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Table of Contents

Bone and Arthrosurgery Science, 2024, Volume 2, Issue 5
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Analysis of the Effect of Bone Cement Distribution Patterns on Surgical Outcomes of Percutaneous Vertebroplasty for Osteoporotic Vertebral Compression Fractures

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Abstract: *Objective:* To evaluate the impact of bone cement distribution patterns on the surgical outcomes of percutaneous vertebroplasty (PVP) for osteoporotic vertebral compression fractures (OVCF). *Methods:* Sixty-four patients with OVCF treated at our hospital from January 2022 to December 2023 were included and divided into two groups based on bone cement distribution patterns: the clustered group and the diffuse group. Both groups underwent PVP. We compared the incidence of bone cement leakage, operative time, blood loss, changes in Visual Analog Scale (VAS) pain scores, and Oswestry Disability Index (ODI) scores before and after treatment between the two groups. *Results:* The number of cases with bone cement leakage was significantly higher in the diffuse group compared to the clustered group ($P < 0.05$). There were no significant differences between the two groups in terms of volume of bone cement injected, intraoperative blood loss, or surgical time ($P > 0.05$). Post-treatment, both VAS and ODI scores were lower than pre-treatment scores in both groups, with the diffuse group showing significantly lower scores than the clustered group ($P < 0.05$). No postoperative adverse complications were observed in either group. *Conclusion:* PVP is highly effective for treating OVCF. A more uniform distribution of bone cement is associated with a greater reduction in postoperative pain and improved functional outcomes. However, careful attention is needed to prevent bone cement leakage.

Keywords: Percutaneous vertebroplasty; Bone cement; Osteoporotic vertebral compression fractures

Online publication: November 4, 2024

1. Introduction

Thoracolumbar vertebral fractures are common and prevalent conditions in spinal surgery, typically resulting from traumatic injury or osteoporosis [1]. With advancements in societal productivity and improvements in healthcare, life expectancy has increased, leading to more pronounced aging issues. Particularly in elderly patients, exacerbated calcium loss and severe bone tissue calcification make the spine highly susceptible to fractures from minor trauma, thus increasing the incidence of osteoporotic vertebral compression fractures (OVCF) [2,3]. The unique nature of spinal fractures significantly impacts patients' daily lives, especially affecting the physical and psychological health of elderly individuals [4,5]. Consequently, percutaneous vertebroplasty (PVP) has become widely used in clinical practice for treating vertebral fractures due to its simplicity and speed [6,7]. During the procedure, bone cement commonly exhibits two distribution patterns within the vertebral body: clustered and diffuse [8]. The effect of these two bone cement distribution patterns on surgical outcomes remains controversial. Therefore, this study aims to analyze the impact of different bone cement distribution patterns on postoperative symptom improvement to provide clinical guidance.

2. Materials and methods

2.1. General information

We selected 64 patients who underwent PVP for OVCF at our hospital between January 2022 to December 2023. The cohort included 16 males and 48 females, with 25 cases of thoracic fractures and 39 cases of lumbar fractures. The patients' ages ranged from 64 to 93 years, with a mean age of 75.81 ± 7.83 years. Based on the distribution patterns of bone cement within the vertebral body, patients were divided into two groups: the clustered group and the diffuse group. The comparison showed that the baseline characteristics of patients in both groups were comparable before treatment ($P > 0.05$), with no significant differences (**Table 1**).

Inclusion criteria: (1) Diagnosed with thoracolumbar vertebral fractures by digital radiography or other imaging modalities. (2) Age ≥ 65 years. (3) Clear indications for surgery with informed consent obtained from the patient and their family. (4) Single vertebral body compression fracture. Exclusion criteria: (1) Presence of significant comorbidities such as cardiopulmonary diseases unsuitable for surgery. (2) Multisegmental fractures. (3) Pathological fractures. (4) Pre-existing old fractures.

Table 1. The baseline characteristics of the two groups

Group	Clustered group	Diffuse group	*P*
Age	76.38 ± 7.67	75.04 ± 8.11	0.49
Gender (M/F)	8/29	8/19	0.47
Hypertension (*n*)	26	13	0.07
Diabetes (*n*)	21	12	0.33
Fracture location (Thoracic/Lumbar)	14/23	11/15	0.81

Note: Data are presented as mean ± standard deviation or number of patients. *P* values are from comparisons between the two groups.

2.2. Methods

Upon admission, patients were given absolute bed rest and symptomatic treatment, including pain management. Comprehensive imaging with X-ray, computed tomography, and magnetic resonance imaging was performed to confirm the fracture location and type and to exclude absolute surgical contraindications. PVP was then carried out. Patients were positioned prone on the operating table with routine electrocardiogram monitoring and supplemental oxygen. Using a C-arm fluoroscope, the pedicle projection points on either side of the affected vertebra were marked. The surgical area was disinfected with iodine tincture, and sterile drapes were applied. Local anesthesia was administered with 1% lidocaine at the marked points, progressively deepened until reaching the periosteum. A puncture needle was inserted bilaterally into the pedicles. After breaching the bone, the position, angle, and depth of the needle were confirmed with C-arm fluoroscopy. Adjustments were made until the needle tip reached the anterior third of the vertebral body. The needle core was removed, and a guidewire was inserted, followed by a cannula. Bone cement was prepared and injected bilaterally into the vertebral body in a stringy, viscous state. Under fluoroscopic guidance in both anteroposterior and lateral views, the cement was gradually injected while closely monitoring its distribution and filling. Injection was stopped when the cement approached the posterior wall of the vertebral body. After allowing the cement to solidify, the cannula was removed, and the puncture sites were disinfected and bandaged. Postoperatively, patients were advised to rest in bed for 12 hours, after which they could begin walking with lumbar support.

2.3. Observation indicators

The surgical parameters included: (1) Operation time. (2) Intraoperative blood loss. (3) Volume of bone cement injected. (4) Type of bone cement distribution. (5) Presence or absence of bone cement leakage.

Pain and functional impairment were evaluated using the Visual Analog Scale (VAS) and the Oswestry Disability Index (ODI) preoperatively and 8 hours postoperatively. The VAS scores range from 0 to 10, where 0 indicates no pain, ≤ 3 represents mild pain, 4–6 signifies pain affecting sleep, and 7–10 denotes severe pain. The ODI questionnaire consists of 10 items addressing standing, sitting, walking, traveling, lifting, sexual activity, social life, personal care, and pain intensity. Each item is scored from 0 to 5, with higher scores indicating greater functional impairment.

2.4. Statistical methods

Data analysis was performed using SPSS29.0 statistical software. Measurement data were expressed as mean ± standard deviation (SD). Normality and homogeneity of variance were first tested; if the data were normally distributed and variances were equal, comparisons between two independent groups were made using the independent samples *t*-test. For categorical data, chi-square tests were used. If data did not meet these assumptions, the Mann–Whitney U test was applied. A P value of < 0.05 was considered statistically significant.

3. Results

Based on the distribution patterns of bone cement within the vertebral body, patients were categorized into two groups: the clustered group (37 cases) and the diffuse group (27 cases). No postoperative complications were observed in either group. There were no significant differences between the two groups in terms of volume of bone cement injected, intraoperative blood loss, or surgical time ($P > 0.05$). The number of cases with bone cement leakage was significantly higher in the diffuse group compared to the clustered group ($P < 0.05$). The preoperative VAS and ODI scores showed no significant differences between the two groups ($P > 0.05$); postoperative VAS and ODI scores significantly decreased in both groups ($P < 0.05$), with the diffuse group showing lower scores compared to the clustered group ($P < 0.05$). The results are presented in **Tables 2** and **3**.

Table 2. Perioperative indicator comparison

Indicator	Clustered group	Diffuse group	*t*	*P*
Number of cases	37	27	-	-
Operation time (minutes)	33.19 ± 4.86	32.96 ± 5.58	-0.17	0.86
Volume of bone cement (ml)	6.68 ± 0.77	6.83 ± 0.94	-0.95	0.34
Number of leaks	7	19	17.13	< 0.05
Blood loss (ml)	7.85 ± 1.48	7.76 ± 1.33	-0.26	0.79

Table 3. Comparison of VAS and ODI scores

Group		Clustered group	Diffuse group	*t*	*P*
VAS score	Preoperative	6.59 ± 1.19	6.19 ± 1.15	-1.43	0.15
	Postoperative	2.81 ± 0.94	1.59 ± 0.80	-4.60	< 0.05
ODI score	Preoperative	40.42 ± 4.16	40.30 ± 4.24	-0.13	0.89
	Postoperative	16.95 ± 4.83	11.93 ± 3.76	-4.41	< 0.05

4. Discussion

Osteoporotic vertebral compression fractures are a prevalent issue among the elderly due to age-related bone density loss and calcium metabolism disorders [9,10]. The risk of fractures in this population is further exacerbated by reduced balance and coordination, leading to frequent falls [11]. PVP, initially developed by Galibert and Deramond in 1987, has evolved from treating vertebral hemangiomas [12] to effectively managing vertebral fractures by injecting bone cement to stabilize the vertebral structure and restore height [13].

Traditionally, conservative treatments for thoracolumbar fractures, such as strict bed rest and medication, have long recovery periods and are associated with complications like pneumonia and deep vein thrombosis [14,15]. PVP offers a minimally invasive alternative with benefits such as reduced operative time and quicker mobilization [16,17]. However, with the widespread use of PVP, several issues have emerged, including severe neurological damage from bone cement leakage [18], inappropriate cement volume, inadequate cement dispersion, and insufficient pain relief postoperatively [19]. The relationship between the distribution of bone cement within the vertebra and its leakage, as well as the degree of pain relief experienced by patients, remains controversial and lacks standardized evaluation criteria [20]. Some studies suggest that slower injection speeds, more viscous cement, and lower injection pressures tend to produce a clustered distribution of cement, while faster speeds and higher pressures are associated with a more diffuse distribution. Other factors, such as the total volume of cement injected and the timing of injection, also influence the distribution pattern.

In this study, there were no significant differences between the two groups in terms of volume of bone cement injected, duration of surgery, and intraoperative blood loss ($P > 0.05$). However, the amount of cement leakage was significantly higher in the diffuse group compared to the clustered group (19 vs. 7), with this difference being statistically significant ($P < 0.05$). This discrepancy may be due to the nature of the clustered cement, which tends to bond and concentrate, thus reducing the likelihood of leakage. Conversely, the diffuse cement is more dispersed and does not interconnect as tightly, making it more prone to leakage. Additionally, based on previous surgical experience, the timing of cement injection during the procedure significantly affects leakage. Injecting cement when it has reached a stringy consistency can reduce the likelihood of leakage. Research also indicates that diffuse cement distribution tends to form a tighter mechanical connection with the vertebral bone, and the broader thermal effect of the cement can deactivate local nerves more effectively, leading to more significant pain relief in patients with a diffuse cement pattern.

In this study, the VAS scores significantly decreased postoperatively in both the clustered group and the diffuse group compared to preoperatively, with the reductions being statistically significant ($P < 0.05$). This indicates that, regardless of the bone cement distribution pattern, patients experienced notable pain relief. However, pain relief was more pronounced in the diffuse group (1.59 ± 0.80) compared to the clustered group (2.81 ± 0.94). Similarly, ODI scores showed significant improvement postoperatively in both groups, with the differences being statistically significant.

5. Conclusion

In summary, PVP significantly alleviates patient symptoms postoperatively. The distribution pattern of bone cement within the vertebrae has a substantial impact on the degree of symptom relief and functional impairment [20]. Although the risk of bone cement leakage is higher with a diffuse distribution compared to a clustered one, its symptom improvement is more pronounced. Surgeons should adjust their technique based on intraoperative fluoroscopic findings, tailoring the volume and rate of bone cement injection according to the patient's pain levels and fracture line location to balance the amount and distribution of bone cement with symptom improvement. This study has limitations, including a relatively small sample size, which may affect the robustness of observed differences. Long-term follow-up data is also lacking. Larger sample sizes and extended follow-up are needed to make the conclusions more reliable.

Disclosure statement

The authors declare no conflict of interest.

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Correlation Analysis of Limb Length Differences and Surgical Approaches Following Unilateral Total Hip Arthroplasty

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Abstract: *Aim:* This research aims to analyze the transition from the posterolateral approach (PLA) to the direct anterior approach (DAA) in 101 cases of unilateral total hip arthroplasty (THA). In addition, the study specifically aims to evaluate limb length discrepancy (LLD). *Methods:* We conducted a retrospective analysis of 101 patients who had unilateral THA from September 2021 to August 2024. The causes of THA included femoral neck fracture (n = 28), osteoarthritis (n = 23), osteonecrosis of the femoral head (n = 25), and developmental dysplasia of the hip (n = 25). The mean age was 61.50 years in the PLA group and 63.00 years in the DAA group. Safety feasibility was assessed by analyzing procedure time, incision length, and bleeding volume. LLD was indirectly evaluated by measuring the difference in central edge angles of the postoperative pelvic orthotopic plate. This was done to assess the superiority of the DAA. *Results:* The DAA group had a longer operation time, less blood loss, and a shorter incision length compared to the PLA group, with a statistically significant difference ($P < 0.05$). Additionally, body mass index was found to be linearly correlated with operation length. The LLD in the DAA group was significantly smaller than that in the PLA group ($P < 0.05$). Moreover, this LLD was linearly associated with the difference in the central edge angle. *Conclusion:* DAA may effectively control LLD after THA, resulting in less blood loss and shorter incisions, though it may require longer operative time.

Keyword: Total hip arthroplasty; Limb length discrepancy; Posterolateral approach; Direct anterior approach

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1. Introduction

Total hip arthroplasty (THA) is a surgical procedure that replaces the hip joint with artificial implants. It is suitable for treating osteoarthritis, necrosis of the femoral head, femoral neck fracture, rheumatoid arthritis, traumatic arthritis, bone tumors, ankylosing spondylitis, and other diseases [1]. Limb length discrepancy (LLD) is one of the most common complications following primary THA. Contributing factors include individual variations in femoral morphology, inappropriate selection of the preoperative prosthesis, inadequate release of osteotomy and soft tissue, imprecise prosthesis placement, and challenges in controlling muscle relaxation during various anesthesia methods [2]. Limb shortening after THA is relatively rare compared to limb lengthening. Several common reasons contribute to this phenomenon: (1) a preoperative true LLD greater than 40 mm may lead to incomplete correction; (2) a limb that is only slightly lengthened can easily damage blood vessels and nerves; (3) excessive acetabular filling and upward movement can exacerbate the issue; and (4) postoperative cement subsidence of the cemented prosthesis may result in limb shortening [3-5]. Previous clinical data suggest that LLD greater than 20 mm can cause postural pelvic tilt [6], while LLD greater than 10 mm may lead to new-onset low back pain after surgery [7]. In contrast, LLD less than 10 mm typically allows for compensation within three months, as the range of motion (ROM) of the unoperated hip improves [8]. It is generally accepted that an LLD of 10 mm may serve as a cut-off value for assessing whether compensation occurs in the contralateral limb [9]. Reducing LLD to less than 5 mm in patients with ankylosing spondylitis significantly improves clinical outcomes after hip arthroplasty, making it a more accurate target than the current standard of less than 10 mm [10]. Although LLD less than 7 mm is considered a reasonable threshold for reducing residual discomfort after THA [11], patients with radiographic LLD (R-LLD) less than 5 mm and longer perceived LLD (P-LLD) over one year still report poor Forgotten Joint Score (FJS-12) outcomes [12].

The surgical approaches for THA include the direct anterior approach (DAA), the direct lateral approach (DLA), the anterolateral approach (ALA), and the posterolateral approach (PLA). Although the traditional THA approach, represented by PLA, achieves remarkable anatomical results, it can also lead to muscle injuries around the joint, resulting in soft tissue release and a heightened risk of dislocation after surgery [13]; to prevent early postoperative dislocation, surgeons may implement compensatory measures on the femoral side, as previously mentioned [14]. For example, a larger femoral head can improve the head-to-neck ratio, thereby increasing the ROM before the initial impact point and reducing the dislocation rate [15]. However, inaccurate repairs of the acetabular position or lower LLD do not independently increase the risk of dislocation [16]. Additionally, increasing limb length does not reduce the likelihood of late dislocation associated with neurological diseases or muscle tension. For patients at a higher risk of postoperative dislocation, it is recommended to use a femoral component with a lower neck angle (larger offset) to lower this risk [17].

The DAA for THA is a minimally invasive surgical technique that provides faster recovery, less pain, and a lower postoperative dislocation rate compared to other methods, leading to a surge in research [18,19]. However, less experienced joint surgeons may still face significant challenges, such as neurological dysfunction and intraoperative femur fractures [13]. DAA utilizes a midplane positioned between the tensor fascia latus, gluteus medius, sartorius, and rectus femoris, which helps to avoid the superior gluteal and femoral nerves. Despite this, injury to the lateral cutaneous femoral nerve (LCFN) is a common mild complication that is often reported only when patients are directly asked about their skin sensitivity. Anatomical studies have shown that around 70% of LFCN display a sartorius-type branching pattern. To minimize the risk of injury to the LFCN branch, a skin incision should be made 2 cm lateral to the anterior superior iliac spine (ASIS) and extended distally [20]. The difficulty of exposing the femur with the DAA approach increases the risk of intraoperative fracture. While a short shaft component can help reduce this risk [21], a longer stem can effectively guide the pull direction and prevent improper contact with the femoral cortex. This helps to minimize stress concentration in the proximal femur [22].

Previous studies have indicated that ALA may be more effective than PLA in managing postoperative LLD following THA [23]. However, few studies have compared the DAA with the PLA in this area. To this end, we conducted a three-year retrospective study evaluating data from 101 patients who underwent unilateral THA. Our goal was to assess the safety and feasibility of joint surgeons transitioning from the PLA to the DAA. Additionally, we aimed to evaluate the latter's effectiveness in controlling postoperative limb length differences.

2. Materials and methods

2.1. General information

In accordance with the Declaration of Helsinki, this study ensured compliance with established ethical standards. We conducted a retrospective analysis of data from 101 patients, including 49 males and 52 females, who received unilateral THA using either the DAA or the PLA between September 2021 and August 2024. The inclusion criteria were as follows: (1) a preoperative diagnosis of a femoral neck fracture, hip osteoarthritis, osteonecrosis of the femoral head (ONFH), or developmental dysplasia of the hip (DDH); (2) meeting the criteria for THA and having undergone unilateral THA for the first time; (3) aged between 25 and 80 years; (4) patients from the same surgical group. The exclusion criteria were as follows: (1) individuals with osteoporosis, cancer, or abnormal muscle and ligament function; (2) those with venous thrombosis or other factors that could raise the preoperative venous thromboembolism score; (3) individuals who have had major surgery in the past month; (4) those with contraindications to surgery or anesthesia. **Table 1** demonstrates that the statistical data sets were comparable ($P > 0.05$).

Table 1. Demographics and baseline characteristics of included cases

Characteristics		PLA (n = 48)	DAA (n = 53)	P
Age (y)		61.50 (53–74)	63.00 (52–72)	0.989
Gender (male/female)		23/25	26/27	0.909
BMI		27.12 ± 4.76	26.98 ± 4.55	0.881
Surgical side (left/right)		24/24	28/25	0.932
Diagnosis	Femoral neck fracture	13	15	0.947
	Hip osteoarthritis	10	13	
	ONFH	13	12	
	DDH	12	13	

Abbreviations: DAA: Direct anterior approach; PLA: Posterolateral approach; BMI: Body mass index; ONFH: Osteonecrosis of the femoral head; DDH: Developmental dysplasia of the hip

2.2. Surgical methods

All procedures were carried out by a highly experienced surgical team to minimize the risk of LLD after THA [24].

PLA-THA: The patient was in the lateral position. The surgical area was routinely disinfected and then covered with an aseptic surgical towel and skin envelope. A posterolateral incision was made in the hip joint. The skin and subcutaneous tissue were cut, followed by cutting the greater trochanteric capsule and fascia lata. The gluteus maximus was split, the outer spinor muscle group was cut, and the posterior joint capsule was exposed. After making a U-shaped incision in the joint capsule, yellow fluid was observed in the joint cavity and pathological changes of the femoral head were noticed along with dislocation. The femoral neck was truncated 1 cm along the lesser trochanter of the femur, and the femoral head was removed. The soft tissue in the acetabulum was cleaned before filing the acetabular component. The acetabular component was placed and consolidated with a 15-degree forward tilt and 45-degree outward angle, and the ceramic lining was placed after flushing. A 36 mm standard femoral head was tested to check the position and tightness, with no signs of dislocation, to reset the hip joint. The incision was washed thoroughly, the joint capsule and posterior muscle group were repaired, and the gauze was counted. The incision was then closed layer by layer, a drain tube was placed, and the area was wrapped sterilely.

DAA-THA: The patient was positioned horizontally. The surgical area was disinfected, aseptic surgical towels were placed, and the skin envelope was secured. The DAA approach was utilized to incise the skin and subcutaneous tissue, and the fascia muscularis of tensor fasciae latae was cut, allowing the tensor fasciae latae to be pulled outward. This fully exposed the rectus femoris space beneath, providing access to the ascending branch of the free lateral femoral artery for ligation and hemostasis. Cutting the joint capsule reveals pathological changes at the junction of the femoral head and neck. This procedure allows the identification of the saddle area and small nodules to determine the osteotomy line. The surgeon performed a femoral neck osteotomy, removed the femoral head, and cleaned the soft tissue, glenoid labrum, and some osteophytes in the acetabulum. The acetabulum was filed until uniform bleeding was achieved. The acetabular cup was then positioned at an angle of 15 degrees of abduction and 40 degrees of anteversion, secured with two 2-mm screws, and firmly placed ceramic lining. Shuck-test and Drop-test were qualified. The operating bed was adjusted to an inverted position of 30 degrees, providing a clear view of the proximal femur. The femoral bone marrow cavity was treated with a specialized file, and tests were performed on both the prosthetic handle and the femoral head (32 + 6 mm). The intraoperative fluoroscopic prosthesis was correctly placed and showed no signs of dislocation. The marrow cavity was drained, and the prosthesis handle was inserted into the bone marrow cavity. Subsequently, a 32 + 6 mm ceramic artificial femoral head prosthesis was installed, and the hip joint was reset without any evidence of dislocation. The incision was washed thoroughly, the joint capsule and fascia muscularis of the tensor fasciae latae were repaired, and the gauze was counted. The incision was then closed layer by layer, a drain tube was placed, and the area was wrapped sterilely.

2.3. Observation indexes

2.3.1. Perioperative index

Surgical time, total blood loss, and incision length are defined as follows: Surgical time is the duration from the initial skin incision to the completion of wound closure; total blood loss includes both blood lost during surgery and the amount of blood drained afterward; and incision length refers to the length of the surgical cut made in the skin.

2.3.2. Postoperative radiographic index

In this retrospective study, we measured the height difference at the center of rotation by using pelvic normotopia X-ray to indirectly evaluate LLD. The pelvic reference points consist of the teardrop-shaped structures and the ischium. We aimed to eliminate the influence of pelvic factors on LLD by aligning specific anatomical landmarks on X-ray film, these landmarks include the lines drawn between the lower edge of the tear and the lower edge of the ischium of both acetabula. Patients were enrolled in the study if the two lines were parallel. Since all enrolled patients underwent unilateral THA, our method for quantitative assessment of LLD was defined as subtracting the height of the contralateral rotation center from the height of the intraoperative rotation center.

An increase in the central edge angle is a crucial indicator of postoperative LLD [25], therefore the difference between the two center-edge angles was measured to explore the degree of correlation. The measurement method was performed as follows: When a circle overlaps the edge of the acetabular component, its center corresponds to the operative hip; similarly, if the opposite side overlaps the edge of the femoral head, its center corresponds to the opposite hip. To find the height of the center of rotation, measure the vertical distance from the hip joint's center of rotation to the lower edge of the teardrop on both sides. The center of rotation of the hip joint is similar to the center of the femoral head. Therefore, a vertical line is drawn from this center to measure the central edge angle, which is the angle between this vertical line and the outer upper edge of the acetabulum.

2.4. Statistical methods

Data analysis was performed using the SPSS27.0 software. Measurement data were presented as mean ± standard deviation (SD). We employed a group *t*-test for comparisons between groups and a paired *t*-test for within-group comparisons. Count data were reported as percentages (%), with relationships assessed using Pearson's correlation test. A P value of < 0.05 indicates statistically significant differences.

3. Results

3.1. Perioperative index

As shown in **Table 2**, the DAA group had a longer operation time, less blood loss, and a shorter incision length compared to the PLA group, with these differences being statistically significant ($P < 0.05$). The study found a strong correlation of 0.675 between BMI and operation duration in the PLA and DAA groups, which was highly statistically significant ($P < 0.001$).

Table 2. Perioperative index

	PLA (*n* = 48)	**DAA (*n* = 53)**	***P***
Operation time (min)	109.35 ± 12.026	123.47 ± 11.998	< 0.001
Amount of bleeding (ml)	279.17 ± 41.557	245.66 ± 39.735	< 0.001
Incision length (cm)	11.33 ± 1.917	9.79 ± 2.222	< 0.001

Abbreviations: DAA: Direct anterior approach; PLA: Posterolateral approach

3.2. Postoperative radiographic index

In comparison to the PLA group, we found a smaller yet statistically significant difference in the height of the rotation center and the center edge angle ($P < 0.05$), as illustrated in **Table 3**. The correlation between the height difference of the rotation center and the center edge angle was 0.863 ($P < 0.001$), indicating statistical significance. Additionally, our results indicated that the height difference in the center of rotation was not significantly related to gender ($P = 0.711$).

Table 3. Postoperative radiographic index

	PLA (n = 48)	DAA (n = 53)	P
The difference in RCH (mm)	6.718 ± 2.342	5.090 ± 1.922	< 0.001
The difference in CEA (°)	3.922 ± 1.390	2.941 ± 1.181	< 0.001

Abbreviations: DAA: Direct anterior approach; PLA: Posterolateral approach; RCH: Rotation center height; CEA: Central edge angle

3.3. Postoperative complications

After surgery, all patients experienced stage I healing of their incisions without complications, including infection, dislocation, or periprosthetic fracture. In the PLA group, four patients had a height difference of rotation centers greater than 10 mm, resulting in a complication rate of 8.33% (4/48). In contrast, the DAA group reported numbness in the lateral femoral skin innervation zone, with a complication rate of 5.66% (3/53). There was no significant difference between the two groups (c^2 = 0.018, P = 0.892).

4. Discussion

Our results indicated that patients in the DAA group had longer operation times but experienced less blood loss and shorter incisions compared to the PLA group. This agrees with the analysis by Sun *et al.* [26]. DAA procedures have a narrower operating space compared to other surgical approaches. In patients with acetabular issues, each additional unit of BMI increases surgery time by 0.9 minutes [27]. Additionally, our data revealed a positive linear correlation between BMI and surgery duration. Studies show that robotic-assisted technology can provide more precise cup positioning and better leg length recovery for obese patients [28]. In obese patients, special attention is given to correct reaming and subsequent positioning to avoid excessive lateral positioning [29].

Anatomical studies have identified morphological differences between male and female hip joints, which make women more prone to developing LLD postoperatively compared to men [30]. However, our results showed no significant correlation with gender. This may require categorizing the indicators of LLD before conducting correlation comparisons. It is noteworthy that the selection of the neck shows no gender differences and has no significant correlation with intraoperative ROM or postoperative dislocation [31]. LLD is influenced not only by bony relationships but also by varying degrees of tissue tension. The two-stage treatment involving skeletal traction for limb lengthening after extensive soft tissue release has shown good efficacy in addressing limb length discrepancies resulting from developmental dysplasia of the hip or sequelae of infectious hip disease [32]. Furthermore, the anterior-based muscle-sparing total hip arthroplasty (ABMS-THA), developed from the DAA approach, has been shown to yield better surgical outcomes [33].

Three-dimensional image analysis techniques (3D-IAT) can more accurately predict the position after surgery. These techniques significantly enhance the accuracy of component placement in joint replacement. This offers more options for patients needing THA.

Our data indicated that DAA is likely more effective than the conventional surgical approach in reducing LLD. In contrast to PLA, patients adopt the supine position when choosing the DAA approach during surgery, the pelvis stays in place, improving the accuracy of imaging feedback [34]. Although the positioning of the acetabular component in the recumbent position may differ from the postoperative standing position, 3D-IAT can more accurately predict the position of the acetabular component in the postoperative standing position [35,36]. Additionally, new non-invasive measurement techniques [37], such as robot-assisted (RA) and computer navigation (CN), assist in positioning acetabular components. These new techniques are superior to artificial THA (manual THA, mTHA) [38,39]. This will provide more options for patients requiring THA.

In 2024, researchers discovered a linear relationship between bilateral femoral offset (FO), bilateral rotational center height (RCH), and postoperative limb length discrepancy (LLD). This relationship can be expressed by the regression equation: LLD = 0.038x – 0.099y + 0.257, where x represents the difference in postoperative FO and y represents the difference in postoperative bilateral RCH, measured in centimeters. Additionally, reconstructing FO makes it easier to achieve equal lengths in the lower limbs [40]. The primary weakness of our study is its retrospective design, which did not include full-length photographs of patients' lower limbs, thus we were unable to predict and verify the value of LLD in postoperative patients using this formula. Additionally, the inclusion criteria were limited to four common THA indications: femoral neck fracture, hip osteoarthritis, femoral head osteonecrosis, and DDH. Research is lacking on whether DAA surgery is equally effective for other indications. Moreover, excluding patients over 80 years may introduce selection bias, artificially reducing the number of recorded postoperative complications. Furthermore, all patients in the study underwent hip replacement by the same joint surgeon, which included his learning curve [41]. Therefore, phased comparisons may be necessary to analyze the data results more effectively [42].

In future work, we will enhance the postoperative evaluation index to include various levels of orthopedic surgeons, and we will also verify the effects of other surgical approaches on patient outcomes through further prospective randomized controlled trials.

5. Conclusion

In short, DAA may effectively control LLD after THA, resulting in less blood loss and shorter incisions, though it may require longer operative time.

Disclosure statement

The authors declare no conflict of interest.

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Comparison of Short-Term Clinical Effects of Minimally Invasive Anterior Talofibular Ligament Reconstruction versus Suture Anchor Repair for Chronic Lateral Ankle Instability

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Abstract: *Objective:* To compare the short-term clinical effects of minimally invasive anterior talofibular ligament (ATFL) reconstruction versus suture anchor repair in patients with chronic lateral ankle instability. *Methods:* A retrospective analysis was conducted on 68 patients at the 960th Hospital of the Chinese People's Liberation Army Joint Logistics Support Force between January 2022 and June 2023, patients were divided into two groups based on surgical procedure: Group A (ATFL reconstruction, 35 cases) and Group B (suture anchor repair, 33 cases). Follow-up ranged from 1 to 12 months, assessing the American Orthopaedic Foot and Ankle Society (AOFAS) score, VAS pain score, Tegner activity score, and patient satisfaction, while noting any recurrence of ankle instability or complications such as numbness or infection. *Results:* In Group A, the AOFAS score improved from 74.46 ± 2.96 preoperatively to 90.91 ± 2.79 at final follow-up, Tegner score from 2.40 ± 0.50 to 5.69 ± 0.76, and VAS from 3.14 ± 0.85 to 1.60 ± 0.50; patient satisfaction was 8.31 ± 0.72. In Group B, AOFAS improved from 74.48 ± 2.29 to 90.55 ± 3.12, Tegner from 2.48 ± 0.51 to 5.76 ± 0.79, and VAS from 3.45 ± 0.83 to 1.73 ± 0.50, with patient satisfaction at 8.27 ± 0.63. No significant statistical difference was found between groups in any score ($P > 0.05$), with both groups showing significant postoperative improvement ($P < 0.05$) and no serious complications within 1-year follow-up. *Conclusion:* Both ATFL reconstruction and suture anchor repair yield favorable short-term outcomes in treating lateral ankle instability. Further research is needed to assess if anatomical reconstruction offers superior biomechanical benefits in scar healing over the suture anchor repair in long-term follow-up.

Keywords: Chronic lateral ankle instability; Ankle arthroscopy; Anterior talofibular ligament injury

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1. Introduction

As a critical weight-bearing joint, the ankle relies heavily on its lateral collateral ligaments to maintain stability. This ligament complex primarily consists of the anterior talofibular ligament (ATFL), calcaneofibular ligament (CFL), and posterior talofibular ligament (PTFL), forming a solid barrier that safeguards the stability of the ankle's lateral aspect [1,2]. Ankle sprains are common injuries in everyday activities and sports, often involving damage to the lateral collateral ligaments [3]. Studies show that the ATFL is injured in about 85% of ankle sprains, while the CFL injury rate ranges between 50% and 75%; PTFL injuries are relatively rare, occurring in less than 10% of cases [4,5]. Most lateral collateral ligament injuries can be effectively treated with conservative measures such as immobilization and physical therapy, resulting in satisfactory recovery. However, 20–40% of patients continue to experience persistent pain, recurrent sprains, and joint instability, ultimately leading to chronic lateral ankle instability [6]. Consequently, exploring effective treatment options for chronic lateral ankle instability is essential. This article compares the short-term clinical effects of two methods: minimally invasive ATFL reconstruction and suture anchor repair.

2. Materials and methods

2.1. General information

This study selected a total of 68 patients with chronic lateral ankle instability who were admitted to the hospital between January 2022 and June 2023 as the research subjects. All enrolled patients underwent corresponding surgical treatments and were scheduled for regular follow-up observations postoperatively.

The specific inclusion criteria are as follows:

(1) Patients must meet the diagnostic criteria for chronic lateral ankle instability.

(2) Patients must have the diagnosis confirmed through physical examination (positive anterior drawer test of the ankle, **Figure 1**) and imaging with magnetic resonance imaging (MRI) showing injury to the anterior talofibular ligament (**Figure 2**).

(3) Patient age must be within the range of 18 to 60 years old.

(4) Patients with ankle instability caused by other diseases or injuries must be excluded.

Figure 1. Positive anterior drawer test of the ankle

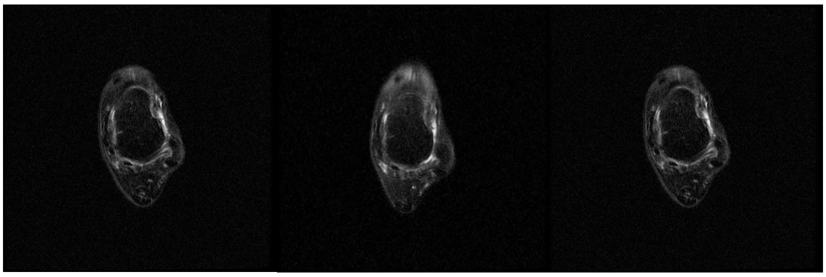

Figure 2. MRI showing injury to the anterior talofibular ligament

The 68 patients were divided into two groups according to different surgical methods:

(1) Group A: The anterior talofibular ligament reconstruction group included 35 patients, with 18 male and 17 female patients, and an average age of 35.61 ± 7.21 years.

(2) Group B: The suture anchor repair group consisted of 33 patients, with 17 male and 16 female patients, and an average age of 34.80 ± 6.50 years.

Statistical analysis showed no significant differences between the two groups in terms of gender, age, and disease course ($P > 0.05$), indicating good comparability between the groups.

2.2. Surgical method

Arthroscopic examination revealed the condition of the anterior talofibular ligament injury. If there was a major tear with only minor connections, and the ligament appeared loose and thin, anterior talofibular ligament reconstruction surgery was chosen, and the patient was included in Group A (**Figure 3**). If there was a partial tear with evident ligament laxity and scar thickening, a suture anchor repair surgery was selected, placing the patient in Group B (**Figure 4**).

Figure 3. A major tear with only minor connections, and the ligament appeared loose and thin

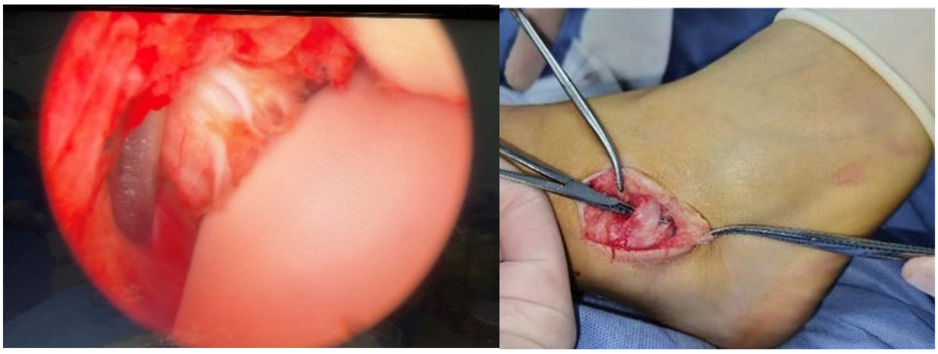

Figure 4. A partial tear with evident ligament laxity and scar thickening

Group A underwent anterior talofibular ligament reconstruction (**Figure 5**): The procedure involved exposing the peroneus brevis tendon both proximally and distally while preserving the superior peroneal retinaculum. The anterior half of the tendon was isolated distally and split proximally up to the musculotendinous junction. A guide pin was inserted at the talar attachment point of the anterior talofibular ligament near the tip of the lateral malleolus. A bone tunnel was created through the talus and fibula. The isolated half of the peroneus brevis tendon was passed through the fibular tunnel and directed into the talar tunnel. After tension adjustment, the tendon was secured with a suture anchor.

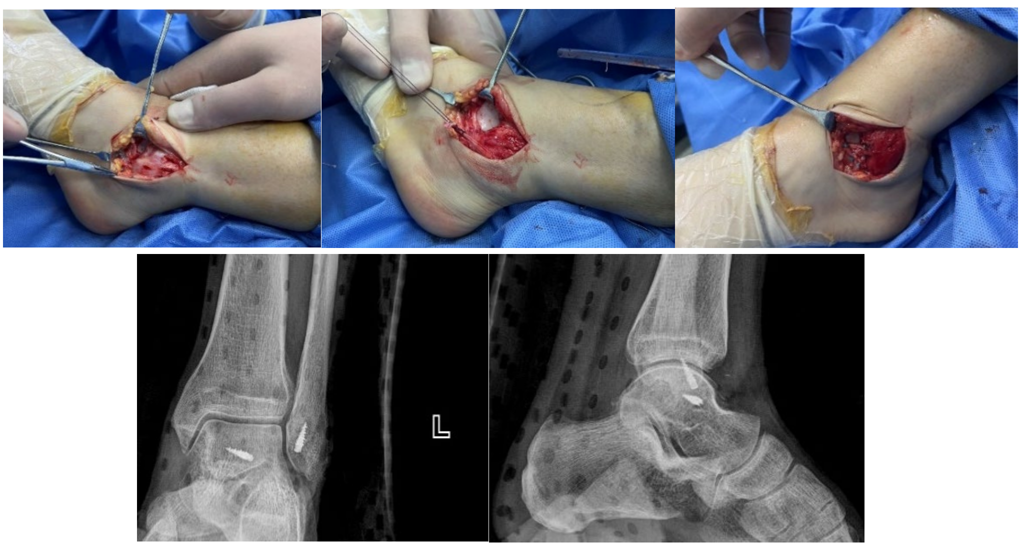

Figure 5. Anterior talofibular ligament reconstruction and X-rays after the procedure

Group B underwent suture anchor repair surgery using the Broström-Gould approach (**Figure 6**).

Figure 6. X-rays after suture anchor repair surgery

After surgery, both groups of patients were treated with an ankle brace in an eversion position for six weeks and encouraged to begin early functional rehabilitation exercises. Specifically, suture removal was performed two weeks post-surgery, after which passive ankle joint exercises were initiated and gradually progressed to active movement. At six weeks post-surgery, weight-bearing exercises were introduced, with incremental increases based on the patient's recovery progress.

2.3. Observation indicators

(1) American Orthopaedic Foot & Ankle Society (AOFAS) score: This score is used for a comprehensive assessment of ankle function, covering aspects such as pain, range of motion, and stability. Higher scores indicate better ankle function.

(2) Visual Analog Scale (VAS) for pain: This 0–10 visual scale assesses the patient's pain level, with 0 representing no pain and 10 representing the worst possible pain.

(3) Tegner activity level scale: This scale evaluates the patient's level of physical activity, with higher scores indicating a better level of activity function.

(4) Patient satisfaction: A satisfaction survey developed by the hospital was used, with a maximum score of 10, where higher scores indicate greater patient satisfaction.

(5) Complication rate: Various postoperative complications were recorded in both groups, including lateral ankle instability recurrence, limb numbness, and wound infection.

2.4. Statistical methods

Statistical analysis was conducted using SPSS27.0 software. For continuous variables, data were expressed as mean ± standard deviation (SD) and compared between the two groups using an independent-samples *t*-test. Categorical data were expressed as percentages (%) and compared using the chi-square (χ^2) test. A *P*-value of less than 0.05 was considered statistically significant.

3. Results

3.1. Comparison of general information between the two groups

There were no statistically significant differences between the two groups in terms of gender, age, duration of illness, or injury mechanism ($P > 0.05$), as shown in **Table 1**.

Table 1. Comparison of general information between the two groups

Group	*n*	Gender (*n*)		Age (years)	Average disease duration (months)	Injury mechanism (cases)	
		Male	Female			Sports injury	Non-sports injury
Group A	35	18	17	35.61 ± 7.21	12.55 ± 4.81	23	12
Group B	33	17	16	34.80 ± 6.50	11.85 ± 3.97	21	12
χ^2/t		0.001		0.486	0.652	0.032	
P		0.992		0.629	0.517	0.858	

3.2. Comparison of AOFAS scores, VAS scores, Tegner scores, and patient satisfaction before and after surgery

Prior to surgery, there were no significant differences between the two groups in AOFAS, VAS, and Tegner scores ($P > 0.05$). Postoperatively, AOFAS and Tegner scores significantly improved compared to preoperative scores ($P < 0.05$), while VAS scores significantly decreased ($P < 0.05$). There was no statistically significant difference in patient satisfaction between the two groups ($P > 0.05$). The results are shown in **Table 2**.

Table 2. Comparison of AOFAS scores, VAS scores, Tegner scores, and patient satisfaction at various time points before and after surgery

Group	*n*	AOFAS score		Tegner score		VAS score		Satisfaction
		Before surgery	Final follow-up	Before surgery	Final follow-up	Before surgery	Final follow-up	Final follow-up
Group A	35	74.46 ± 2.96	90.91 ± 2.79*	2.40 ± 0.50	5.69 ± 0.76*	3.14 ± 0.85	1.60 ± 0.50*	8.31±0.72
Group B	33	74.48 ± 2.29	90.55 ± 3.12*	2.48 ± 0.51	5.76 ± 0.79*	3.45 ± 0.83	1.73 ± 0.50*	8.27±0.63
t		0.031	0.502	0.653	0.372	1.520	1.072	0.243
P		0.975	0.617	0.516	0.711	0.133	0.288	0.809

Note: *indicates that there is statistical significance between the final follow-up and pre-operation in the same group ($P < 0.05$)

3.3. Comparison of postoperative complications between the two groups

Neither group experienced complications such as recurrent lateral ankle instability, limb numbness, or wound infection after surgery.

4. Discussion

Lateral ankle instability is a common type of sports injury, primarily caused by damage to the ATFL. There is currently no unified standard for the treatment of chronic lateral ankle instability. For patients with relatively mild symptoms, conservative treatment is often a suitable option. In contrast, surgical intervention is recommended for those who do not respond to conservative treatment or experience recurrent issues. In recent years, the application of minimally invasive techniques in ankle surgery has become increasingly widespread. Compared to traditional open surgery, minimally invasive procedures offer numerous advantages, including smaller incisions, faster recovery times, and lower rates of complications.

The results of this study indicate that both ATFL reconstruction and the use of suture anchors for ATFL repair achieve favorable postoperative outcomes during short-term follow-up. At various postoperative time points, both groups showed significant improvements in the AOFAS scores, VAS pain scores, and Tegner activity scores compared to preoperative levels, with statistical significance ($P < 0.05$). Furthermore, there were no statistically significant differences between the two groups ($P > 0.05$). This confirms that both surgical approaches can effectively enhance ankle function and improve patients' quality of life.

The advantage of ATFL reconstruction lies in its ability to restore the anatomical structure of the ligament, theoretically providing stronger stability to the ankle joint. In contrast, the suture anchor repair method is simpler and causes less trauma, resulting in a quicker recovery for patients. With the ongoing development and maturation of arthroscopic techniques, the reconstruction of the lateral collateral ligaments of the ankle joint under arthroscopy has garnered considerable attention from researchers, showing efficacy comparable to that of traditional open surgery [7,8]. For instance, Zhang *et al.* [7] conducted a retrospective analysis of 28 patients who underwent arthroscopic lateral collateral ligament reconstruction and 32 who received open reconstruction, finding no significant differences in clinical outcomes at two-year follow-up. Similarly, Yang *et al.* [9] compared clinical data of two groups (10 patients each) who underwent lateral collateral ligament reconstruction using allografts via either open or arthroscopic methods, and found no notable differences in outcomes at two-year follow-up. Su *et al.* [8] prospectively compared 31 patients undergoing arthroscopic reconstruction and 26 patients undergoing open reconstruction, reporting that the arthroscopic group resumed full weight-bearing and activity earlier than the open group at three and six months postoperatively, along with higher relevant scores.

However, this study also has limitations. Firstly, the sample size is relatively small, and the follow-up period is short; thus, further studies with larger sample sizes and longer follow-ups are needed to more thoroughly validate the long-term efficacy of these two surgical approaches. Secondly, this research did not compare the biomechanical properties of the two surgical methods, which could be explored in future studies using biomechanical experiments.

5. Conclusion

In conclusion, both minimally invasive ATFL reconstruction and suture anchor repair effectively treat chronic lateral ankle instability and yield good clinical outcomes. Each surgical method has its own advantages and limitations, and the choice of surgical approach should be based on the specific clinical condition of the patient.

Disclosure statement

The authors declare no conflict of interest.

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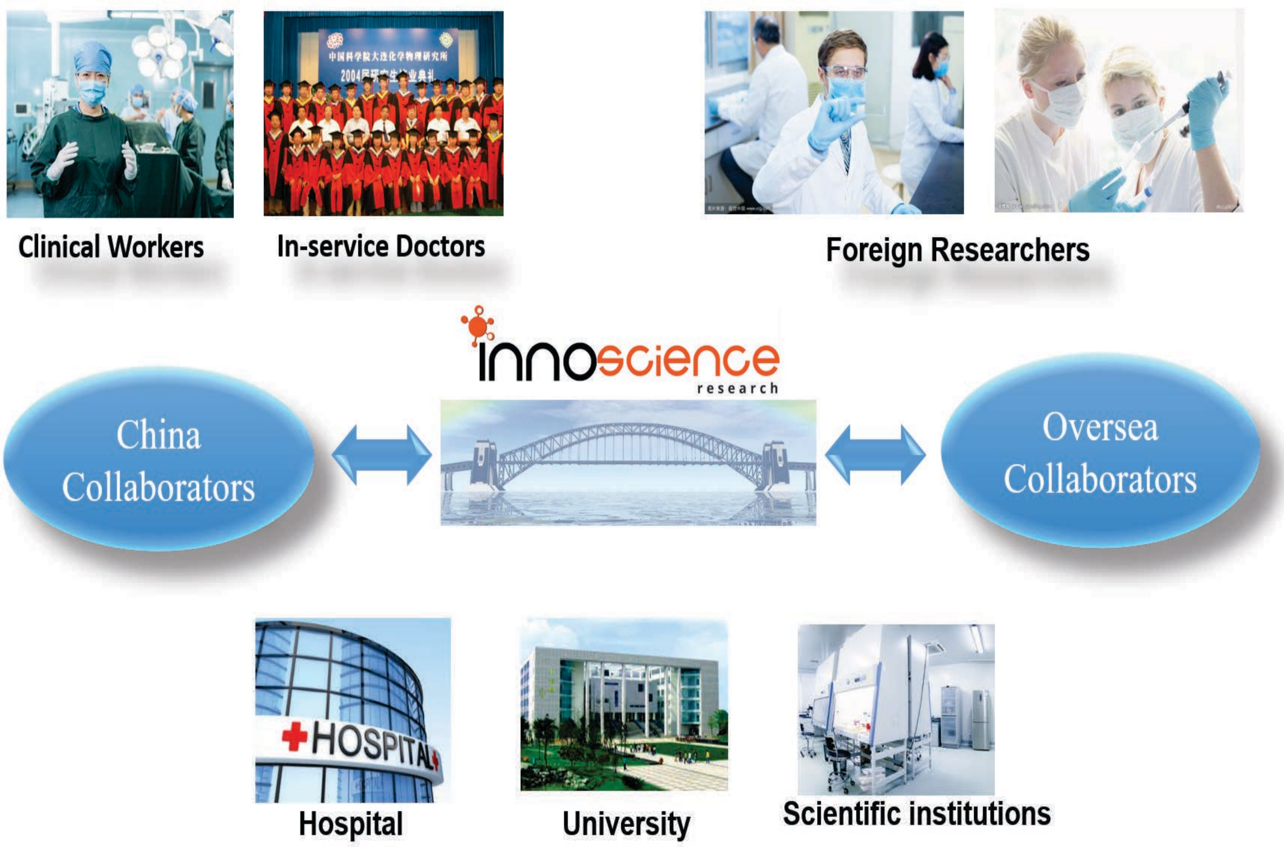

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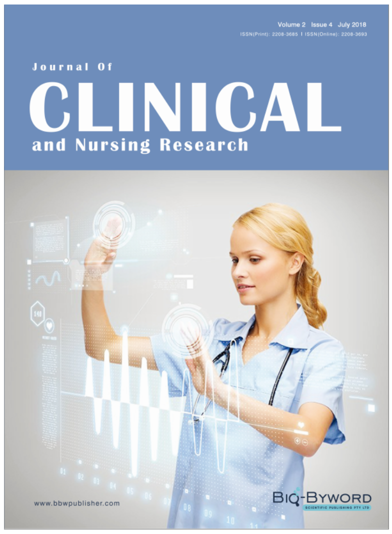

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