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Clinical Outcomes and Prehabilitation Strategies of Patients Treated with Cement-Screw Technique for Tibial Defects in Total Knee Arthroplasty

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Abstract

Objective: To investigate the clinical efficacy of the cement-screw technique in repairing tibial plateau bone defects in total knee arthroplasty (TKA) recipients and summarize the preoperative prehabilitation strategies for such surgeries. **Methods:** A total of 33 TKA recipients (45 knees) in our department underwent repair of unilateral or bilateral tibial defects using the cement-screw technique. The subjects were divided into two groups based on the differences in preoperative interventions. The control group received routine preoperative health education according to the consensus, while the observation group received instructive and standardized prehabilitation exercises for four weeks in addition to the routine education. Scale scores, intraoperative parameters, and postoperative recovery indicators were recorded at different time pointsand subjected to statistical analysis for intra-group and inter-group differences. All subjects underwent long-term follow-up for at least 24 months. **Results:** Within each group at different time points, there were statistically significant differences in VAS, ROM, and HSS scores ($p < 0.001$). At various time points, there were statistically significant differences in VAS, ROM, and HSS scores between the two groups ($p < 0.001$). The observation group showed a significantly shorter time for quadriceps femoris strength recovery and discontinuation of assistive devices compared to the control group ($p < 0.05$). During the follow-up period (24 - 30 months), no serious complications were observed. **Conclusions:** Cement-screw technique for repairing tibial plateau bone defects in TKA recipients can significantly relieve pain, and improve joint function. Prehabilitation can improve preoperative rehabilitation reserves in these patients, accelerate postoperative recovery, and contribute to better short-term clinical outcomes.

Keywords

Cement-Screw Technique, Total Knee Arthroplasty, Tibial Bone Defect, Prehabilitation

1. Introduction

Tibial bone defects are common problems encountered in total knee arthroplasty (TKA) and are one of the significant risk factors for postoperative failure of the prosthesis [1]. Currently, there is no consensus on the treatment of such defects in clinical practice, and the cement-screw technique is a commonly used method for repairing such defects [2] [3] [4]. The technique has been recommended for the repair of tibial defects, whether contained or uncontained, that are larger than 5 mm during total knee arthroplasty (TKA). This method offers various benefits compared to alternative approaches, such as streamlining the surgical procedure, reducing the duration of the operation, lowering surgical expenses, improving cement durability, and minimizing the likelihood of prosthesis loosening [2] [3].

Patients with these defects often have preoperative joint deformities and severe pain. They also tend to have poor compliance with routine postoperative rehabilitation instructions, resulting in slow functional recovery and low efficiency, which poses a challenge to their rehabilitation and surgical outcomes. Preoperative "prehabilitation" is an advanced concept and approach in accelerated surgical rehabilitation. It aims to significantly accelerate postoperative recovery by improving patients' preoperative rehabilitation reserve. It has gradually gained attention in joint surgery rehabilitation [5] [6].

The most important goal of cement-screw technology in repairing tibial defects is to provide immediate and long-term stable support for the prosthesis. Patients with knee joint diseases experience decreased joint stability due to degenerative changes in the surrounding tissues and a decrease in muscle strength [7] [8]. Research results show that neuromuscular training can improve joint stability in patients with knee joint diseases and can also improve patients' pain, quality of life, and joint function. Regardless of the severity of joint disease, knee joint disease patients can benefit from improved joint stability through neuromuscular training [9]. Therefore, preoperative rehabilitation may have a synergistic effect with bone cement screw technology in providing knee joint stability.

However, currently there are few reports in the literature on the application of preoperative prehabilitation in relation to the repair of such defects using the bone cement-screw technique. This study aims to explore the clinical efficacy of the bone cement-screw technique in repairing tibial plateau bone defects in recipients of unilateral or bilateral staged or simultaneous TKA. It also intends to summarize and evaluate the interventions and effectiveness of prehabilitation measures for such patients.

2. Material and Methods

2.1. Study Subjects

Patients with end-stage knee joint diseases who underwent primary TKA in our department from January 2021 to July 2021 were selected as the study subjects.

Inclusion criteria for study subjects: 1) End-stage knee joint disease with ineffective conservative treatment, and TKA has been identified as the ultimate treatment after a rigorous evaluation; 2) Preoperative imaging examination shows significant unilateral or bilateral tibial plateau bone defects, with a defect area ranging from 10% to 50% of the tibial plateau total area, and a defect depth ranging from 5 mm to 20 mm. The defects cannot be eliminated by increasing the amount of bone resection according to the evaluation; 3) Strong willingness for surgery and ability to cooperate well with treatment and complete relevant questionnaire tests.

Exclusion criteria: 1) Coexistence of severe organ dysfunction; 2) Concurrent severe femoral bone defects; 3) Participants who request to withdraw from the study midway.

All participants signed an informed consent form. This study has been reviewed and approved by the Ethics Committee of our hospital (Ethics number: K-2021-036-02).

2.2. Grouping

All study subjects underwent the cement-screw technique to repair unilateral or bilateral tibial plateau bone defects. The same surgeon performed the surgeries, and they followed the "Consensus" [10] for perioperative management, including multi-modal pain management, health education, nutritional intervention, early and appropriate functional exercises, and more.

Based on the differences in preoperative interventions, the subjects were randomly divided into a control group and an observation group. The cases were randomly assigned using a random number table method as follows: all cases were assigned random numbers from a random number table, and those with odd numbers were placed in the observation group, while those with even numbers were placed in the control group.

Control group: The doctors and nurses provided routine preoperative health education according to the consensus, including the importance of rehabilitation exercises, common issues during the perioperative period and their solutions, rehabilitation plans, and the use of assistive devices, etc.

The observation group received an additional 4-week preoperative instructive and standardized prehabilitation exercise prescription on top of the routine education provided in the control group.

2.3. Prehabilitation Exercise Prescription

Participants scheduled for prehabilitation intervention before surgery were all enrolled in a rehabilitation WeChat group led by medical staff. The exercises were first demonstrated in person by the medical staff and then distributed through online platforms for reference practice. The participants were encouraged to perform the prescribed exercises at home in a standardized manner through videos, voice instructions, and other means. The participants performed the following exercise prescription under the guidance of medical staff for a duration of 4 weeks.

1) Quadriceps strength training: In the supine position with the knee extended, perform quadriceps isometric contractions and straight leg raises. Each set consists of 50 repetitions, and three sets are performed daily (morning, noon, and evening).

2) Range of motion exercises: In a sitting or supine position, actively flex and extend the knee joint to the maximum range and hold and relax for 5 seconds each. Each set consists of 20 repetitions, and three sets are performed daily.

3) Ankle pump exercises: In a sitting or supine position, dorsiflex and plantarflex the ankle joint to the maximum range and hold and relax for 5 seconds each. Each set consists of 20 repetitions, and three sets are performed daily.

4) Gait training: Practice walking with assistive devices in advance, including walking on level ground and going up and down stairs. Perform three sessions per day, with each session lasting 5 minutes.

5) Balance exercises: Perform forward and backward stepping, stepping across, half squats, and single-leg standing exercises daily (select exercises based on the patient's knee joint function). Hold each position for 5 seconds, followed by a 5-second relaxation period, constituting one repetition. Each set consists of 10 repetitions, and three sets are performed daily.

2.4. Surgical Procedures

The surgeries were performed under combined spinal-epidural anesthesia or endotracheal general anesthesia. The patient was placed in a supine position with the knee flexed and maintained in a neutral position using a tourniquet and a knee support. A medial parapatellar approach was used, and after lateralization of the patella, the knee joint was adequately exposed. Soft tissues, such as the medial and lateral collateral ligaments, were released in the flexed position. Osteophytes, hypertrophic synovium, and cruciate ligaments were removed. Tibial plateau was dislocated to assess the extent of bone defects, and the number of screws required was estimated. The femur was osteotomized using an intramedullary guide, and the tibia was osteotomized using an extramedullary guide. After osteotomy, the extent of bone defects and their depth were reevaluated. Further release of soft tissues was performed to obtain the desired extension and flexion gaps. The base and surrounding sclerotic bone at the site of tibial plateau defect were removed, and the defect site was roughened by drilling holes. Depending on the size of the defect, 2 - 6 screws were inserted, with the screw heads placed parallel or slightly below the osteotomy surface. After thorough irrigation of the bone surface, bone cement was evenly applied to fill the defect, covering and burying the screws. Subsequently, the tibial and femoral prostheses were sequentially implanted. The alignment of the lower limb, extension and flexion gaps, patellar tracking, and knee joint range of motion were ensured. Patellar replacement or peripatellar denervation was performed as needed, and intra-articular injection with a cocktail was administered. A drainage tube was placed, followed by wound closure using sutures and compression bandaging with elastic bandages. The tourniquet was released. Surgical repair of bone defects in both sides requires a comprehensive evaluation and discussion based on the patient's overall condition and their preferences to determine whether to perform simultaneous or staged surgery.

2.5. Postoperative Management and Follow-Up

All subjects received postoperative ice packs and multimodal analgesia. Antibiotics were discontinued within 24 hours after surgery, and wound drainage tubes were removed within 24 hours. Anticoagulation therapy was administered within one month. A dedicated person supervised early mobilization and early ambulation of the affected limb. The postoperative rehabilitation measures were conducted according to the "Consensus" [10]. All subjects underwent long-term outpatient follow-up or follow-up via telephone or WeChat.

Included in the analysis were the following parameters: 1) Baseline characteristics; 2) Visual Analog Scale (VAS) for pain assessment, Knee range of motion (ROM), Knee function assessment using the Hospital for Special Surgery (HSS) score at baseline, 1 day before surgery and 3 months after surgery; 3) Surgical parameters including operation time, percentage of bone defect area (defect area/tibial plateau total area) and its depth, and the number of screws used; 4) Postoperative parameters including time to ambulation, time for quadriceps strength recovery, time to walking without assistive devices, and number of perioperative blood transfusions. Intra-group and inter-group differences of the aforementioned parameters were compared and subjected to statistical analysis.

Visual Analog Scale (VAS) measurement method: A ruler with 10 scales, approximately 10 cm in length, was used, with "0" indicating no pain and "10" representing the most severe, unbearable pain. Patients were asked to self-describe their pain score, and this was cross-checked by two individuals. Range of motion (ROM) measurement method: A specialized orthopedic goniometer was used for measurement, with 0˚ recorded as complete extension and the maximum angle of flexion recorded. This measurement was also cross-checked by two individuals. Knee joint function was assessed using the Hospital for Special Surgery (HSS) Knee Score, which includes aspects such as pain, function, activity level, muscle strength, flexion deformity, stability, and deductions. This assessment was also cross-checked by two individuals.

2.6. Statistical Analysis

The data were analyzed using SPSS 20.0 software and Generalized Estimating Equations (GEE). Normally distributed data are presented as $\chi \pm s$. Group comparisons for continuous variables were performed using independent t-tests (between groups) or paired t-tests (within groups). Categorical data were compared using chi-square tests. A significance level of $p < 0.05$ was considered statistically significant for data differences.

3. Results

In total, 33 cases involving 45 knees were included for analysis, with 15 cases and 20 knees in the control group, and 18 cases and 25 knees in the observation group. The gender composition, age, location of defect repair, primary disease, and underlying conditions of the two groups are detailed in **Table 1**. Statistical analysis showed no significant differences in baseline characteristics between the two groups, indicating comparability.

Statistical analysis using Generalized Estimating Equations (GEE) revealed significant differences in VAS, ROM, and HSS scores between the experimental and control groups ($p < 0.001$). At various time points (preoperative day 1 and 3 months postoperative), there were statistically significant differences in VAS, ROM, and HSS scores between the groups ($p < 0.001$). Detailed results of the VAS, ROM, and HSS data analysis for both groups are provided in **Table 2**.

Intraoperative analysis of relevant indicators (per knee unit) showed no significant differences in surgical time, bone defect area, bone defect depth, and number of screws used between the control group and the observation group ($p > 0.05$). Please refer to **Table 3** for details.

Table 1. Comparison of the baseline characteristics between the control and observation groups.

Baseline Characteristics	Control Group (n = 15)	Observation Group (n = 18)	χ^2 or t	p
Gender Composition (Female: Male)	10:5	13:5	0.120	0.730
Average Age (years)	68.07 ± 3.37	68.39 ± 2.35	0.322	0.749
Defect Repair Site (U: BD: BS)#	10:2:3	11:2:5	0.277	0.871
Primary Disease of Knee Joint (O: R: G)*	9:4:2	12:5:1	0.605	0.739
Comorbid Hypertension	9	10	0.066	0.798
Comorbid Diabetes	3	6	0.733	0.392
Comorbid Overweight (BMI ≥ 24)	12	13	0.270	0.604

Note: "U" indicates unilateral, "BD" indicates bilateral in different stages, and "BS" indicates bilateral in the same stage.*Note: "O" refers to osteoarthritis (OA); "R" refers to rheumatoid arthritis (RA); "G" refers to gouty arthritis (GA).

Table 2. The results of within-group and between-group comparisons of VAS, ROM, and HSS scores at baseline, one day before surgery, and three months after surgery.

Parameters \ Time Points		Baseline (t1)	1 D before Surgery (t2)	3 M after Surgery (t3)	t (t1 VS t2)	p (t1 VS t2)	t (t1 VS t3)	p (t1 VS t3)
VAS	Control	6.73 ± 0.46	6.67 ± 0.49	3.13 ± 0.64	0.435	0.670	16.837	<0.001
	Observation	6.72 ± 0.57	5.33 ± 0.69	2.39 ± 0.61	8.444	<0.001	23.971	<0.001
	t	0.061	6.307	3.421	-	-	-	-
	p	0.952	<0.001	0.002	-	-	-	-
ROM	Control	64.13 ± 12.53	64.33 ± 12.83	93.87 ± 5.67	1.000	0.334	7.216	<0.001
	Observation	63.88 ± 9. 35	76.78 ± 10.50	103.06 ± 7.50	6.164	<0.001	12.704	<0.001
	t	0.064	3.065	3.902	-	-	-	-
	p	0.949	0.004	<0.001	-	-	-	-
HSS	Control	56.53 ± 6.93	56.8 ± 7.97	80.47 ± 2.36	0.367	0.719	13.063	<0.001
	Observation	57.67 ± 4.89	67.94 ± 4.65	85.61 ± 3.88	12.988	<0.001	16.395	<0.001
	t	0.550	5.009	4.483	-	-	-	-
	p	0.586	<0.001	<0.001	-	-	-	-

Table 3. Comparative analysis of intraoperative relevant indicators between groups*.

Intraoperative Parameters	Control Group	Observation Group	t	p
Surgery Time (min)	84.10 ± 3.28	83.72 ± 4.25	0.329	0.743
Percentage of Bone Defect Area (%)	31.00 ± 5.53	30.40 ± 4.77	0.391	0.698
Depth of Bone Defect (mm)	14.65 ± 1.76	14.96 ± 1.95	0.554	0.582
Number of Screws Used	3.10 ± 0.85	2.92 ± 0.91	0.678	0.501

*Note: The indicators in this table are calculated per knee unit, with 20 knees in the control group and 25 knees in the observation group.

In the analysis of postoperative recovery indicators, there were no statistically significant differences between the two groups in terms of time to ambulation and proportion of patients requiring blood transfusion ($p > 0.05$). The observation group showed a significantly shorter time for quadriceps femoris strength recovery and discontinuation of assistive devices compared to the control group ($p < 0.05$). Please refer to **Table 4** for details.

During the follow-up period (24 - 30 months), no serious complications such as deep infection, aseptic loosening of the prosthesis, periprosthetic fractures, or symptomatic visceral embolism were observed. All the patients showed remarkable relief of pain and significant improvement in joint function, quality of life, and disappearance.

Table 4. Comparative analysis of postoperative recovery indicators between groups*.

Postoperative Recovery Parameters	Control Group	Observation Group	χ^2 or t	p
Time to Get Out of Bed after Surgery (days)	2.46 ± 0.52	2.33 ± 0.48	0.764	0.451
Time for Quadriceps Strength Recovery (Days)	4.13 ± 0.74	3.17 ± 0.71	3.821	<0.001
Time to Ditch Assistive Devices (Days)	17.13 ± 1.85	15.44 ± 1.10	3.258	0.001
Number of Blood Transfusions (Patients)	2	2	0.038	0.846

*Note: The indicators in this table are calculated per case. For patients undergoing bilateral bone defect repair in stages, the average value of the indicators from two separate occasions was used for the overall analysis.

4. Discussion

The surgical management and perioperative rehabilitation of total knee arthroplasty (TKA) with significant tibial plateau bone defects present challenging problems in joint surgery, which are closely related. Currently, there is more literature on surgical techniques, including bone cement filling, cement-screw technique, metal wedges, autograft or allograft impaction grafting, high stability prostheses, and others [11] [12] [13] [14]. However, there are relatively few reports on rehabilitation techniques for such patients. This study aims to explore both the surgical management and perioperative rehabilitation protocols for patients with this type of condition, intending to provide a more comprehensive and systematic intervention strategy for this disease.

Freeman *et al.* [15] first reported the use of bone cement combined with screws for the treatment of tibial plateau bone defects and obtained favorable follow-up results. Lotke *et al.* [16] pointed out in a 1991 report that for defects with an area < 50% of the plateau surface and a depth < 20 mm, simple bone cement filling could meet the intraoperative needs for prosthesis fixation. However, an increasing number of scholars tend to believe that the elastic modulus of bone cement is lower than that of bone tissue, resulting in uneven loading on the tibial plateau with larger areas of use. Simple bone cement filling is prone to subsidence and loosening of the prosthesis, and it is not recommended to use unilateral bone cement filling for large-area defects [17]. Compared to simple bone cement filling, the use of screws in combination can significantly enhance the strength of the bone cement and reduce the risk of aseptic loosening and subsidence of the prosthesis [18]. Compared to metal wedges and bone graft filling, the cement-screw technique reduces the use of internal implants, thereby reducing the risk of infection [19]. It is also a simpler procedure and cost-effective. In this study, both groups of 33 cases (45 knees) of TKA recipients underwent repair of tibial plateau bone defects using the cement-screw technique. During the follow-up period (24 - 30 months), all patients showed significant relief of pain and remarkable improvement in joint function, quality of life, disappearance and basic correction of radiographic indicators, achieving satisfactory treatment outcomes.

In this study, the procedures for each side were completed within a tourniquet time of 90 minutes. During the follow-up period, no serious complications such as deep infection, aseptic loosening of the prosthesis, periprosthetic fractures, or symptomatic visceral embolism were observed, indicating the good safety of the cement-screw technique for repairing tibial plateau bone defects in TKA. However, for patients who underwent bilateral surgery during the same period, some (4/8) required perioperative blood transfusion, suggesting the need for careful preoperative evaluation and adequate preoperative preparation, especially regarding postoperative blood transfusion, for patients undergoing simultaneous bilateral knee joint surgery.

Currently, there is no consensus on the optimal indications and limitations for the use of cement-screw technique in repairing bone defects of different sizes and depths in total knee arthroplasty (TKA). Most scholars tend to consider the combination of bone cement and screws appropriate for defects with an area < 50% of the tibial plateau and a depth of 5 - 20 mm. For smaller defects in terms of area and depth, increasing the amount of bone resection and wedge thickness or simple bone cement filling may be sufficient. For larger defects with greater area and depth (>50% of the plateau area and >20 mm depth), it is recommended to use bone grafts, metal wedges, or custom-made prostheses [11] [12] [13]. However, Berend *et al.* [20] reported that the use of this technique for defects with an area > 50% of the tibial plateau and a depth exceeding 10 mm did not increase the surgical failure rate, suggesting that the depth criterion can be expanded to 30 mm. Zheng *et al.* [21] argued that the cement-screw technique should also be used for defects with an area > 50% of the plateau area but a depth < 5 mm.

Considering that some of the patients included in this study required simultaneous bilateral repair of bone defects, the technical difficulty and higher risk were taken into account. Therefore, the indications were approached conservatively, strictly controlling the defect area at 10% < defect area/tibial plateau total area < 50%, and 5 mm < defect depth < 20 mm. This approach aimed to avoid potential risks associated with expanding the indications, which is an important factor in achieving favorable outcomes.

In addition to surgical methods, rehabilitation is also one of the challenges faced by patients with significant tibial plateau bone defects undergoing total knee arthroplasty (TKA). Patients with knee diseases accompanied by significant tibial plateau bone defects often have severe joint damage and deformity, and their preoperative joint function is usually much worse than that of patients without obvious bone defects. Compliance with routine postoperative rehabilitation measures is also often poor. The successful use of the cement-screw technique in repairing bone defects in TKA can significantly improve knee joint morphology and biomechanics, providing an anatomical basis for functional recovery in this patient population. However, to achieve good treatment outcomes, proactive and scientifically sound rehabilitation measures are crucial.

With the gradual standardization of TKA procedures and postoperative rehabilitation treatments, as well as the maturation of knee joint prosthesis designs, the influence of intraoperative and postoperative factors on TKA outcomes has become increasingly smaller [22]. Recent domestic and international studies have shown that preoperative conditions and the state of the disease have a more direct impact on the postoperative outcomes of TKA [22] [23]. In response to this situation, the role of efficient "prehabilitation" before surgery in postoperative rehabilitation after TKA has received increasing attention [5] [6] [24] [25].

According to the latest rehabilitation concepts, preoperative prehabilitation enhances patients' rehabilitation "reserve" through training. Compared to patients who did not undergo prehabilitation, those who underwent prehabilitation showed significant improvements in knee joint function before surgery. Both groups experienced a similar degree of functional decline after surgery, but the prehabilitation group had higher functional levels and a faster and easier return to functional independence [26]. Additionally, preoperative prehabilitation allows patients to better understand the importance of rehabilitation training and adapt in advance, effectively enhancing patient compliance with postoperative rehabilitation training [27].

In this study, the observation group underwent 4 weeks of preoperative prehabilitation training. Compared to the control group without specific prehabilitation instructions, the observation group showed significant improvements in preoperative pain, increased joint range of motion, and improved joint scores. Moreover, this positive effect persisted until 3 months postoperatively and contributed to earlier recovery of major muscle strength and ambulation without assistive devices. This demonstrates that preoperative prehabilitation has a facilitating effect on postoperative rehabilitation in TKA recipients with significant tibial plateau bone defects repaired using the cement-screw technique. It significantly improves the preoperative rehabilitation reserve of such patients, accelerates postoperative rehabilitation speed, and contributes to better short-term (3 months) clinical outcomes.

Based on the data from this study, we believe that the strategy of preoperative "prehabilitation" has further research and promotion value for complex primary total knee arthroplasty with significant tibial plateau bone defects.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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