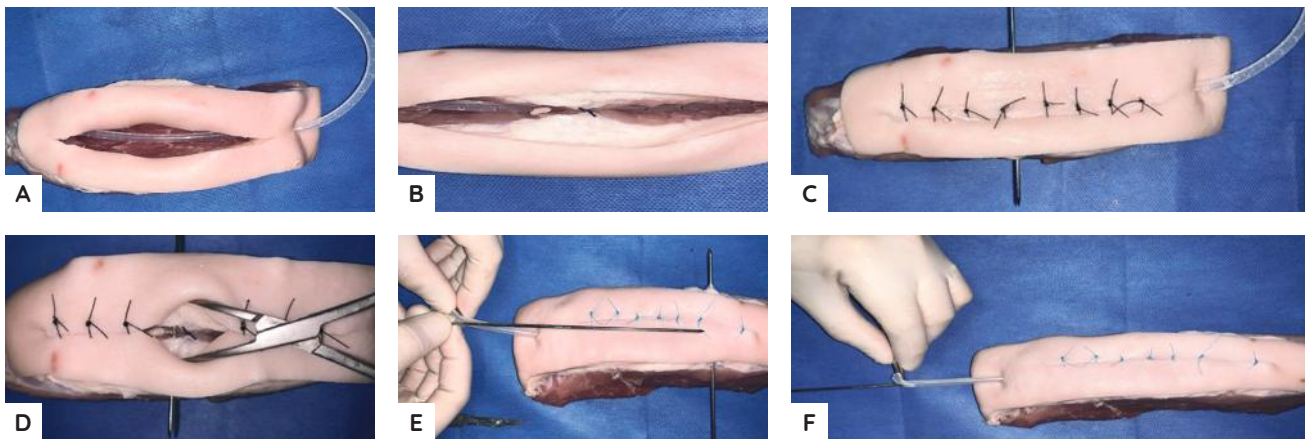
With eight possible combinations of wire type, drain diameter, and suture size, we required a minimum of seven replicates per combination. The sample size was calculated using the formula in the study by Arifin and Zahiruddin for animal models.<sup>12</sup>

$$\text{Minimum: } 10/(r - 1) + 1^{a,b}$$

$$\text{Maximum: } 20/(r - 1) + 1^{a,b}$$

### Materials and specifications

- 1.6 mm (threaded and smooth) Kirschner wire with trocar tip – stainless steel, Olten Instruments
- 2.0 mm (threaded and smooth) Kirschner wire with trocar tip – stainless steel, Olten Instruments
- Drain tube Fr. 15 silicone – Cardinal Health (Figure 1)
- Drain tube Fr. 10 medium polyvinyl chloride (PVC) – Biometrix (Figure 2)
- Smooth, synthetic, absorbable suture (Polyglactin 910) – Vicryl 2-0, Vicryl 1-0 – Johnson & Johnson
- Ultrasound machine – Sonosite M-Turbo



**Figure 2.** (A) Pork loin specimen sample with the Fr. 15 silicone drain tube placed subfascially, approximately 3 cm in depth from the skin. (B) Vicryl 2.0 sutured through the drain tube within the fascial layer. (C) With the skin closed using interrupted sutures, the approximated location of tethering was determined via ultrasound, and the level was marked by a K-wire. (D) With the skin closed using interrupted sutures, the approximated location of tethering was determined via ultrasound, and the level was marked with a K-wire. (E) Accuracy of the ultrasound was determined via visual inspection with a cut-off distance value of 0.5 cm. (F) A straight clamp was used to maintain in-line tension while the K-wire was being inserted.

Unlike Lazarides' study, we used trocar tips (because diamond-pointed tips were not available locally), and included threaded Kirschner wires.

### Pork loin preparation

Specimens were prepared by an orthopedic resident. The specimens were secured manually by one end to a table. Each specimen was incised in the midline. Subcutaneous tissue, fascia, and muscle were incised in line with the skin incision, with an approximate depth of 3 cm. The suction drain tube was placed subfascially. The fascia was closed with an absorbable suture in a simple interrupted inverted T technique with one suture stitch passing through the lumen of the drain tube. The skin was closed with non-absorbable sutures in a simple interrupted manner, obscuring the site of tethering. A minimum of 10 cm of drain tube length was placed inside the pork loin specimen (Figure 2). The combinations of the Kirschner wire type, tube diameter, and suture size used are listed in Table 1.

### Locating the site of tethering using ultrasound

A second examiner (an orthopedic surgeon fellowship-trained in sports and musculoskeletal ultrasound) used a portable ultrasound machine's (Sonosite M-Turbo) linear probe (6–13 mHz) in standard 2D mode to locate the site of tethering. On longitudinal view, the drain tube, its perforations, and its path within the surrounding soft tissue were identified based on the difference in echogenic properties. The free end was repeatedly tugged to elicit the "sliding sign." The "vanishing point", where the sliding sign disappeared was also determined (Figure 3). This corresponded to the transition point where the drain tube slides freely within the surrounding soft tissue and the drain tube and soft tissue move as one during repeated tugging. The "vanishing point" matched the site where the drain was tethered and was pinned in place with a separate



**Figure 3.** The black star represents the "vanishing point" where the suture was located within the drain tube.

(marking) Kirschner wire inserted within the soft tissue, perpendicular to the incision. The specimen was then visually inspected. The attempt was marked successful if the marking wire was found within a set distance of 0.5 cm from the actual suture location.

### Introduction of Kirschner wire within the drain tube lumen

A third examiner (an orthopedic surgeon fellowship-trained in trauma) performed this step. The free end of the tube was measured and cut to the same length as the depth of the Kirschner wire to be introduced into the lumen, determined by the surface marking from the previous step. This was done to allow ease in the handling of the Kirschner wire. The free end of the drain tube was cut longitudinally (about 1 cm) and a straight clamp was applied. With firm in-line traction on the clamp and tube, the drain was pulled taut, straightening the drain, making it easier to introduce the wire, and reducing the risk of tube perforation. The Kirschner wire was advanced intraluminally and once there was resistance from the suture was felt, the wire was thrust forcefully one to two times per second, with forward, backward, and rotational movements. The durations were recorded for each material combination.

**Table 1.** Combinations for wire type, drain diameter, and suture size

1	Smooth 1.6 mm Kirschner wire x No. 10 drain x Vicryl 2.0
2	Smooth 1.6 mm Kirschner wire x No. 10 drain x Vicryl 1.0
3	Smooth 2.0 mm Kirschner wire x No. 15 drain x Vicryl 2.0
4	Smooth 2.0 mm Kirschner wire x No. 15 drain x Vicryl 1.0
5	Threaded 1.6 mm Kirschner wire x No. 10 drain x Vicryl 2.0
6	Threaded 1.6 mm Kirschner wire x No. 10 drain x Vicryl 1.0
7	Threaded 2.0 mm Kirschner wire x No. 15 drain x Vicryl 2.0
8	Threaded 2.0 mm Kirschner wire x No. 15 drain x Vicryl 1.0

If the procedure could not be completed in five minutes, the attempt was marked as failed. This endpoint was set arbitrarily, since previous studies did not mention any time endpoints for their attempts (Lazarides), or were successful within five minutes. All attempts exceeding the 5-minute cut-off were designated a value of 5 minutes and 1 second (5'01"). Attempts were also marked as failed if the Kirschner wire perforated the tube.

**Disposal**

Pork loin specimens and the materials used were disposed of properly according to local health standards.

**Outcome measures**

The efficacy of ultrasound in identifying the site of tethering was based on the success rate (number of successful attempts within 0.5 cm cut-off distance of the actual suture location divided by the total number of attempts).

The efficacy of the Kirschner wire in cutting the suture intraluminally was evaluated based on the duration (starting from probe placement onto the pork loin specimen after successful ultrasound identification and ending with the K-wire reaching the site of tethering) and the success rate (number of successful attempts divided by the total number of attempts).

**Statistical analysis**

Descriptive statistics (mean and standard deviation) were used to summarize the data. There were three factors for this

**Table 2.** Ultrasound location success rate

	Number located successfully via ultrasound		p-value
	n	%	
<b>Overall</b>	47	83.93	-
<b>Drain diameter</b>			
No. 10	24	85.71	0.7185
No. 15	23	82.14	
<b>Suture size</b>			
Vicryl 1.0	23	82.14	0.7185
Vicryl 2.0	24	85.71	

analysis: A – Wire type (smooth, threaded), B – drain diameter (No. 10, No. 15), and C – suture size (Vicryl 1-0, Vicryl 2-0). Three-way ANOVA was used to determine any difference in the attempt durations. Three-way analysis (A x B x C) was performed, followed by two-way analysis (A x B, A x C, B x C), and then the main effects analysis (A, B, C).

All valid data were included in the analysis. Missing variables were neither replaced nor estimated. STATA 15.0 was used for data analysis.

**RESULTS**

**Success rate of locating the site of tethering using ultrasound**

Using the ultrasound, the examiner was able to successfully locate the site of tethering in 47 out of 56 attempts (83.93%). The success rate was 85.71% for No. 10 size tubes and 82.14% for No. 15 size tubes (p = 0.7185). The success rate was 85.71% for Vicryl 2-0 and 82.14% for Vicryl 1-0 (p = 0.7185) (Table 2).

**Duration**

The overall mean duration required to cut the suture and removing the tethered drain was 1'35" (1.58 ± 1.62). Using threaded Kirschner wires took a mean of 1'34" (1.56 ± 1.61) compared to a mean of 1'37" (1.61 ± 1.65) using smooth wires. The mean duration was 1'20" (1.34 ± 1.50) for tube size Fr. 10 and 1'50" (1.83 ± 1.72) for Fr. The mean duration was 1'25" (1.42 ± 1.31) for Vicryl 2-0 and 1'45" (1.75 ± 1.88) for Vicryl (Tables 3 and 4).

**Table 3.** Mean durations

	Mean ± SD	Label
<b>Overall</b>	1.58 ± 1.62	1'35"
<b>Wire type</b>		
Smooth	1.61 ± 1.65	1'37"
Threaded	1.56 ± 1.61	1'34"
<b>Drain diameter</b>		
No. 10	1.34 ± 1.50	1'20"
No. 15	1.83 ± 1.72	1'50"
<b>Suture size</b>		
Vicryl 1.0	1.75 ± 1.88	1'45"
Vicryl 2.0	1.42 ± 1.31	1'25"

**Table 4.** Mean durations per combination of wire type, drain diameter, and suture size

Wire type	Drain diameter	Suture	Mean	SD	N	Label
<b>Threaded</b>	No. 10	Vicryl 1.0	1.17	1.84	7	1'10"
		Vicryl 2.0	1.92	1.51	7	1'55"
	No. 15	Vicryl 1.0	1.31	1.65	7	1'19"
		Vicryl 2.0	1.85	1.68	7	1'51"
<b>Smooth</b>	No. 10	Vicryl 1.0	1.75	1.62	7	1'45"
		Vicryl 2.0	0.50	0.59	7	30"
	No. 15	Vicryl 1.0	2.76	2.34	7	1'46"
		Vicryl 2.0	1.41	0.88	7	1'25"

### Success rate of tethered drain removal

Out of a total of 56 attempts, 48 (85.71%) attempts were successful in cutting the tethered suture and removing the drain. The success rate was 85.71% for both smooth and threaded Kirschner wires. The success rate for removing No. 10 tubes was higher than for No. 15 tubes (89.29% vs 82.14%,  $p = 0.449$ ) (Table 5).

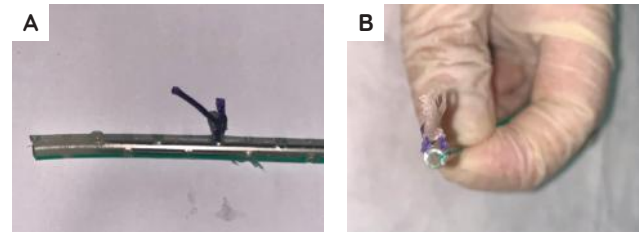
Three-way ANOVA showed no significant effect on duration among the three factors of wire type, drain diameter, and suture size ( $p = 0.944$ ). Main effects analysis showed that wire type ( $p = 0.919$ ), tube diameter ( $p = 0.253$ ), and suture size ( $p = 0.443$ ) did not significantly affect duration (Table 6).

### DISCUSSION

This study aimed to determine the efficacy of Kirschner wire under ultrasound guidance in non-invasively removing tethered drains in terms of duration and success rates.

The examiner performing the ultrasound was able to locate the area of the tethering in 47 out of 56 attempts (83.9%), with an accuracy within 0.5 cm. Most of the nine failed attempts were located between 0.5 and 1 cm of the suture and only one attempt was more than 2 cm off. This radius may have little implication as it is often exposed during open removal. It was encouraging that the “sliding sign” and “vanishing point” (Li et al.) were easily reproduced. This method is easy to learn, quick, and simple.<sup>11</sup> The PVC tubes were more hyperechoic than the silicone, making them easier to visualize within the soft tissue. There were no differences in ultrasound characteristics between Vicryl 1-0 and 2-0.

The high overall success rate for cutting the suture and removing tethered drains (85.71%) showed that using a Kirschner wire was effective in cutting the suture within the lumen of the drain tube. Out of the 56 attempts, there were eight failed attempts: three attempts took longer than the 5-minute cut-off, two attempts resulted in tube perforation by the Kirschner wire, and in the remaining three attempts, the wire failed to cut the suture. Both instances of perforation involved No. 15 silicone



**Figure 4.** Suture thread adjacent to the inner wall on the drain tube lumen: (A) longitudinal view; (B) cross-sectional view.

tube drains, which were softer and more pliable compared to the No. 10 medium PVC. Upon visual inspection of the three attempts wherein the sutures were not cut, the suture thread was seen tightly adjacent to the inner lumen wall (Figure 4). Thereby, in these instances, the tip and the threaded part of the Kirschner wires introduced into the lumen had limited contact with the suture, making this technique unsuccessful.

The three-way ANOVA analysis of the different variables (wire type, drain diameter, and suture size) yielded no significant differences, implying that these factors (singly or in combination) did not affect the procedure duration.

The success rate was 89.29% when using drain size No. 10 and 82.14% for No. 15 ( $p = 0.449$ ). Lazarides used 1.6 mm wires for No. 10 tubes and 2.5 mm wires for No. 14 tubes, corresponding to the thickest introducer diameter per drain size. For this study, since 2.5 mm Kirschner wires were not available, we used 2.0 mm wires instead. Since the wire was much smaller than the tube, the suture moved around within the lumen, making it more difficult to cut. The success rate was higher for Vicryl 2-0 than 1-0 sutures (92.86% vs 78.57% respectively,  $p = 0.130$ ), likely because the thinner 2-0 suture was easier to completely cut.

For both smooth and threaded wires, the trocar tip's contact with the suture could be felt as the wire was being advanced in and out of the lumen. However, the threaded Kirschner wires provided more tactile feedback than the smooth Kirschner wires, thanks to the additional contact of the threaded portion, and an audible “grittiness.” In terms of palpability of

**Table 5.** Removal success rate

	Success of cutting		p-value
	n	%	
<b>Overall</b>	48	85.71	-
<b>Wire type</b>			
Smooth	24	85.71	1.000
Threaded	24	85.71	
<b>Drain diameter</b>			
No. 10	25	89.29	0.449
No. 15	23	82.14	
<b>Suture size</b>			
Vicryl 1.0	22	78.57	0.130
Vicryl 2.0	26	92.86	

**Table 6.** Three-way interaction ANOVA table

	Type III Sum of Squares	df	Mean Square	F	p-value
<b>Main effects</b>					
Wire type	0.026	1	0.026	0.010	0.919
Drain diameter	3.425	1	3.425	1.340	0.253
Suture size	1.528	1	1.528	0.598	0.443
<b>Two-way interaction</b>					
Wire type x Drain diameter	2.979	1	2.979	1.166	0.286
Wire type x Suture size	13.195	1	13.195	5.164	0.028
Drain diameter x Suture size	0.083	1	0.083	0.032	0.858
<b>Three-way interaction</b>					
Wire Type x Drain Diameter x Suture Size	0.013	1	0.013	0.005	0.944
<b>Residual Error</b>	122.662	48			
<b>Total</b>	284.354	56			

R squared = 0.148 (Adjusted R squared = -0.023)

suture size, Vicryl 1-0, being thicker, was more easily felt by the wire within the lumen tube, regardless of the drain size and wire type used.

Ultimately, preventing drain retention is still more effective than any treatment. When cutting the inner end of the drain, the cut should be made between the holes. This aids in early detection, as pulling out the tube and finding the inner end through holes indicates an unintentional break and drain retention. Jaafar recommended purposefully cutting the drain with a consistent number of holes and documenting this in the surgical technique.<sup>3</sup> During drain removal, the number of holes should be confirmed to be the same. Another technique is to leave slack in the drain such that the black dot (or any mark on the drain denoting the appropriate skin level) is buried below the skin. After closing the wound, the slack is to be pulled out until the marker is at the skin. If the tube glides easily, it is unlikely to be sutured in.<sup>3,13</sup>

## LIMITATIONS AND RECOMMENDATIONS

While the present study's findings provide valuable outcomes, these results must be interpreted with care. This technique may be unsuccessful in cases where the suture stitch is tightly adjacent to the inner lumen wall or is around the tube, rather than through it. Some orthopedic surgeons who are not trained in musculoskeletal ultrasound might encounter difficulty in identifying the drain tube and locating the exact site of tethering. In this study, we did not infiltrate the site with local anesthetic, as in the setting of actual human subjects. Local infiltration can change the echogenicity of the soft tissue surrounding the tethered drain and might affect visualization. We recommend that careful thrusting should be done when removing silicone drain tubes since the material is softer and easier to perforate as compared to medium PVC drain tubes. If available, the authors also recommend the use of threaded Kirschner wires since they provide better tactile and auditory feedback.

Future researchers can investigate applying this technique in cadaveric specimens to simulate human tissue. When considering human subjects, informed consent should be secured. While ultrasound should not pose any undue risk to the patient, proper aseptic technique should be applied for the rest of the procedure.

## CONCLUSION

Here, we report the efficacy of using Kirshner wire with ultrasound guidance to non-invasively remove tethered drains in-vitro. This method may be a first-line option done aseptically at the bedside under local anesthesia.

## STATEMENT OF AUTHORSHIP

All authors certified fulfillment of ICMJE authorship criteria.

## AUTHOR DISCLOSURE

The authors declared no conflict of interest.

## FUNDING SOURCE

None.

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## Negative Pressure Wound Therapy versus Traditional Dressing in Posterior Spinal Surgery: A 10-year Retrospective Study

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### ABSTRACT

**Introduction.** Spine surgical site infections are serious complications with significant morbidity and economic burden. Negative pressure wound therapy has recently become popular in treating open wounds. This study aimed to compare the incidence of infections between patients treated with negative pressure wound therapy and traditional sterile dressing/closed suction drain after posterior spinal surgery.

**Methodology.** This was a retrospective study of patients in Chong Hua Hospital from May 2011 to May 2021. The patients treated from May 2011 to December 2016 received traditional dressing and those treated from January 2017 to May 2021 received NPWT. The rates of post-operative wound dehiscence, postoperative seroma, erythema, and pain were compared.

**Results.** A total of 324 patients were included with 194 patients under the traditional dressing group and 130 under negative pressure wound therapy group. Six patients in the traditional dressing group and two in the NPWT group developed SSIs. All six patients in the NPWT group had risk factors for infection such as multiple comorbidities and high BMI, whereas the two patients in the traditional dressing group had no documented risk factors. All patients from the NPWT group achieved clean closed post-operative sites after debridement and antibiotic treatment whereas one patient from the traditional dressing group underwent a revision surgery.

**Conclusion.** Results were comparable between the two groups. While NPWT showed promise in achieving a clean wound, these results should be interpreted with caution due to the small sample size. Further research is needed.

**Keywords.** Negative Pressure Wound Therapy (NPWT), Surgical Site Infection (SSI), spine surgery, posterior spinal surgery, traditional dressing

### INTRODUCTION

Spinal surgery, due to its complexity and the significant trauma involved, carries considerable risks. This includes the potential for surgical wound infections, complications, and the failure of internal fixation devices. These factors can cause severe pain, prolonged hospital stays, and increased healthcare costs. Postoperative infections in spinal surgery are particularly problematic because they can hinder healing, lead to complications like radiating pain, and necessitate longer recovery periods. This not only burdens the patient with physical and psychological stress but also places additional demands on healthcare resources.<sup>1</sup>

To address this, an alternative to the usual interventions is the use of negative pressure wound therapy (NPWT) immediately after surgery. Increasing NPWT usage for complex soft tissue injuries accelerates wound healing compared to traditional methods. Evidence shows it enhances wound healing by

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reducing edema, increasing the rate of granulation tissue formation, and stimulating circulation. Increased blood flow translates into a reduction in the bacterial load (removal of interstitial tissue) and delivery of infection-fighting leukocytes, thereby, possibly preventing wound complications in patients who underwent spine surgery.<sup>2</sup>

Lower rates of surgical site infection could lead to reductions in costs associated with length of hospital stay, diagnostic tests for microbiology, antibiotic use, and antimicrobial resistance.<sup>3</sup>

The meta-analysis conducted by Lu et al.<sup>4</sup> demonstrated that NPWT is beneficial for spinal surgery patients. NPWT significantly reduced the incidence of surgical wound infections and other postoperative complications. Furthermore, it was associated with a shorter hospitalization duration compared to traditional wound dressings. By enhancing wound healing and reducing the risk of infection and complications, NPWT helps achieve less pain, faster recovery, and a more efficient rehabilitation process. This ultimately leads to lower healthcare costs and an improved overall patient experience.<sup>5</sup>

## METHODOLOGY

This is a retrospective chart review study of patients treated at Chong Hua Hospital from May 2011 to May 2021. The patient population was taken from a group of surgeons who followed a similar protocol: traditional dressing was used from 2011 to 2016, while NPWT was used from 2017 to 2021.

We included patients who underwent posterior spinal surgery (cervical, thoracic, lumbar), and who were treated with negative pressure wound therapy from January 2017 to

May 2021 and with traditional sterile dressing/closed suction drain postoperatively from May 2011 to December 2016.

We excluded patients who underwent anterior cervical spinal surgery, removal of implants, epidural steroid injection, patients with cerebrospinal fluid leak, patients with metastatic/neoplastic tissue in the wound, and patients allergic to NPWT dressing materials.

Evaluation of two groups (Negative pressure wound therapy group vs. Traditional sterile dressing/closed suction drain group) were compared in terms of: wound dehiscence, postoperative seroma, and erythema or pain which would indicate a surgical site infection. Any repeat procedure or intervention for SSI was taken into account including the organisms isolated, antibiotics used and any revision surgery done afterwards. Demographic variables documented were patient's age, sex, BMI, and comorbidities.

All patients underwent primary closure of their postoperative site (Figure 1). Patients' wounds in the traditional dressing group were dressed with sterile pads, foam dressings, silver coated dressings, or other adhesive dressings (Figure 2), with or without a closed suction drain (JP drain, hemovac, or penrose).

The NPWT system included a black polyurethane soft foam which is cut to fit the entire post-surgical area (closed primarily). A transparent adhesive fluid- and gas-impermeable film sealed the wound and surrounding skin. A hole was then cut in the center, covered with a pre-cut adhesive which connected to the machine with a suction tube (Figure 3). A negative pressure of 125 mmHg was intermittently generated,



Figure 1. Post-operative site.



Figure 2. Wound dressing under negative pressure.



Figure 3. Traditional sterile dressing.

collapsing the foam, generating a uniform vacuum, evacuating the wound fluid into the container. The NPWT dressing was maintained for about 7 to 14 days, depending on the amount of fluid. For older patients with delicate skin, pressure was decreased to -105 intermittent pressure to avoid blisters or ulcer formation.

## RESULTS

Between May 2011 to May 2021, 439 patients underwent spine surgery, 324 of whom underwent posterior spinal surgeries (Table 1).

Of the 324 patients, 194 patients were treated with traditional dressing postoperatively. Out of the 194 patients, six patients (Table 2) developed surgical site infections (incidence rate of 3.1%) (Tables 3 and 4). The mean age affected was 50 years old. There were four women and two men. Out of the

130 patients treated with NPWT dressing, two developed superficial infections (Table 5) suggesting an incidence rate of 1.5% with a mean affected age of 50 years old. Both patients were men (Tables 3 and 4).

All patients from the NPWT group achieved clean closed post-operative sites after undergoing debridement and appropriate antibiotic use. One patient from the traditional dressing group underwent a revision surgery after two years. None of the patients had a recurrence after the appropriate treatment.

## DISCUSSION

There was no statistically significant difference in the baseline demographics, incidence of comorbidities, and infection rate between the two groups. The cause of the revision surgery in one patient from the traditional dressing group was implant loosening, attributed to infection after the first surgery (Table 5).

There was no significant difference between the two groups in terms of BMI and incidence of comorbidities. Of those who developed infections, two of the six patients in the traditional dressing group had normal BMI and no comorbidities, while both patients in the NPWT group had high BMI and multiple comorbidities (Tables 5 and 6).

The NPWT group achieved clean and closed postoperative sites, highlighting NPWT's potential benefits in wound management, particularly in lessening the number of

**Table 1.** The profile of the patients who underwent spine surgery, n = 324

Characteristics	Patients with:	
	Traditional dressing n = 194	NPWT dressing n = 130
Age, in years <sup>#</sup>	48.10 (20.10)	45.48 (22.08)
Sex <sup>*</sup>		
Male	88 (45.36)	63 (48.46)
Female	106 (54.64)	67 (51.54)

Note: Values in <sup>#</sup>mean (Standard Deviation) and in <sup>\*</sup>frequency (Percentage).

**Table 2.** NPWT dressing

Patient	Age/ Sex	Diagnosis	Procedure/ Duration	Blood loss	BMI	Comorbidities	NPWT removed (Postop day)	Culture and sensitivity	Antibiotics	Treatment
1	15/M	Adolescent idiopathic scoliosis	Scoliosis surgery; 5 hours	600cc	25.5	None	7 days	<i>Pseudomonas stutzeri</i>	Clindamycin and Oxacillin	Debridement x 1 reapplication of NPWT - No recurrence; 3 days after detection
2	81/M	Lumbar spinal stenosis L3-L4, L4-L5	Lumbar laminotomy, PSF; 5 hours	600cc	26.5	Hypertensive, Diabetes Mellitus, Bronchial asthma, Chronic obstructive pulmonary disease	2 weeks	Methicillin-resistant <i>Staphylococcus aureus</i>	Ciprofloxacin and Linezolid	Debridement x1 reapplication of NPWT - No recurrence; 4 days after detection

**Table 3.** The incidence rate of infection of the patients who underwent spine surgery, n = 324

Incidence rate	Patients with:		
		Traditional dressing	NPWT dressing
Overall	Value	6 (3.09)	2 (1.54)
	n	194	130
<b>According to Sex</b>			
Male	Value	2 (2.27)	2 (3.17)
	n	88	63
Female	Value	4 (3.77)	0 (0.00)
	n	106	67

Note: Values in frequency (Incidence Rate in %)

**Table 4.** The comparative analysis of the incidence rate of infection of the patients who underwent spine surgery, n = 324

Incidence rate	Patients with:			Chi-squared (P-value)
		Traditional dressing	NPWT dressing	
Overall	Value	6 (3.09)	2 (1.54)	0.774 (0.379)
	n	194	130	
<b>According to Sex</b>				
Male	Value	2 (2.27)	2 (3.17)	0.115 (0.735)
	n	88	63	
Female	Value	4 (3.77)	0 (0.00)	2.571 (0.109)
	n	106	67	

Note: Values in frequency (Incidence Rate in %); \*Significant at 0.05 using "N-1" Chi-squared test as recommended by Campbell<sup>7</sup> and Richardson.<sup>8</sup>

**Table 5.** Traditional dressing

Patient	Age/ Sex	Diagnosis	Procedure/ Duration	Blood loss	BMI	Comorbidities	Culture and sensitivity	Antibiotics	Treatment
1	62/M	Lumbar spinal stenosis L4-L5	Lumbar laminotomy, PSF; 5 hours	600cc	26.3	Hypertensive	<i>Pseudomonas aeruginosa</i>	Piperacillin-tazobactam	Debridement x1, 3 days after detection
2	68/M	Lumbar spinal stenosis L4-L5	Lumbar laminotomy, PSF; 4 hours	500cc	31.61	Hypertensive	Methicillin-resistant <i>Staphylococcus epidermidis</i>	Linezolid	Debridement x1, 4 days after detection
3	68/F	Lumbar spinal stenosis L4-L5	Lumbar laminotomy, PSF; 4 hours	400cc	23.4	Hypertensive	<i>Escherichia coli</i>	Metronidazole	Debridement x1, 4 days after detection
4	13/F	Adolescent idiopathic scoliosis	Scoliosis surgery; 4 hours	500cc	20.59	None	No growth	Cefuroxime	Debridement x1, 2 days after detection
5	57/F	Burst fracture sec to MVA	Thoracic laminectomy PSF; 4.5 hours	300cc	24.6	Diabetes Mellitus	<i>Mycobacterium tuberculosis</i>	Cefuroxime and HRZE	Debridement x1, 3 days after detection
6	13/F	Adolescent idiopathic scoliosis	Scoliosis surgery; 4 hours	500cc	18.87	None	<i>Klebsiella pneumoniae</i>	Cefuroxime	Debridement x2 – Revision of scoliosis surgery (2 years after)

**Table 6.** The demographic and medical profile of the patients with infection after the spine surgery, n = 8

Characteristics	Patients with:		Test statistic (P-value)
	Traditional dressing n = 6	NPWT dressing n = 2	
Age, in years*	59.50	48.00	-0.506 (0.613) <sup>A</sup>
Sex <sup>†</sup>			
Male	2 (33.33)	2 (100.00)	2.334 (0.1266) <sup>B</sup>
Female	4 (66.67)	0 (0.00)	2.334 (0.1266) <sup>B</sup>
Body Mass Index <sup>#</sup>	24.23 (4.51)	26.02 (0.69)	-0.531 (0.615) <sup>C</sup>
Comorbidities <sup>†</sup>			
Diabetes Mellitus	1 (16.67)	1 (50.00)	-(0.766) <sup>D</sup>
Hypertensive	3 (50.00)	1 (50.00)	
Bronchial Asthma	0 (0.00)	1 (50.00)	
Chronic Obstructive Pulmonary Disease	0 (0.00)	1 (50.00)	
None	2 (33.33)	1 (50.00)	

Note: Values in \*mean (Standard Deviation), in †frequency (percentage), in ‡median; \*Significant at 0.05 using <sup>A</sup>Mann-Whitney U Test, using <sup>B</sup>“N-1” Chi-squared test as recommended by Campbell<sup>7</sup> and Richardson<sup>8</sup>, using <sup>C</sup>T-Test for two independent samples, and using <sup>D</sup>Fisher’s Exact Test

dressing changes and reducing exposure to environmental contaminants. This suggests that NPWT provides a controlled healing environment, with benefits that extend beyond direct wound healing.<sup>5</sup>

NPWT is versatile and can be applied to clean, nonhealing, or infected wounds. This raises the question of whether its effectiveness is context-dependent; further research is needed to establish guidelines for its use in different types of wounds.

## CONCLUSION

The study demonstrates comparable results between the two groups. While NPWT shows promise in managing clean, closed postoperative sites, its application, mechanisms of action, and comparative effectiveness in various contexts should be further explored. To minimize the risk of infection following posterior spinal surgery, patients should also be evaluated for risk factors that also impact wound healing and recovery. The results should be interpreted with caution due to the limited number of patients in the study. In the future, it is suggested that a prospective study is done with controlled variables to reduce bias and validate the efficacy of NPWT in spinal surgery.

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## STATEMENT OF AUTHORSHIP

All authors certified fulfillment of ICMJE authorship criteria.

## AUTHOR DISCLOSURE

The authors declared no conflict of interest.

## FUNDING SOURCE

None.

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## Meta-analysis of Randomized Controlled Trials: Comparing Standard versus Stump-preserving Techniques in Anterior Cruciate Ligament Reconstruction Using An Autologous Hamstring Graft

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### ABSTRACT

**Background.** Anterior cruciate ligament (ACL) injuries are prevalent among younger demographics due to sports-related incidents, contributing to knee joint instability. Current anterior cruciate ligament reconstruction (ACLR) involves either debriding the stump (standard) or preserving the stump (stump-preserving), which retains the vascular network and mechanoreceptors in the tibial stump, aiming to improve postoperative outcomes. The autologous hamstring tendon graft is the most used, providing a higher maximum load to failure than bone-patellar tendon-bone grafts.

**Objective.** This meta-analysis aimed to compare outcomes between the standard and stump-preserving ACLR techniques using an autologous hamstring tendon graft. The specific objectives were to evaluate primary outcomes (Lysholm Scores and the KT-1000 Arthrometer results), secondary outcomes (International Knee Documentation Committee (IKDC) Scores, results of the Lachman and pivot shift tests), and postoperative complications.

**Methodology.** The authors comprehensively searched PubMed, Embase, Cochrane Library, and grey literature, identifying randomized controlled trials meeting the inclusion criteria. Study characteristics and participant information were extracted, and potential bias was assessed using the Cochrane Collaboration methodology.

**Result.** Ten studies, encompassing 552 patients, met the inclusion criteria. Lysholm score and KT-1000 arthrometer results favored the stump-preserving group, achieving statistical significance. IKDC, pivot shift test and Lachman test favored the stump-preserving group, without statistical significance. Postoperative complications exhibited a higher incidence in the stump-preserving group, favoring the standard group, without statistical significance.

**Conclusion.** The meta-analysis suggested advantages in outcomes for stump-preserving ACLR, achieving statistical significance for the Lysholm scores and the KT-1000 arthrometer results. The stump-preserving group had better results in the IKDC scores, the pivot shift test results and the Lachman test results, while the standard group had fewer postoperative complications, but statistical significance was not achieved. In conclusion, while stump-preserving ACLR demonstrated promising trends in enhancing postoperative outcomes, further studies are necessary.

**Keywords.** anterior cruciate ligament reconstruction, ACL, stump, preservation, stump-preserving, remnant

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## INTRODUCTION

The anterior and posterior cruciate ligaments work in tandem to prevent excessive anterior and posterior movement of the tibia relative to the femur. The anterior cruciate ligament (ACL) also provides rotational stability.<sup>1</sup> The anterior cruciate ligament (ACL) injury is one of the most common knee injuries worldwide. An ACL rupture or tear can occur with both contact and non-contact injuries and is often caused by knee hyperextension or a sudden change in direction.<sup>2</sup>

ACL injuries are generally seen in the younger population, especially those 20–24 years old. Sports-related injuries are more often seen in females while the overall incidence is higher in males.<sup>3,4</sup> In contrast to developed countries, in developing countries, road traffic accidents are the leading cause.<sup>5</sup>

The nonviability of the frayed edges of the injured ACL precludes successful repair. Anterior cruciate ligament reconstruction (ACLR) is the mainstay of management. For a primary ACLR, approximately 90% of the time, single-bundle reconstruction is performed. The hamstring tendon was the most used autograft at 53%, followed by the bone-patellar tendon-bone (BPTB) graft at 36%,<sup>6</sup> both being the gold standard for the younger population.<sup>7</sup> The standard or conventional ACLR technique involves debridement of the ACL stump before placement of the autograft.

In recent years, the stump-preserving technique has received more attention, but studies are few, with small populations and short follow-up periods. Preserving the ACL stump may promote cell proliferation, healing, and improved proprioception due to the presence of a vascular network and viable mechanoreceptors.<sup>8-12</sup> Takahashi et al. concluded that preserving the ACL remnant enhanced the overall cell proliferation, cell vascularization, and regeneration of the proprioceptive organs in the ACL graft, and ultimately reduced anterior tibial translation.<sup>13-16</sup> This was further supported by Gohil et al., who noticed increased tissue intensity on Magnetic Resonance Imaging (MRI), suggesting earlier revascularization.<sup>17</sup> The stump may also be used as a landmark for the placement of the autograft.<sup>18</sup> Current practice largely depends on the surgeon's preference.

The cyclops lesion was described by Jackson and Schaeffer in 1990 as an incidental finding of a fibrous nodule of granulation tissue anterior to the graft.<sup>19-21</sup> This occurred in 3.9% of patients who underwent stump-preserving ACLR.<sup>20-24</sup> Most cases are asymptomatic, but symptomatic lesions can be surgically excised.<sup>24-28</sup>

Previous meta-analyses by Wang et al. and Allende et al. have studied this topic. However, there is concern regarding heterogeneity in the studies and variability among the grafts used (inclusion of grafts other than autologous hamstring).<sup>29,30</sup>

We investigated whether individuals who underwent ACL stump-preserving techniques had better patient-reported

outcomes compared to the traditional standard ACL reconstruction. Specifically, we used the following outcomes: 1) the Lysholm score, which assesses subjective knee-specific symptoms; 2) the measurement of anterior tibial translation using the KT-1000 Arthrometer; 3) the International Knee Documentation Committee (IKDC) score, which subjectively measures functional outcomes; 4) the Lachman test, which also passively tests anterior tibial translation; 5) the pivot shift test, a dynamic test of the knee to assess rotational instability, and 6) the prevalence of postoperative complications.

Our rationale was to establish whether the stump-preserving technique's theoretical anatomic and physiological benefits translate into measurable clinical improvement in terms of patient-reported outcomes and objective measurements. To address existing limitations, we focused exclusively on randomized controlled trials using autologous hamstring grafts. We assessed both functional outcome scores and objective measurements for a comprehensive evaluation.

## OBJECTIVES

### General objective

The study aimed to evaluate the effectiveness of ACL reconstruction using the stump-preserving technique compared to the standard technique.

### Specific objectives

1. Evaluate the Lysholm score to assess knee function and symptoms
2. Measure anterior tibial translation using the KT-1000 Arthrometer
3. Assess overall knee function using the IKDC Score
4. Evaluate anterior knee laxity with the Lachman and pivot shift tests
5. Monitor and document any postoperative complications, including the incidence of cyclops lesions, to compare the safety

## METHODOLOGY

### Search strategy

A comprehensive search of literature in PubMed, Embase, Cochrane Library, and grey literature was performed. Studies published from 2007 to 2024 were considered for meta-analysis. The initial search began in August 2024, and then a more comprehensive search was conducted between November and December 2024. Search terms include “anterior cruciate ligament reconstruction,” “ACL,” “stump,” and “remnant.” The Boolean terms “OR” and “AND” were applied along with the search terms in the PubMed database for randomized controlled trials, as follows “remnant OR stump” AND “anterior cruciate ligament reconstruction” AND “ACL,” which resulted in four hundred thirty-five studies.

### Inclusion and exclusion criteria

We included randomized controlled trials comparing the standard ACLR technique and the stump-preserving ACLR technique in humans using autologous hamstring grafts. Studies must have had a minimum of six months of follow-up with documentation of the Lysholm scores, KT-1000 arthrometer results, IKDC scores, Lachman test results, pivot shift test results and incidence of postoperative complications for both techniques. Non-comparative clinical trials, studies using any graft other than an autologous hamstring allograft, animal experiments, retrospective studies, reviews, case reports, and non-English language publications were excluded.

### Risk of bias assessment

The researchers evaluated potential bias using the Cochrane Handbook for Systematic Reviews of Interventions criteria. The following domains were examined: bias related to the randomization process, bias resulting from deviations from intended interventions, bias due to missing outcome data, bias in outcome measurement, bias in result selection, and any other sources of bias.

Each potential source of bias was categorized as "high," "low," or "some concerns," and presented in a "Risk of Bias" table. The researchers provided a summary of the "Risk of Bias" judgments across the various studies for each of the specified domains. An overall assessment, categorized as low risk of bias, some concerns, or high risk of bias, was assigned to each study. The researchers did not exclude studies based on their potential for bias.

### Data extraction

The researchers extracted data on study characteristics (such as publication year, author names, study countries, study duration, and participant withdrawals), as well as participant information (comprising sample size, age, sex, and inclusion and exclusion criteria).

### Outcomes

The outcomes of the studies that were included were the postoperative Lysholm score, the KT-1000 Arthrometer, the IKDC score, the Lachman test, the pivot shift test, and the incidence of postoperative complications.

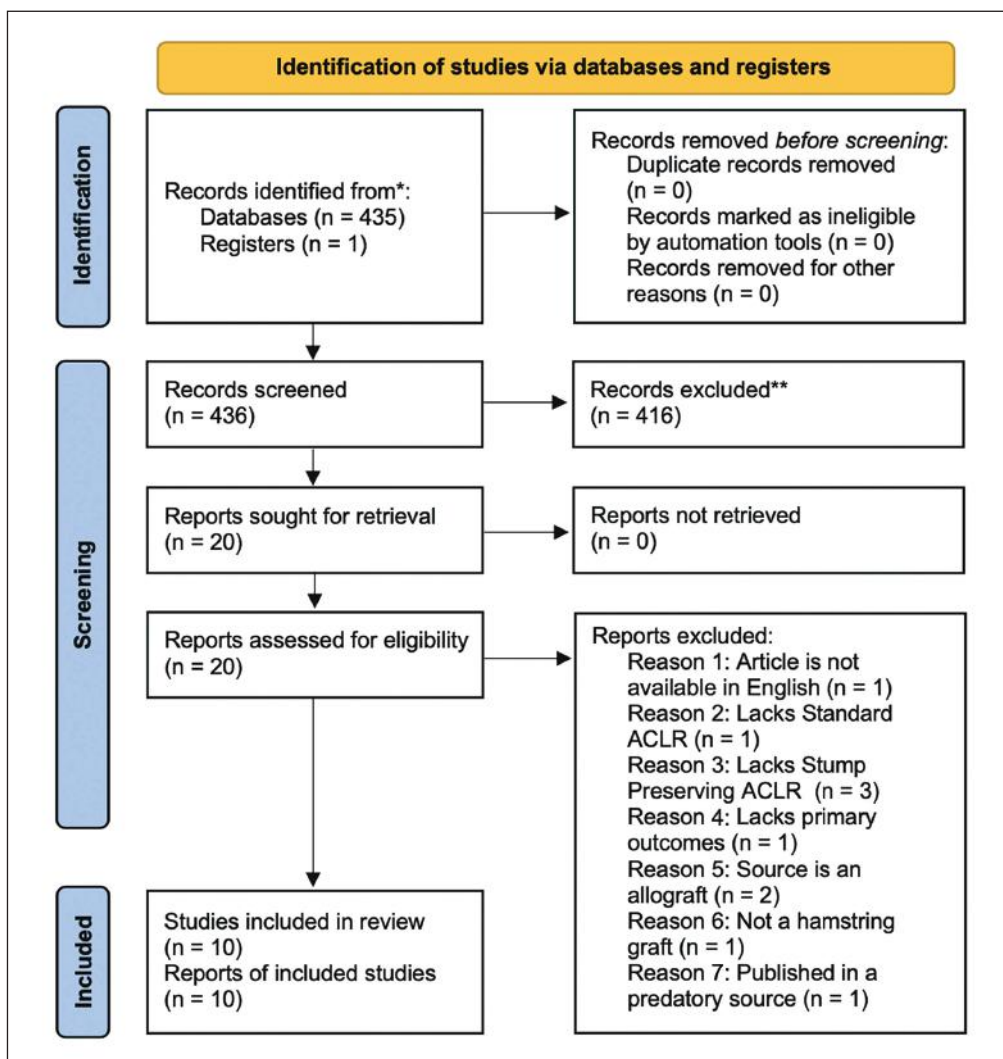


Figure 1. Systematic selection of articles.

### Assessment of heterogeneity

Heterogeneity was assessed using the Chi-square test and I<sup>2</sup> Index. An I<sup>2</sup> of less than 50% indicates no statistical heterogeneity between studies while an I<sup>2</sup> of greater than 50% indicates statistical heterogeneity.

### Statistical analysis

Data synthesis and analysis were conducted using RevMan 5.4 software. A Forest plot was generated to tabulate and visually represent the data from the selected studies.

This study was conducted by four members of the Department of Orthopaedic Surgery at Veterans Memorial Medical Center, including a Fellow of the Philippine Orthopaedic Society of Sports Medicine and a Fellow of the Philippine Orthopaedic Association. Disagreements between the researchers were settled by a majority vote.

## RESULTS

Using the search terms above, 435 records were retrieved from PubMed, Embase, and Cochrane Library, and one published record was retrieved from a different source (Figure 1). After screening the titles and abstracts, twenty articles fulfilled the

criteria. We excluded ten studies for the following reasons: one study was not available in English, one study lacked the Standard ACLR, three studies lacked the Stump Preserving ACLR, one study lacked the primary outcomes, two studies utilized a hamstring allograft, one study utilized a bone patellar tendon bone graft, and one study was published in a predatory source. A total of ten studies were assessed to be eligible and were included in this research.

All ten studies demonstrated a low risk of selective reporting bias, with most studies also showing a low risk of detection and attrition bias regarding blinding of outcome assessment and handling of incomplete outcome data (Figures 2 and 3). However, there were notable concerns regarding selection bias in most studies, particularly related to random sequence generation and allocation concealment. Additionally, the studies exhibited possible performance bias due to limitations in the blinding process, and other sources of bias partly due to the sample sizes involved.

A total of 552 patients were included, with 283 patients in the standard ACLR group (Group A) and 269 patients in the stump-preserving group (Table 1). Years of publication ranged from 2012 to 2022 (Table 2). Six studies reported Lysholm scores, six studies used the KT-100 arthrometer, three studies reported IKDC scores, two studies reported Lachman test, and three studies reported the pivot shift test results and the incidence of postoperative complications.

The pooled difference of -1.15 of the Lysholm score (95% CI [-2.06, -0.25], *p* = 0.01, I<sup>2</sup> 0%) favored stump-preserving ACLR (Figure 4). This difference was statistically significant.

The pooled KT-100 arthrometer measurement was 0.28 (95% CI [0.13, 0.43], *p* = 0.002, I<sup>2</sup> 54%), indicating greater postoperative laxity in the standard ACLR group (Figure 5). The difference was statistically significant.

The pooled IKDC score was 0.73 (95% CI [0.39, 1.35], *p* = 0.31, I<sup>2</sup> 60%), favoring the stump-preserving group, but not achieving statistical significance (Figure 6).

The pooled Lachman test result was 1.46 (95% CI [0.54, 3.96], *p* = 0.45, I<sup>2</sup> 0%) indicating greater postoperative laxity in the standard ACLR group, without achieving statistical significance (Figure 7).

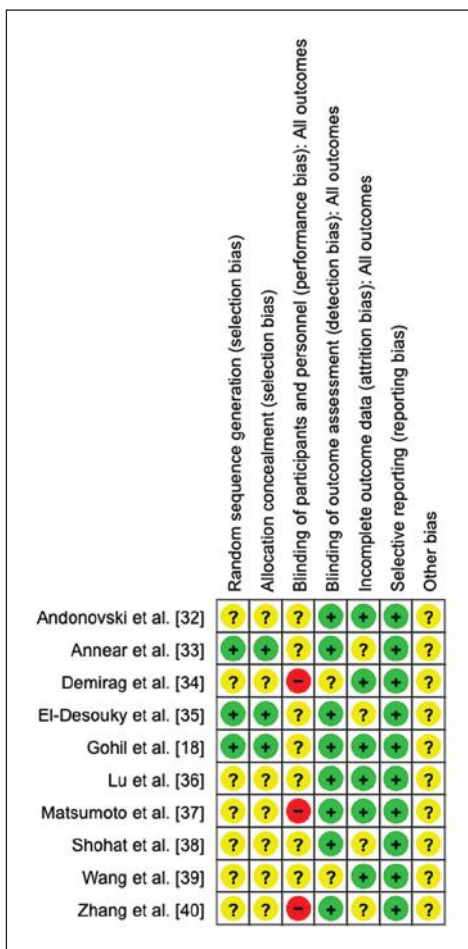


Figure 3. Individual risk of bias assessment.

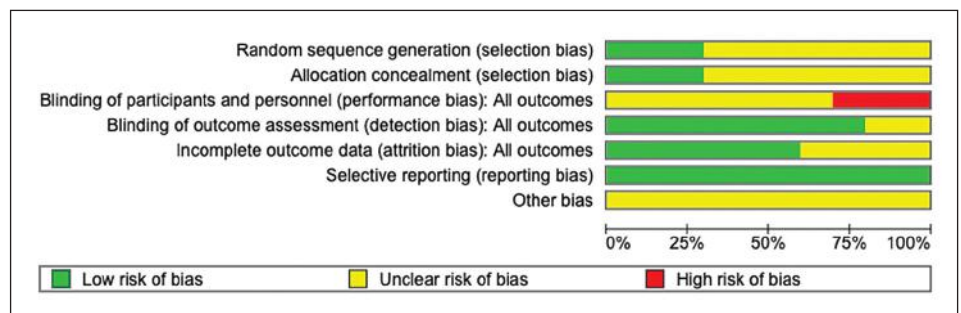


Figure 2. Overall risk of bias assessment.

The pooled pivot shift test result was 1.17 (95% CI [0.39, 3.48],  $p = 0.78$ , I2 0%), which indicates greater postoperative laxity in the standard group, without statistical significance (Figure 8). In the three studies that reported complications, 22 complications occurred in the 98 cases in the standard group

and 28 complications occurred in the 100 cases in the stump-preserving group. The pooled result was 0.69 (95% CI [0.35, 1.37],  $p = 0.29$ , I2 0%) indicating a greater incidence of postoperative complications in the stump-preserving group, without statistical significance (Figure 9).

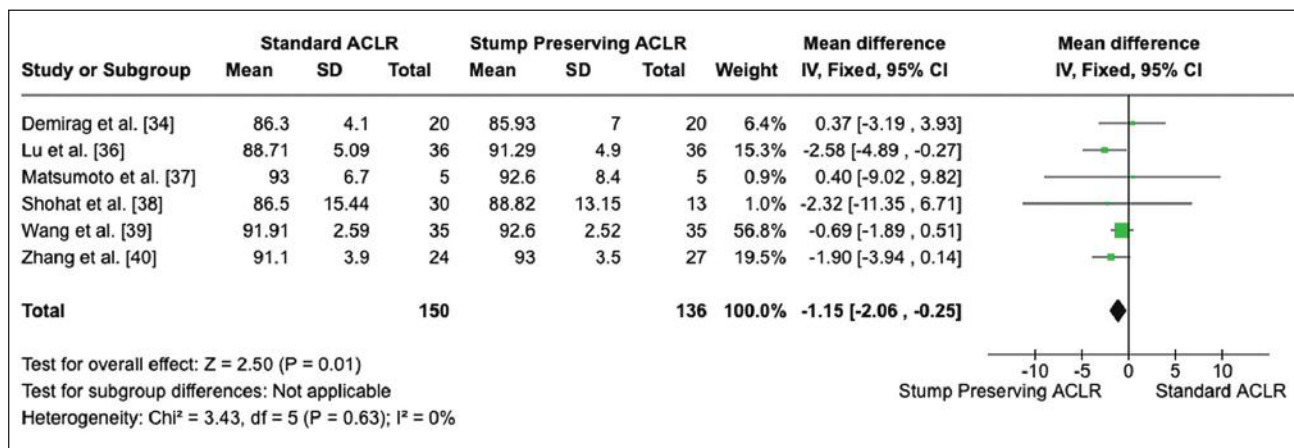


Figure 4. Forest plot for the Lysholm scores.  
 CI: Confidence Interval; IV: Inverse Variance.

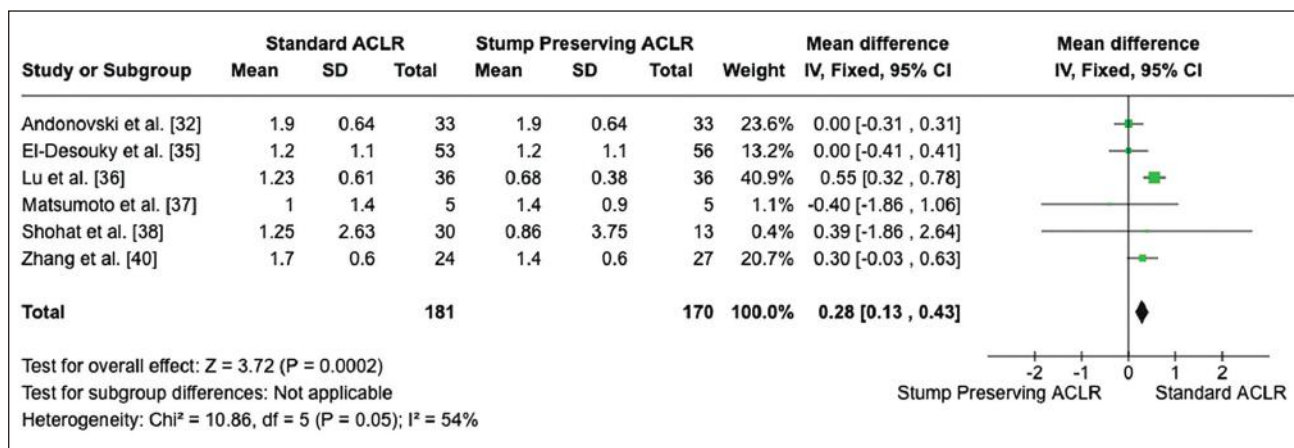


Figure 5. Forest plot for the KT-1000 arthrometer.  
 CI: Confidence Interval; IV: Inverse Variance.

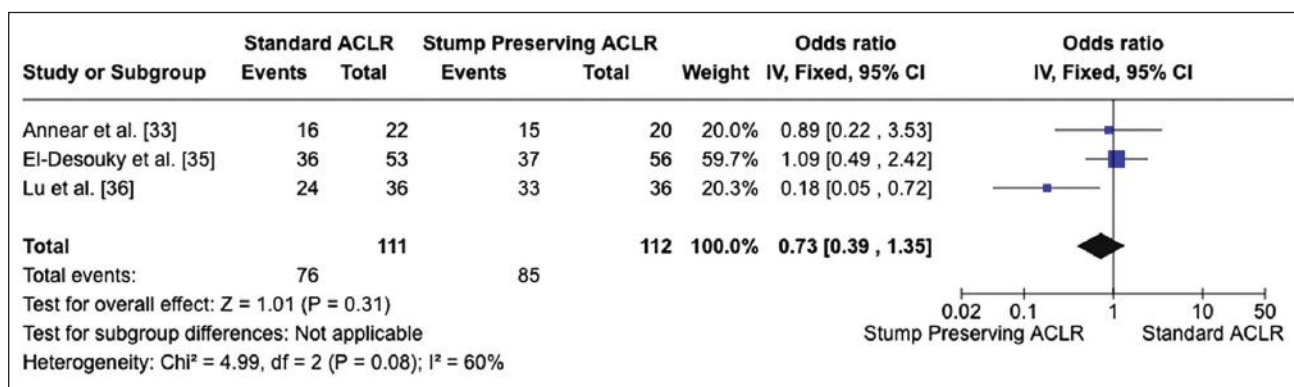


Figure 6. Forest plot for the IKDC score.  
 CI: Confidence Interval; MH: Mantel-Haenszel.

## DISCUSSION

The principal findings of this meta-analysis were as follows: 1) Stump-preserving ACLR resulted in higher Lysholm Scores, with the difference being statistically significant. 2) Stump-preserving ACLR resulted in less postoperative anteroposterior knee laxity as measured by the KT-100 arthrometer, with the difference being statistically significant. 3) Stump-preserving

ACLR resulted in superior IKDC scores, however the difference was not statistically significant. 4) Stump-preserving ACLR had less postoperative laxity as measured by the Lachman test and the pivot shift test, with the difference not being statistically significant. 5) Stump-preserving ACLR resulted in more postoperative complications, with the difference not being statistically significant.

**Table 1.** Study data characteristics

Study	Patients	Follow-up	Outcome Measure	Results	Complications	Conclusion
<i>Andonovski et al.<sup>32</sup></i>	Group A: 33 Group B: 33	6-8 months	KT-1000, *Lysholm Score, *Tegner Activity Score	Statistically significant postoperative improvement in anteroposterior knee stability, favoring Group B. Improvement in Lysholm Score and Tegner Activity for Group B, however, significance was not mentioned.	N/A	The stump-preserving technique provides better anteroposterior knee stability and a better proprioceptive function.
<i>Annear et al.<sup>33</sup></i>	Group A: 22 Group B: 20	10 years	IKDC Score	No significant difference in IKDC scores.	N/A	No long-term clinical. the benefit of remnant preserved ACLR
<i>Demirag et al.<sup>34</sup></i>	Group A: 20 Group B: 20	24.3 months	*IKDC Score, Lysholm Score, Lachman, Pivot Shift Test, Cyclops Lesion	IKDC and Lysholm scores improved, however not significant, favoring Group B.	Cyclops lesion (Group B: 1) Arthrofibrosis (Group A: 7; Group B: 7)	The stump-preserving technique is comparable to the standard technique concerning clinical. outcome and complications
<i>El-Desouky et al.<sup>35</sup></i>	Group A: 53 Group B: 56	24 months	IKDC Score, *Lysholm and Tegner Activity scores, and KT-1000, Cyclops Lesion	No significant difference between Group A and B for the IKDC, Lysholm, and Tegner Activity scores	Infection (Group B: 1) Hematoma (Group A: 2; Group B: 3) Quadriceps wasting (Group A: 3; Group B: 3) DVT (Group A: 1)	Stump preserving had better IKDC, Lysholm, and Tegner Activity scores, however it did not achieve statistical. significance. KT-1000 assessment revealed no statistical. significance between the two groups.
<i>Gohil et al.<sup>36</sup></i>	Group A: 25 Group B: 24	12 months	*KT-1000, *IKDC Score, Cyclops Lesion, *Lachman Test	No significant difference between the KT-1000 measurement, IKDC Score, Cyclops Lesion, and Lachman Test.	Cyclops lesion (Group A: 9) Group B: 13)	Minimal debridement leads to earlier revascularization, accelerating the strength of recovery.
<i>Lu et al.<sup>36</sup></i>	Group A: 36 Group B: 36	24 months	KT-1000, *Tegner Activity Score, Lysholm Score, IKDC Score, Pivot Shift Test	A significant difference in KT-2000 arthrometer measurement and Lysholm scores, favoring Group B.	Knee Instability (Group A: 2)	ACLR utilizing the existing remnant footprint shows superior postoperative results in anteroposterior laxity, functional outcome scoring, ROM recovery, and revision cases.
<i>Matsumoto et al.<sup>37</sup></i>	Group A: 5 Group B: 5	24 months	Lysholm Score, KT-1000, Pivot Shift Test	No significant difference between Group A and B for the Lysholm Score, KT-1000 assessment, and the Pivot Shift Test	N/A	No significant difference between the clinical outcomes of stump-preserving and the standard ACLR technique.
<i>Shohat et al.<sup>38</sup></i>	Group A: 30 Group B: 13	24 months	*Knee Society Score (KSS), *Visual Analog Scale (VAS), Lysholm Score, *Tegner Activity Score, *Short Form Health Survey 36, KT-1000, *Thigh and Calf Circumference Measurement	No significant difference in functional outcome scores, VAS, or KSS. KT-1000 arthrometer measurements favored Group B, however not statistically significant.	N/A	No statistically significant difference between the two groups, however further studies are required on a larger group of patients.
<i>Wang et al.<sup>39</sup></i>	Group A: 35 Group B: 35	12 months	Lysholm Score, *IKDC Score, Lachman Test,	Lysholm and IKDC scores were superior in Group B, but the difference was not statistically significant.	N/A	Utilizing the modified Crain classification, remnant preserving techniques can be used to preserve the remnant ligament tissue to improve knee joint function and joint stability with few complications.
<i>Zhang et al.<sup>40</sup></i>	Group A: 24 Group B: 27	24.5 months	Lysholm Score, KT-1000	The Lysholm Score for Group B had a higher increase however it was not statistically significant. The difference between the KT-1000 assessment was not statistically significant.	N/A	Stump preservation does not affect short-term clinical outcomes even though there are higher Lysholm Scores and better knee laxity.

Group A = Standard ACLR; Group B = Stump Preserving ACLR; IKDC = International Knee Documentation Committee; KT- 1000/2000 = Knee Arthrometer; N/A = Not applicable; \*Not included in the study

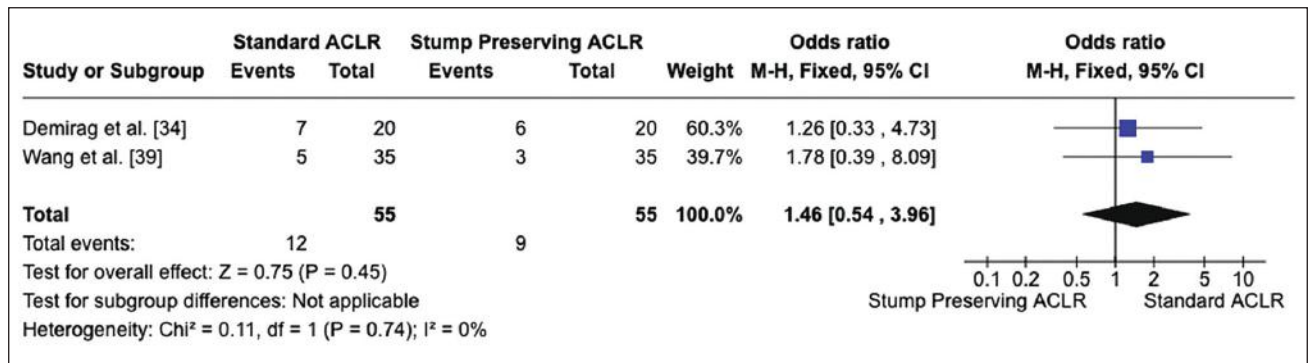


Figure 7. Forest plot for the Lachman test.

CI: Confidence Interval; MH: Mantel-Haenszel.

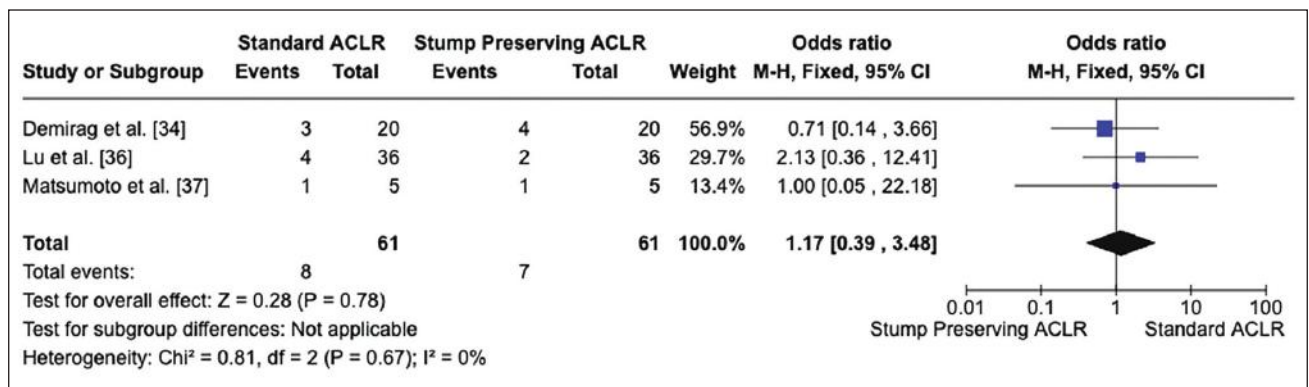


Figure 8. Forest plot for the pivot shift test.

CI: Confidence Interval; MH: Mantel-Haenszel.

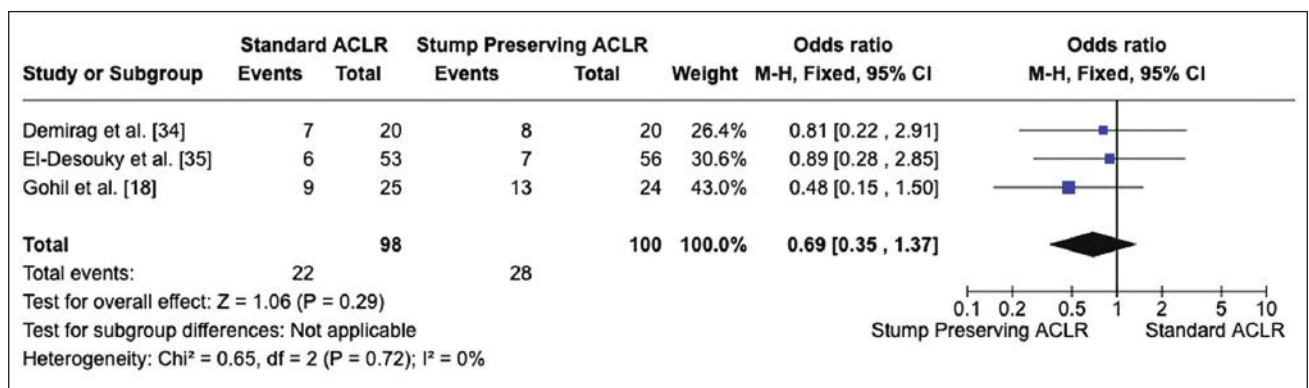


Figure 9. Forest plot for the postoperative complications.

CI: Confidence Interval; MH: Mantel-Haenszel.

Table 2. Study characteristics

Study	Publication Year	Country	Type of Study	Level Evidence
Andonovski et al. <sup>32</sup>	2017	Macedonia	Randomized Controlled Trial	II
Annear et al. <sup>33</sup>	2018	Australia	Randomized Controlled Trial	I
Demirag et al. <sup>34</sup>	2012	Turkey	Randomized Controlled Trial	II
El-Desouky et al. <sup>35</sup>	2022	Egypt	Randomized Controlled Trial	I
Gohil et al. <sup>18</sup>	2007	Australia	Randomized Controlled Trial	II
Lu et al. <sup>36</sup>	2015	China	Randomized Controlled Trial	II
Matsumoto et al. <sup>37</sup>	2013	Japan	Randomized Controlled Trial	II
Shohat et al. <sup>36</sup>	2017	Israel	Randomized Controlled Trial	II
Wang et al. <sup>39</sup>	2022	China	Randomized Controlled Trial	II
Zhang et al. <sup>40</sup>	2012	China	Randomized Controlled Trial	I

A similar recent meta-analysis by Wang et al. compared the same two groups,<sup>29</sup> but lacked high-quality studies. Allende et al.'s meta-analysis also lacked high-quality studies and additionally included different grafts.<sup>30</sup> To minimize bias, this research exclusively focused on randomized controlled trials studying autologous hamstring grafts. Both this study and the Allende et al. meta-analysis found no statistically significant difference in IKDC scores and incidence of complications between the two groups. In contrast to this study, Allende et al. found a statistically significant difference in pivot shift test results, no significant difference in Lysholm scores and KT-1000 results, and did not report on the results of the Lachman test.

The stump-preserving ACLR technique is gaining popularity as an alternative to the standard technique due to the stump's vascular network which improves cell proliferation, and mechanoreceptors providing proprioception.

## CONCLUSION

Stump-preserving ACLR resulted in better Lysholm scores and less anteroposterior laxity as measured by the KT-100 arthrometer. For all other outcomes, no statistically significant difference was found between the groups. The choice of the Standard ACLR technique or the stump-preserving ACLR technique will ultimately depend on the surgeon's preference, since at this time, one technique does not hold an advantage over the other.

We encountered several limitations, one of which is the scarcity of published studies that fit our criteria. This may be due to the procedure's novelty.<sup>31</sup> One of the ten studies included was sourced from a database outside of PubMed, Embase, and the Cochrane Library. We also had a short follow-up duration of less than two years, with one study (Andonovski et al.) reporting a follow-up period of only 6–8 months.<sup>32</sup> We also encountered bias across multiple domains. Some studies had a high risk of performance bias due to inadequate blinding. Detection bias related to blinding of outcome assessment was also prevalent, raising concerns about the objectivity of the results. Furthermore, selection bias was unclear, particularly regarding allocation concealment, while attrition bias and reporting bias were generally well managed.

More clinical trials with larger populations are needed. In addition to increasing the sample size, alternative outcome measures, such as the hop test, can be studied. Another important outcome is the time required to return to sport.

## STATEMENT OF AUTHORSHIP

All authors certified fulfillment of ICMJE authorship criteria.

## AUTHOR DISCLOSURE

The authors declared no conflict of interest.

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## Management of a Polytrauma Patient with L4 Bony Fracture-Dislocation, Multi-Level L1-L3 Flexion-Distractio (Bony Chance) Injuries, Lateral Compression III Pelvic Injury, and Lower Extremity Fractures: A Case Report

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### ABSTRACT

This is the first documented case of a neurologically impaired polytrauma patient with multiple bony Chance injuries, a windswept pelvis, and lower extremity fractures.

The patient was a male miner in his mid-30s who incurred multiple injuries in his lower extremities and spine. He initially consulted at a secondary care facility but transferred hospitals for further management.

The index surgery was done four days post-injury (beyond 72 hours) and included open reduction, and stabilization of the affected spinal segments with pedicle screws/rods from the thoracolumbar spine to both sacroiliac joints. The patient was discharged after debridement for a surgical site infection of the spine, and definitive fixation of the right femur and left tibial plateau. At one year follow-up, the patient was ambulatory without assistance and with no complications.

In dealing with polytrauma patients with multiple spinal, pelvic, and lower extremity fractures, early treatment is recommended to prevent future complications.

**Keywords.** case report, polytrauma, Chance fracture, fracture-dislocation, flexion-distractio, spine

### INTRODUCTION

Fracture-dislocations of the thoracolumbar spine are unstable injuries disrupting the three columns of the spine. These may be subdivided into flexion-rotation, shear, and flexion-distractio types. These must be immediately stabilized regardless of neurologic status.<sup>1-3</sup>

Flexion-distractio injuries, also known as Chance fractures or Chance variants, commonly occur with lap belt car restraints, and come with a high incidence of concomitant intraabdominal injuries. For isolated injuries with minimal angulation, brace treatment may be successful. Unstable injuries warrant surgical management, typically consisting of posterior pedicle screw instrumentation and fusion across the injured levels.<sup>4</sup> However, if this type of fixation is not possible, posterior pedicle screw instrumentation and fusion limited to two levels above and below the injury would be sufficient.<sup>1,4</sup>

Lateral Compression III fractures of the pelvis (“windswept pelvis”) must be reduced and fixed. The recommendation is to apply a sacroiliac screw for unilateral injuries and transiliac screws for bilateral injuries.

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Concurrent spinal fracture-dislocations and pelvic injuries rarely occur. For patients with such injuries and with signs of spinopelvic instability, spinopelvic fixation is needed.<sup>5</sup> We have found reports of non-contiguous lumbar fracture-dislocations,<sup>6</sup> but none involving multiple Chance fractures, a pelvic injury, and lower extremity fractures.

Principles of damage control orthopedics (DCO) are applied to polytrauma patients.<sup>7</sup> In addition to this, spinal injuries should be fixed as early as 24 hours from the time of injury. Complications are more likely when treatment is delayed later than 72 hours; these include prolonged mechanical ventilation and sepsis.<sup>6</sup>

**CASE**

Our patient was a male miner in his mid-30s who was working in a quarry and got trapped between a boulder and multiple construction aggregates. He suffered direct trauma to his face, chest, hip, and lower extremities. The patient was initially seen in a local hospital where fluid resuscitation, oxygen supplementation, nasal laceration suturing, and insertion of a closed tube thoracostomy (for pleural effusion) were done. The patient and his family opted to transfer to our institution three days post-injury due to financial constraints and the need for further specialized management.

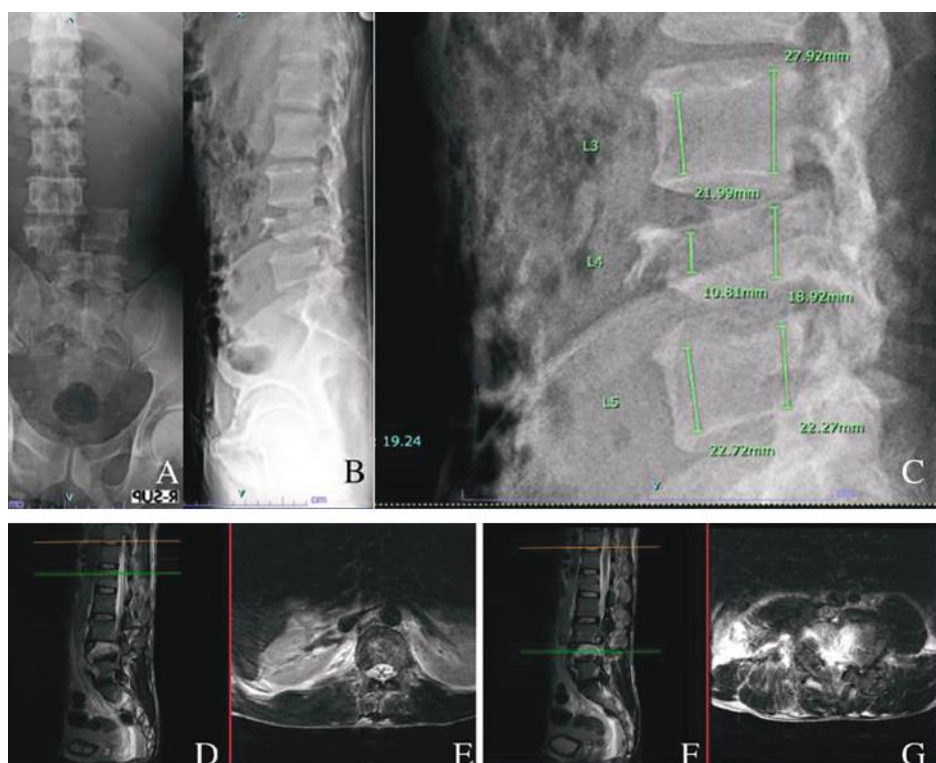
Upon his arrival at our institution’s emergency room, additional venous access was obtained for fluid resuscitation. He was then cleared by the general surgery service of any intraabdominal injuries via examination and Focused Assessment with Sonography in Trauma (FAST). The CT was maintained.

**Table 1.** Pre-operative neurological examination

Sensory	Right	Left	Motor	Right	Left
C2-T12	2/2	2/2	C5-T1	5/5	5/5
L1-L2	2/2	2/2	L2	Deferred	Deferred
L3-L4	2/2	2/2	L3	Deferred	Deferred
L5	2/2	1/2	L4	Deferred	Deferred -
S2-S5	2/2	2/2	L5	3/5	0/5
			S1	5/5	0/5
<b>Reflexes</b>					
Biceps reflex (C5-C6)				++	++
Brachioradialis reflex (C5-C6)				++	++
Triceps reflex (C6-C7)				++	++
Patellar tendon reflex (L2-L4)				Deferred	Deferred
Medial hamstring reflex (L5-S1)				Deferred	Deferred
Ankle jerk reflex/ Achilles tendon (S1)				Deferred	Deferred

The Orthopaedic Trauma and Spine teams diagnosed the patient’s injuries through physical examination, radiographs of the spine and extremities, and a spinal MRI. The spinal injuries included: an L4 burst fracture-dislocation, L1-L3 bony Chance injuries, and L1-L5 spinous process fractures. The patient also had a lateral compression Type III pelvic injury, an open right femoral shaft fracture, and a closed left tibial plateau fracture (Figures 1-5). A neurologic exam, limited by the existing injuries, yielded an ASIA score of C (Table 1).

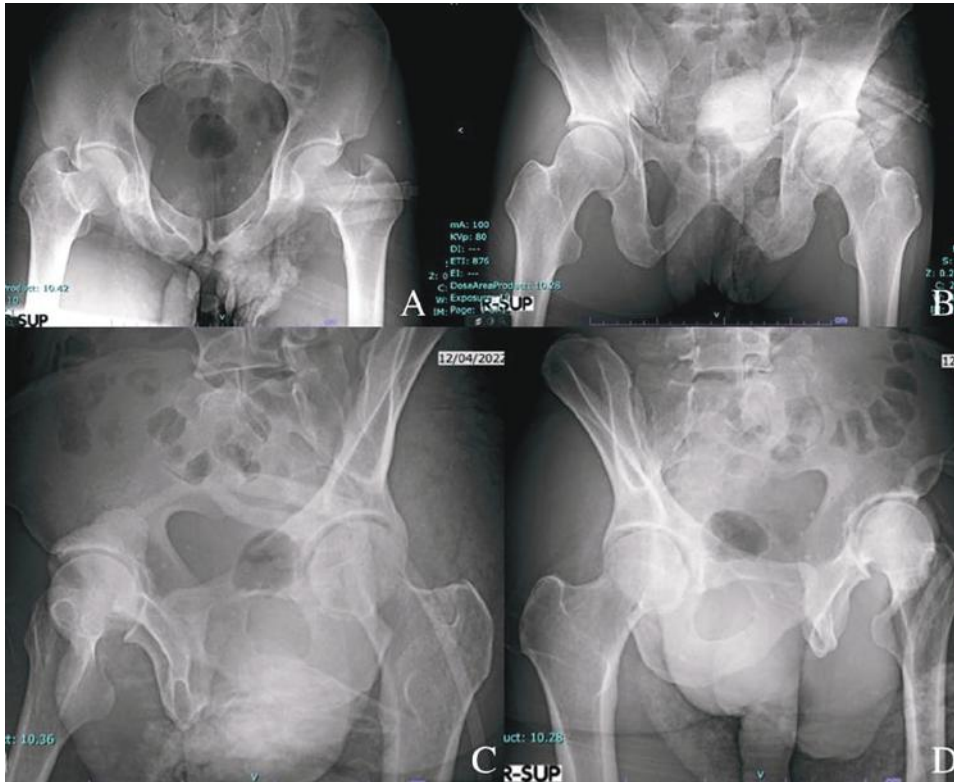
At four days post-injury, open reduction, decompression, and stabilization were done on the lumbar spine and pelvis. The patient was positioned prone on a radiolucent table. After aseptic prepping and draping, a midline incision was used, curving to avoid skin abrasions (Figure 6).



**Figure 1.** Initial antero-posterior (AP) (A) and Lateral x-rays (B) show decreased vertebral body height on L4 and multiple spinous process fractures from L1-L5 (C). Bony chance fractures/hyperintense fracture lines on L1-L3 were seen on the T2-weighted sagittal (D) and axial (E) cuts of the MRI. The fracture-dislocation was evident as a hyperintense lesion on the Sagittal cut (F) causing canal compromise and absence of spinal fluid on the axial cut of the MRI (G).

Dissection was carried out subperiosteally. We found that the L4 vertebral body was translated laterally 3 cm from the midline. The posterior elements from L1-L5 were unstable, due to the injuries to the spinous processes (Figure 6). After exposure, pedicle screws were inserted on T11, T12, L1, L2, L3, L5, and bilateral iliac wings. Rods were inserted on

both sides followed by sequential persuader and set screw application. A stable reduction was achieved (Figure 7). We copiously irrigated the wound and applied autograft before closing. The right femur was debrided, and external fixators were applied to the right femur, and the left lower extremity (knee-spanning) (Figure 8). The total operative time for this



**Figure 2.** Pre-operative pelvic x-rays specifically the inlet (A), outlet (B), and Judet views (C and D) show no acetabular or femoral neck fractures. There was an iliac wing fracture on the right and a sacroiliac joint dissociation on the left.



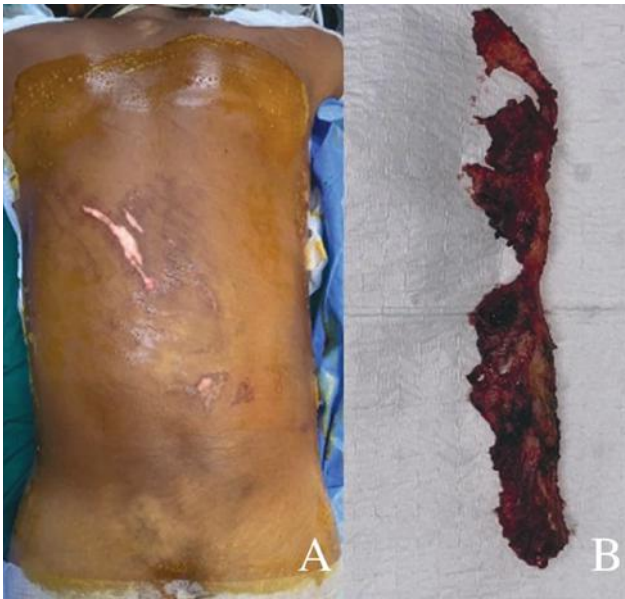
**Figure 3.** Initial AP (A) and lateral (B) x-rays of the right femur show a comminuted fracture of the proximal third of the femoral shaft.



**Figure 4.** Initial AP (A) and lateral (B) x-rays of the Left leg show a comminuted tibial plateau fracture with intra-articular extension.



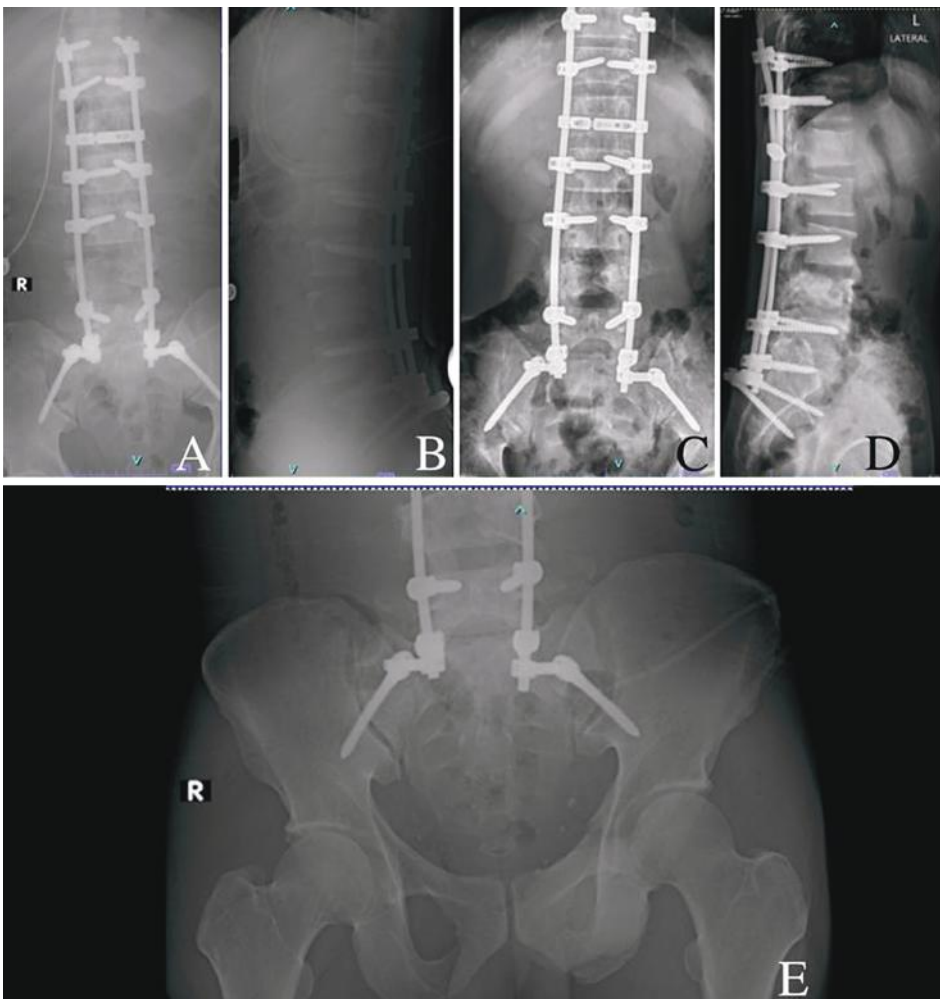
**Figure 5.** Initial left knee x-rays show the AP (A) and oblique views (B-D) of the tibial plateau fracture.



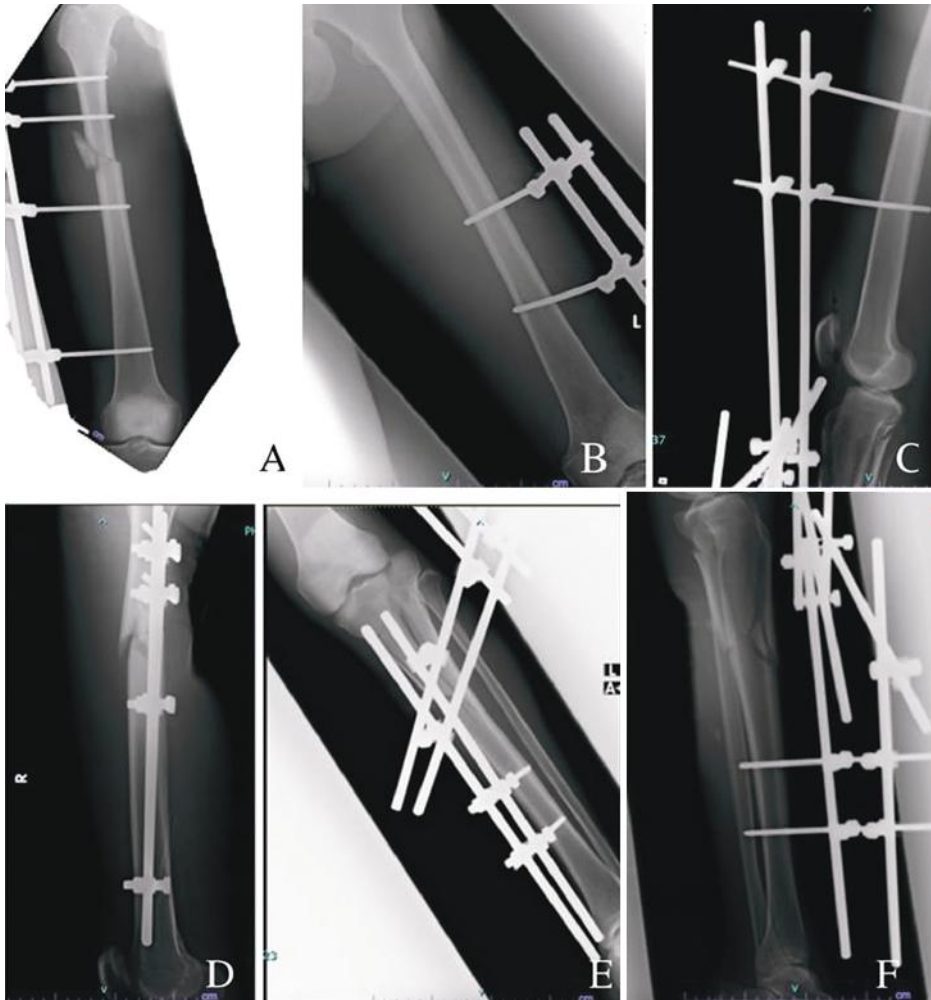
**Figure 6.** Intraoperative pictures showing the clinical appearance of the patient's thoracic and lumbar spine with abrasions (A) as well as the spinous process fractures which were immediately friable during dissection (B).

procedure was six hours with a total blood loss of 1000 mL. Two bags of packed red blood cells were transfused intra-operatively with no transfusions post-operatively.

Two weeks postoperatively, the patient developed a surgical site infection of the spine that required debridement. The implants were maintained and a drain was inserted. The right femur was debrided a second time and fixed with a ring external fixator, and the left tibial plateau was reduced and fixed with plate and screws (Figures 9 and 10). Specimens were obtained from the spine and the pin tract sites of the right femur at the time of the second operation. Blood culture and sensitivity studies were also done in coordination with the infectious disease service. Both tissue and blood cultures revealed few colonies of *Pseudomonas aeruginosa* (Table 2). The drain was removed after five days once output was minimal (15 mL in 24 hours). Intravenous ciprofloxacin was given for two weeks. All operative sites were infection-free and CRP trends (Table 3) were decreasing. The patient was discharged on oral ciprofloxacin for one week.



**Figure 7.** AP (A) and lateral (B) views of the lumbar spine immediately post-op and the AP (C) and lateral (D) views of the lumbar spine and pelvic x-ray after 6 months.



**Figure 8.** Postoperative (index surgery) x-rays of the patient’s extremities. AP view of the right femur (A) and left femur (B), lateral view of the left femur (C) and the right femur, AP (E) and lateral (F) views of the left tibia.

**OUTCOME AND FOLLOW-UP**

One month post-operatively, the patient’s wounds were healed and the chest tube thoracostomy was removed. The patient was admitted to the Rehabilitation service ward for continued physical therapy. At two months post-operatively, he was able to do transfers (supine to sitting and sitting to standing) with assistance. At three months post-operatively, he was able to ambulate with assistance. Some neurologic deficits remained: manual muscle testing of 2/5 of great toe extension and plantarflexion (left), 4/5 of great toe extension (right), and sensation of 1/2 on the L5 dermatome (left).

At six months post-op, the patient was ambulatory without assistance. Despite improvement, certain deficits remained: manual muscle testing of 3/5 of great toe extension and plantarflexion (left), 4/5 of great toe extension (right), and sensation of 1/2 on the L5 dermatome (left). Also listed are the post-operative reflexes (Table 4 and 5). Wounds were well healed with no complications (Figure 11). At one year post-operatively, he was still ambulatory without assistance and underwent removal of ring external fixators (Figure 12). Left toe extension and plantarflexion (L5, S1) were weak on the left (Table 6). Repeat radiographs for the spine, pelvis, and lower extremities were also done showing no complications (Figures 13-15).

**Table 2.** Culture studies

<i>Tissue gram stain (spine)</i>	12-20 / OIF
<i>Tissue gram stain (pin tract sites)</i>	1-7/OIF
<i>Tissue culture (spine and pin tract sites)</i>	Few colonies of Pseudomonas Aeruginosa
<i>Blood CS</i>	Positive for Pseudomonas Aeruginosa after 16 hours of incubation

**Table 3.** C-reactive protein trends

Pre-operative (mg/L) (Reference Value: less than 6.00)	1 week post-op	2 weeks post-op	Debridement and Definitive Fixation	1 week post definitive fixation	2 weeks post definitive fixation	3 days after previous CRP	3 days after previous CRP	Upon discharge
180.54	116.93	142.87	110.91	78.16	48	24	12	6

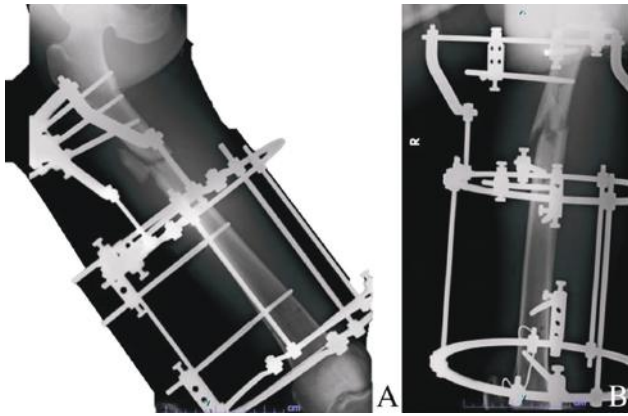


Figure 9. Conversion to ring external fixator via Ilizarov technique of the right femur. AP (A) and lateral views (B).

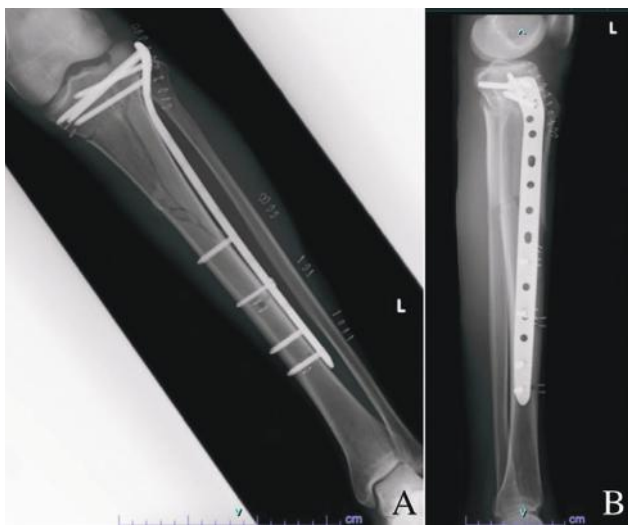


Figure 10. Postoperative x-rays following open reduction and internal fixation with a plate and screws of the left tibial plateau fracture, AP (A) and lateral (B) views.



Figure 11. The clinical picture of the operative site on the thoracolumbar area six months postoperatively shows no wound dehiscence or infection.

Table 4. Post-operative neurologic examination (3 months)

Sensory	Right	Left	Motor	Right	Left
C2-T12	2/2	2/2	C5-T1	5/5	5/5
L1-L2	2/2	2/2	L2	5/5	5/5
L3-L4	2/2	2/2	L3	5/5	5/5
L5	2/2	1/2	L4	5/5	5/5
S2-S5	2/2	2/2	L5	4/5	2/5
			S1	5/5	2/5
<b>Reflexes</b>					
Biceps Reflex (C5-C6)				++	++
Brachioradialis Reflex (C5-C6)				++	++
Triceps Reflex (C6-C7)				++	++
Patellar Tendon Reflex (L2-L4)				++	++
Medial Hamstring Reflex (L5-S1)				++	++
Ankle Jerk Reflex/ Achilles Tendon (S1)				++	++

Table 5. Post-operative neurologic examination (6 months)

Sensory	Right	Left	Motor	Right	Left
C2-T12	2/2	2/2	C5-T1	5/5	5/5
L1-L2	2/2	2/2	L2	5/5	5/5
L3-L4	2/2	2/2	L3	5/5	5/5
L5	2/2	1/2	L4	5/5	5/5
S2-S5	2/2	2/2	L5	4/5	3/5
			S1	5/5	3/5
<b>Reflexes</b>					
Biceps reflex (C5-C6)				++	++
Brachioradialis reflex (C5-C6)				++	++
Triceps reflex (C6-C7)				++	++
Patellar tendon reflex (L2-L4)				++	++
Medial hamstring reflex (L5-S1)				++	++
Ankle jerk reflex/ Achilles tendon (S1)				++	++

Table 6. One year post-operative neurologic examination (motor and reflexes)

Sensory	Right	Left	Motor	Right	Left
C2-T12	2/2	2/2	C5-T1	5/5	5/5
L1-L2	2/2	2/2	L2	5/5	5/5
L3-L4	2/2	2/2	L3	5/5	5/5
L5	2/2	1/2	L4	5/5	5/5
S2-S5	2/2	2/2	L5	5/5	4/5
			S1	5/5	4/5
<b>Reflexes</b>					
Biceps reflex (C5-C6)				++	++
Brachioradialis reflex (C5-C6)				++	++
Triceps reflex (C6-C7)				++	++
Potellar tendon reflex (L2-L4)				++	++
Medial hamstring reflex (L5-S1)				++	++
Ankle jerk reflex/ Achilles tendon (S1)				++	++



**Figure 12.** Clinical pictures of the patient at one year postoperatively, sagittal (A) and coronal (B) views. The patient was ambulatory with assistance.



**Figure 13.** X-rays at 1 year postoperatively, spine AP (A) and lateral (B) views. No implant loosening or recurrence of dislocation. Bony fusion was seen at all levels with callus formation on the sacroiliac joints.

## DISCUSSION

For multiply-injured patients, a multidisciplinary approach is warranted. This patient was treated in coordination among the orthopaedic trauma, orthopaedic spine, and trauma surgery services. Luckily, the patient did not need any thoracic or abdominal surgeries which may have delayed fixation of the spine and extremity injuries.

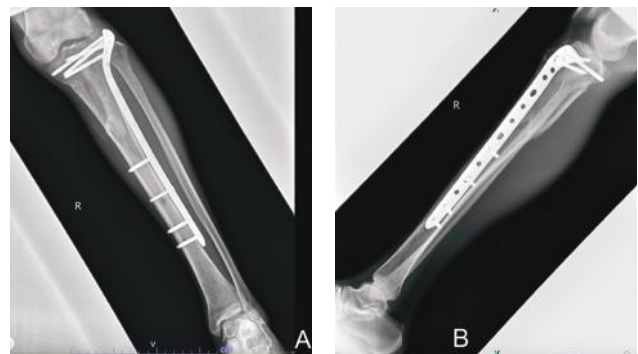
Given the neurologic deficits and the severity of the spinal injury, immediate surgery was needed. There are no reported contraindications in prone positioning for a polytrauma patient. Early spinal stabilization (within 24 hours if possible) improves outcomes in polytrauma,<sup>7</sup> shortening hospital stays and decreasing medical complications.<sup>8</sup>

Spinal procedures have a 2.8–20% infection rate, especially with instrumentation, increased surgical time, prolonged indwelling catheter use, and longer hospital stays.<sup>6</sup> These were factors we encountered in our patient that may have caused the surgical site infection.

Both fracture-dislocation and flexion distraction injuries warrant reduction, decompression, and stabilization with pedicle screws two levels above and below the injury.<sup>9</sup> With



**Figure 14.** X-rays at one year postoperatively, femur AP (A) and lateral (B) views. Callus formation was seen on the femur with no signs of osteomyelitis.



**Figure 15.** X-rays at one year postoperatively, leg AP (A) and lateral (B) views. Bony fusion was seen on the previous fracture with no implant loosening.

a concurrent pelvic injury, instrumentation was extended from the thoracolumbar spine to the pelvis via bilateral iliac screw insertions.<sup>5</sup>

Principles of damage control orthopedics (DCO) were applied for the lower extremity injuries, initially doing debridement and temporary external fixation, and later on shifting to definitive fixation.<sup>7</sup> A ring external fixator was chosen for the open femur fracture to allow immediate ambulation, and because pin tract infections precluded internal fixation.<sup>10,11</sup> The tibial plateau fracture was fixed with a plate and screws to achieve an anatomic reduction of the joint line and a stable fixation that allows immediate range of motion.<sup>12</sup>

## CONCLUSION

Polytrauma patients must be diagnosed accurately and treated quickly, prioritizing life-threatening and unstable injuries. Multi-level and unstable spine injuries must be treated within 72 hours to prevent further complications such as surgical site infections and medical morbidities from prolonged immobilization.

## ETHICAL CONSIDERATION

Patient consent was obtained before submission of the manuscript.

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## STATEMENT OF AUTHORSHIP

All authors certified fulfillment of ICMJE authorship criteria.

## AUTHOR DISCLOSURE

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## Adamantinoma of the Tibial Shaft Treated with Intercalary Reconstruction Using Ipsilateral Pedicled Vascularized Fibular Graft and Screw Fixation\*

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### ABSTRACT

Adamantinoma is a rare primary bone tumor, typically affecting the tibia. While traditionally treated with amputation, limb salvage techniques have become the preferred approach, preserving extremity function. This article reports on a 52-year-old female with a growing mass on her left tibia, confirmed as adamantinoma through biopsy. The patient underwent wide resection of a 16 cm tibial segment and reconstruction using an ipsilateral pedicled vascularized fibular graft. The graft was secured with only one cortical screw each proximally and distally, and the medial gastrocnemius muscle was used to cover the graft. A long leg cast was then applied. We demonstrate a successful strategy for treating adamantinoma, focusing on achieving functional recovery and long-term tumor control.

**Keywords.** adamantinoma, tibial neoplasms, intercalary reconstruction, pedicled fibular graft, limb salvage procedure, vascularized graft hypertrophy

### INTRODUCTION

Adamantinoma is a biphasic malignant bone tumor that occurs most commonly at the diaphyseal area of the tibia (80–85%) during the 2<sup>nd</sup>–5<sup>th</sup> decade of life with a male predilection. It is rare, accounting for only 0.5–1% of all primary bone tumors. Patients most often experience pain and a palpable mass at the anterior surface of the tibia. Radiographs show an eccentric, lobular, lytic lesion with sclerosing margins at the diaphysis of the tibia. It is likened to a “soap bubble” appearance due to the multifocal radiolucencies. The most common site of metastasis is the lungs.<sup>1-3</sup>

In the United States, 92 patients were diagnosed with adamantinoma from 1973 to 2016.<sup>2</sup> In the University of the Philippines – Philippine General Hospital, adamantinoma accounted for only three out of the 337 primary malignant bone tumors from 1993 to 2000.<sup>3</sup>

### CASE

This was a case of a 52-year-old woman with no known comorbidities, who consulted for a one-year history of a mass on her left leg. She had no history of trauma, weight loss, night pains, or infection. She consulted with another institution when the mass became painful and larger. An open biopsy revealed an adamantinoma of the left tibia. She was advised surgical management but then opted to transfer to our institution.

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On examination, there was an approximately 8 x 2 x 3 cm hard, non-movable, tender, non-erythematous mass at the anterior aspect of the leg (Figure 1). The patient could do full range of motion of the ankle and knee and had no sensory deficits. No other lesions were palpated.

Radiographs of the left leg showed a large lytic lesion with permeative borders and neocorticalization with no matrix (Figure 2). An MRI revealed a 2.5 x 3 x 8 cm well-defined lobulated lesion in the anterior aspect of the proximal 1/3 of the tibial shaft with cystic and solid components,

demonstrating T1-weighted hypointense and T2-hyperintense signals (Figure 3).

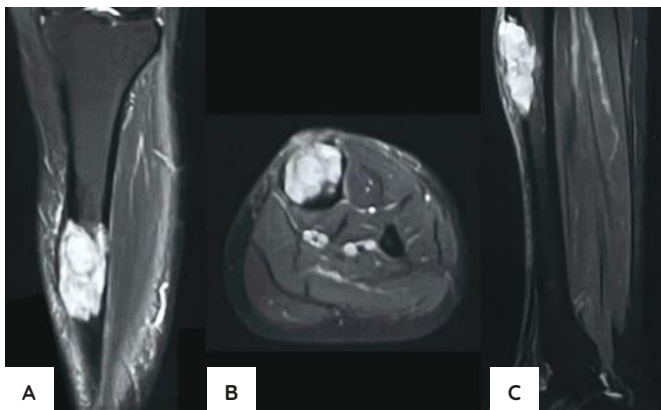
The incision was made starting at the anteromedial proximal tibia, creating an elliptical incision over the biopsy site, extending to the distal 3<sup>rd</sup> of the leg (Figure 4). Lateral and medial flaps were carefully dissected around the tumor. The tibia was osteotomized 3 cm proximally and 5 cm distally from the tumor to achieve wide resection. The entire resected specimen measured 16 cm in length. (Figure 5). The fibula was approached posterolaterally, marking osteotomy sites 5 cm



**Figure 1.** Gross appearance of the mass at the antero-medial middle 3<sup>rd</sup> of the left leg with the biopsy scar. Anterior (A) and medial (B) views.



**Figure 2.** Antero-posterior (AP) (A) and lateral (B) radiographs showing the tumor on the tibial shaft.



**Figure 3.** MRI T2 weighted images showing coronal (A), axial (B), and sagittal (C) cuts.



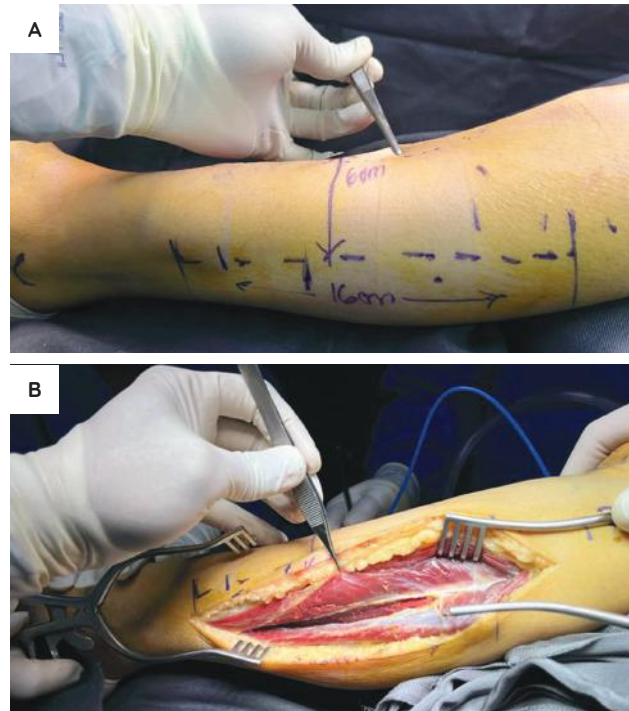
**Figure 4.** Landmarks and planned anteromedial approach (A). Fibular head marked on its lateral aspect (B).

below the fibular head and 8 cm above the lateral malleolus to reduce donor site morbidity and maintain ankle stability (Figure 6). A straight incision was made just posterior to the posterolateral septum. The interval was developed between the peroneus and soleus. The fibula was released from the superficial posterior compartment. The peroneus longus and brevis muscles were released from the fibula through an extraperiosteal plane, while the muscles of the anterior compartment were released close to the fibula. The anterior tibial artery and common peroneal nerve were identified and

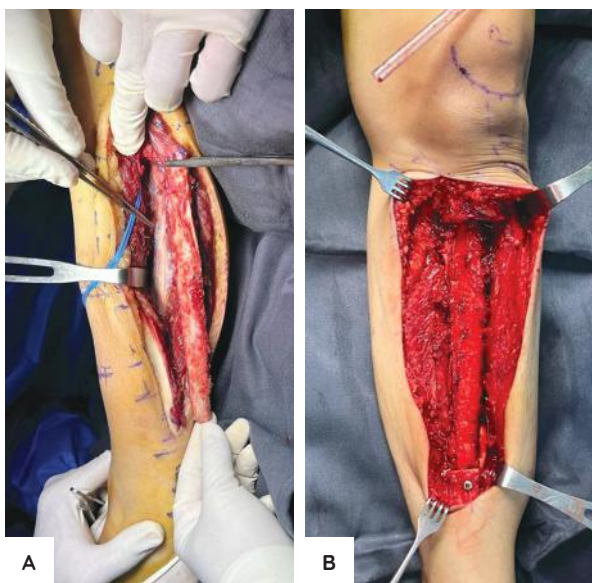
protected. Osteotomies were made on the previously marked levels. Dissection was done going proximally, following the middle of the V shape in the tibialis posterior muscle, preserving the proximal vascular bundle on the side of the fibula (Figure 7A). A total of 19 cm of pedicled fibular graft was harvested, tunneled towards the defect, and secured with two cortical screws (Figure 7B). The medial gastrocnemius was harvested from the superficial compartment and applied as soft tissue coverage for the graft (Figure 8). A long leg splint was applied and the patient was advised no weight



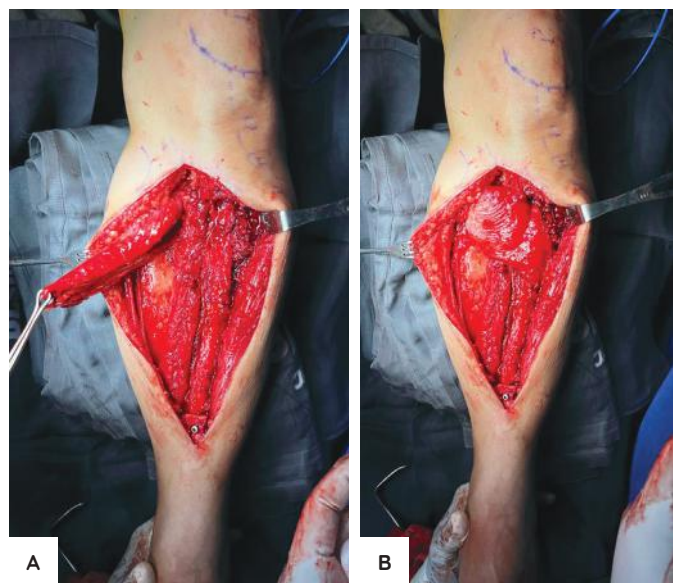
**Figure 5.** Resected mass measuring 16 cm in length.



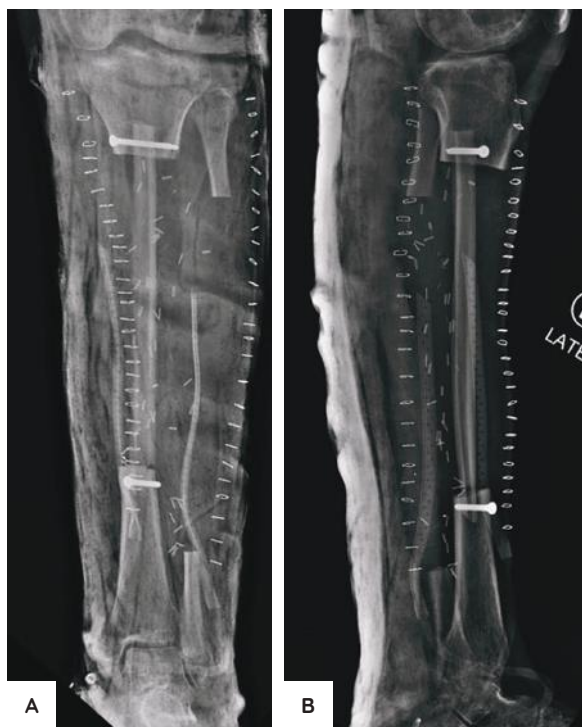
**Figure 6.** Markings of the lateral aspect of the left leg with a 6 cm skin island (A). Interval between peroneus and soleus (B).



**Figure 7.** The 19 cm pedicled fibular graft was harvested (A) and tunneled to the defect and secured with two cortical screws (B).



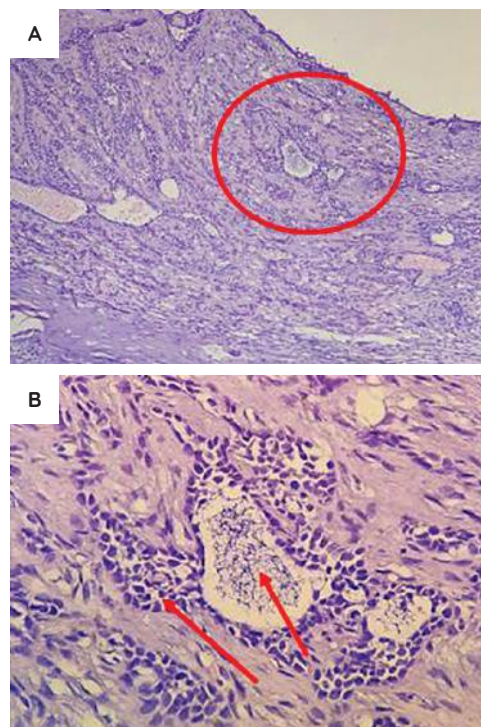
**Figure 8.** The medial gastrocnemius flap was harvested (A) and used for soft tissue coverage of the vascularized fibular graft (B).



**Figure 9.** AP (A) and lateral (B) immediate postoperative radiographs showing the fibular strut graft fixated with two cortical screws.

bearing. Immediate post-operative radiographs are seen in Figure 9. The splint was converted to a long leg cast at two weeks post-op.

The histopathologic examination revealed biphasic stromal and epithelial components, consisting of cords, trabeculae, solid, and cribriform nests observed under low power (LPO) and high power (HPO) magnification, consistent with adamantinoma. In Figure 10, the arrow indicates a basaloid cell arranged in a palisading pattern. Both the proximal and distal margins were free of tumor involvement. Follow-up radiographs after two months showed callus formation at both the distal and proximal fixation sites (Figure 11). At 28 weeks post-op, the long leg cast was converted to a walking boot and the patient was advised partial weight bearing with the help of axillary crutches to stimulate hypertrophy of the graft (Figure 12). At 44 weeks post-op, the proximal and distal tibia were completely united with beginning hypertrophy of the graft (Figure 13). The patient was able to fully extend and flex her knee up to 100 degrees (Figure 14). At 76 weeks post-op the patient had started full weight bearing without crutches and a pneumatic walking boot. There was no pain or local recurrence. Radiographs showed complete union of the graft to the tibia. Hypertrophy was seen on the entire length of the fibular graft (Figure 15). At 100 weeks post-op, the patient walked without any assistive device and exhibited full range of motion of both the ankle and knee joints (Figure 16). Radiographs showed further hypertrophy of the entire fibular graft with no signs of local recurrence (Figure 17).



**Figure 10.** LPO (A) and HPO (B) Arrow shows basaloid cells in a palisading pattern, cribriform nests with dispersed chromatin pattern.

## DISCUSSION

This patient's mass was located at the anterior proximal 3<sup>rd</sup> of the tibia shaft, consistent with the disease's epidemiology. The most common presentation of Adamantinoma is pain and swelling of the affected site and in 72% of the cases, they may present with a palpable mass on the anterior tibia, as seen in our patient.<sup>1</sup>

Radiographically, adamantinoma presents as an eccentric/central lobular lytic lesion with well-defined sclerotic margins of overlapping radiolucency located at the tibial diaphysis. It is described as having a "soap bubble" appearance.<sup>1</sup> Our patient's radiographs showed a gradually enlarging multilobulated lytic lesion with signs of neocorticalization at the proximal left tibia.

Histologically, adamantinoma can be classified into osteofibrous-like and classic adamantinoma.<sup>1</sup> Classic adamantinoma can be classified into four patterns: namely basaloid which consists of solid masses of basaloid cells, tubular which contains cuboidal epithelial cells with central discohesion, spindle-cell which exhibits uniform spindling, and squamous which resembles squamous carcinoma.<sup>1</sup> Osteofibrous-like adamantinoma, on the other hand, consists of osteofibrous tissue containing clusters of epithelial cells and tests positive during cytokeratin staining.<sup>4</sup> Other characteristics of Adamantinoma include a low mitotic rate, foci calcification, giant cells, xanthoma, and spindle cells.<sup>1,4</sup> While its pathogenesis is still in question, the accepted theory is that the skin basal epithelium



**Figure 11.** AP (A) and lateral (B) radiographs at two months post op showing hypertrophy of the fibular graft.



**Figure 12.** AP (A) and lateral (B) radiographs at four months post op showing hypertrophy of the fibular graft.



**Figure 13.** AP (A) and lateral (B) radiographs at seven months post op showing further hypertrophy of the fibular graft.



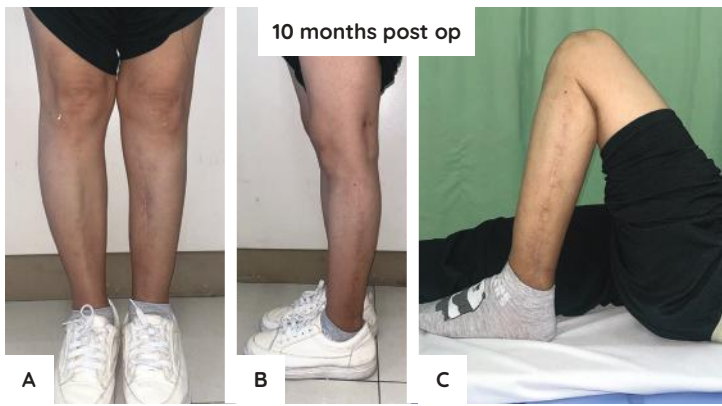
**Figure 14.** Follow-up at 7 months: knee flexion up to approximately 100 degrees.

is displaced during embryonic development, moving the bone and skin closer to the anterior tibia, making this site the most common.<sup>4</sup> This patient's histologic findings include basaloid cells in a palisading pattern and cribriform nests.

Traditionally, adamantinoma has been treated with amputation, but different treatment options have evolved, including distraction osteogenesis, intercalary allografts, nonvascularized fibular auto-grafts, bridging custom-made prosthesis/endoprosthesis, free vascularized fibular grafts, and pedicled fibular grafts.<sup>1,5</sup> Intercalary allografts and nonvascularized grafts can generate new bone but are limited to defects under 6–8 cm and rely on creeping substitution for bone formation, which can weaken the graft and lead to complications. Vascularized fibula autografts support



**Figure 15.** AP (A) and lateral (B) radiographs at 10 months post op showing hypertrophy on the entire length of fibular graft.



**Figure 16.** Able to bear weight without any assistive device (A) and (B) with full range of motion 0-120 degrees (C).

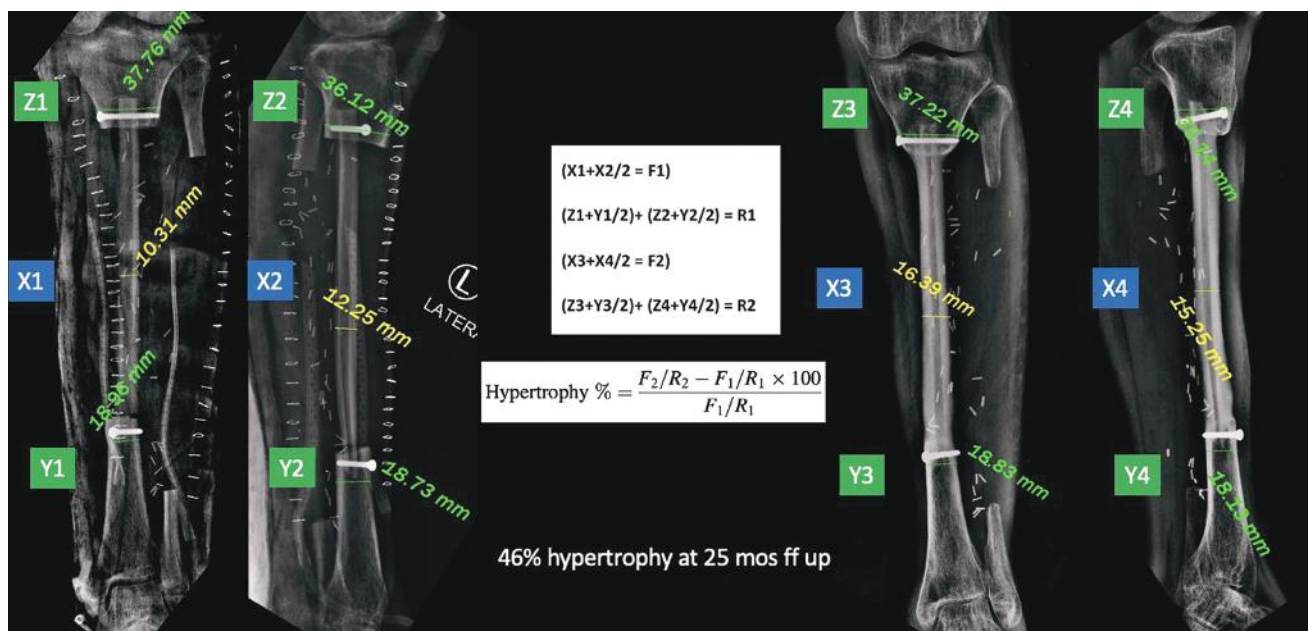
healing via primary bone union and gain strength as they hypertrophy.<sup>6-8</sup> For lower limb cases, full weight-bearing was typically achieved on an average of 7.5 months to 18 months.<sup>9</sup>

In this case, following tibial resection, the bone defect was reconstructed using an ipsilateral pedicled vascularized fibular graft, which was then secured in the medullary cavity with proximal and distal screws. Pedicled fibular grafts retain their native blood supply, making them particularly effective for local reconstructions near the donor site. This approach minimizes the risk of ischemic complications and allows for simpler and shorter surgery without the need for microsurgical vascular reconnection. There are many options for securing the VFG to the tibia—screws, plates, intramedullary nails, or external fixators may be used. Graft hypertrophy is more



**Figure 17.** AP (A) and lateral (B) radiographs at 25 months showing hypertrophy on the entire length of the fibular graft.

robust in grafts that are mechanically loaded and not bypassed by either plate fixation or intramedullary nail.<sup>10</sup> For this case, pedicled fibular graft was secured using two cortical screws, one proximal and one distal, to provide rotational stability. The limb was immobilized in a long leg cast for seven months



**Figure 18.** Graft hypertrophy was measured in relation to host bone according to El-Gammal et al. where F1 = mean fibular graft anteroposterior and lateral width at the midpoint postoperatively, R1 = mean recipient bone anteroposterior and lateral width at a fixed point away from the graft-host junction postoperatively, F2 = mean fibular graft anteroposterior and lateral width at the midpoint at follow-up, and R2 = mean recipient bone anteroposterior and lateral width at a fixed point away from the graft-host junction at 25 months follow-up.

before shifting to a pneumatic walking boot. During this time, repeat radiographs already showed an initial bone bridge between the tibia and the fibular graft which led us to start partial weight-bearing with axillary crutches. Full weight-bearing was allowed after repeat radiographs showed complete union and consolidation of the fibular graft at 19 months post-op. The graft hypertrophy index of 46% hypertrophy at 25 months (Figure 18) was calculated according to the formula used by El-Gammal et al.<sup>9</sup> The fibular graft is expected to have 50% hypertrophy at 18–36 months.<sup>11</sup> Mechanical stress is key to balancing bone formation and resorption, with increased stress promoting bone growth. However, excessive loading can cause stress fractures. Careful monitoring guided our weight-bearing progression to prevent this from happening.

At 25 months post-op, the patient was ambulating without any assistive device, had a full range of motion, was free of pain, local recurrence, and stress fractures, and had an MSTs score of 28 out of 30. Radiographs confirmed both periosteal and endosteal hypertrophy and consolidation at the graft-host interface.

## CONCLUSION

We present a rare case of adamantinoma of the tibia which was successfully treated with resection and reconstruction using an ipsilateral vascularized fibular graft, secured with simple cortical screws and casting. At 25 months, the patient was able to resume her daily activities without pain or restriction of motion.

## ETHICAL CONSIDERATION

Patient consent forms were obtained before manuscript submission.

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## AUTHOR DISCLOSURE

The authors declared no conflict of interest.

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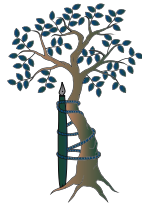
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