Application of a Novel Osteotomy Instrumentation as a Substitute Tool in Total Hip Arthroplasty

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Research Article

Keywords: Total hip arthroplasty, osteotomy instrumentation, femoral neck osteotomy

Posted Date: May 27th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-539000/v1

Abstract

Background: Mechanical failure, power shortage, and unexpected contamination of oscillating saw occasionally happened in actualizing femoral neck osteotomy during total hip arthroplasty, while no appropriate alternative solution be available presently. This study aimed to introduce a novel osteotomy instrumentation (fretsaw, jig, cable passer hook) as a substitute tool while oscillating saw was unavailable in THA.

Methods: This study included 40 patients (40 hips) who underwent femoral neck osteotomy during primary THA using the new osteotomy instrumentation (n=20) and oscillating saw (n=20). Clinical data and intraoperative findings of all patients were evaluated.

Results: The mean osteotomy time was 22.3 ± 3.1 s (range, 17–30 s) and 29.4 ± 3.7 s (range, 25–39 s) in the oscillating saw group and the new osteotomy instrumentation group, respectively ($P<0.001$). The Harris Hip Score (HHS) improved in both groups; the mean HSS was 82.3 ± 2.5 and 83.3 ± 3.5 in the oscillating saw group and new osteotomy instrumentation group at 6 months after surgery, respectively ($P=0.297$).

Conclusion: The original osteotomy instrumentation can be an ideal substitute tool for femoral neck osteotomy in THA, especially when the oscillating saw is unavailable or malfunctional.

Introduction

Total hip arthroplasty (THA) is generally considered one of the most effective and safe procedures for relieving pain and restoring function in patients with hip joint disorders [1, 2]. More than 1 million hip arthroplasties are performed annually worldwide for severe osteoarthritis, osteonecrosis of the femoral head (ONFH), and developmental dysplasia of the hip (DDH) [3]. The number of cases of THAs in China is approximately 40,000 recent years, which increases by 25–30% each year [4]. Oscillating saws are widely used in orthopedics and have become a foundational tool for THA due to its high cutting efficiency and accuracy [5]. However, intraoperative complications occasionally occur due to its mechanical damage and faults. Problems associated with oscillating saws include machine contamination and power shortages during femoral neck osteotomy in THA. Substituting the oscillating saw with a new one may prolong the operation time, which is associated with an increased risk of surgical infection [6]. In addition, most oscillating saws are heavy, and manual handling requires considerable training to avoid overshooting and consequently damage the surrounding soft tissue and neurovascular bundles [7]. Furthermore, the oscillating saw emitted noise emission and a high frequency of blood splash during surgery, which increase the risk of disease transmission and noise-induced hearing loss among orthopedic surgeons. In several cases, orthopedists use a fretsaw or a chisel as a substitute tool for femoral neck osteotomy during THA. However, researches on these osteotomy tools are limited.

In this study, we designed a compact, affordable, and efficient reusable femoral neck osteotomy instrumentation based on a fretsaw, jig, and cable passer hook. This study aimed to introduce and estimate this novel osteotomy instrumentation as a substitute for the oscillating saw in THA.

Materials And Methods

Instrumentation design and model study

The osteotomy instrumentation (Fig. 1) consists of three separate devices: the fretsaw, cable passer hook, and jig. The fretsaw is also called a wire saw, which is easy for sterilization and fast replacement of damaged components and at low cost. The cable passer hook was used to carry the fretsaw to round the formal neck. This cable passer hook is a stainless-steel instrument that contains a curved tube and a special fillister at the distal end (Fig. 1c). The fretsaw can be conveniently inserted into this L-shaped fillister and surround the bone. The cuspidal terminal with a groove for the fretsaw and bending handle comprises the jig (Fig. 1d). The perpendicular handle could provide a satisfied operation field for surgeons without the obstructor in the vision. The jig could seize the femoral neck, hold the fretsaw in place for the osteotomy, and prevent cutting damage to the surrounding tissue. To verify the functional demands for the design criteria, a performance experiment was performed using this new osteotomy system on the formal model (Fig. 2). After we confirmed the duration of the procedure, osteotomy height, and quality of cut in the model study, we decided to continue the experiment on the patients.

Patients

Between January 2020 and June 2020, 40 patients (40 hips) requiring for primary THA in our hospital were included in this study. Patients who met the following criteria were included: (1) patients' age between 25 and 80 years; (2) patients with femoral head necrosis, or primary osteoarthritis, or rheumatoid arthritis; (3) the operation was under the posterolateral approach by using the cementless press-fit cup. The exclusion criteria were: patients with severe hip ankylosis, femoral neck fracture or deformity of the femoral neck, or lost to follow up. The patients were divided into two groups based on the method of osteotomy. In the new osteotomy instrumentation group, 20 patients underwent the femoral neck osteotomy with our designed tools, while in the oscillating saw group, the other 20 patients underwent the femoral neck osteotomy with an oscillating saw.

Surgical technique

All surgeries were performed using a posterolateral approach by the same surgeon with a general anesthesia. The femoral neck osteotomy was implemented according to the preoperative scheme using either a conventional oscillating saw (Group I) or the new osteotomy instrumentation (Group II) (Fig. 3). The remaining perioperative procedures were identical between the two groups. The rehabilitation programs in the two groups were equal: full weight-bearing at 2 days after surgery.

Evaluation method and follow-up

Clinical data were obtained from all patients before surgery and at follow-up examinations. Clinical evaluation was performed based on the Harris Hip Score (HHS) [8], and patients' pain was subjectively described using the visual analogue scale (VAS) [9]. Intraoperative findings, including operation time, osteotomy time, and amount of bleeding, were performed.

Statistical analysis

SPSS software (Version 24; SPSS Inc., Chicago, IL, USA) and Prism (Version 8; GraphPad Software Inc., San Diego, CA) were used for statistical analyses. The Student's t-test was used to compare the measurement data of clinical results, and the Mantel-Haenszel chi-squared test was used to compare the enumeration data of clinical results. Difference was considered statistically significant at a P-value of less than 0.05.

Results

A total of 40 patients participated in this study, with 20 patients in the conventional oscillating saw group (Group II) and the new osteotomy instrumentation group (Group II). No patients were lost to the follow-up. The clinical characteristics of the patients in the two groups are presented in Table 1. Data on gender, age, body mass index, operative side, and etiology were collected, and the results showed no significant difference between Group I and Group II. The intraoperative evaluation showed no significant difference in total operation time ($P = 0.775$) and blood loss ($P = 0.716$) for both groups, while differences existed in the osteotomy time between the two groups ($P < 0.001$); the average osteotomy time in the new osteotomy instrumentation group was longer than that in the oscillating saw group. In addition, the osteotomy time in Group II consisted of the fretsaw-passing time (4.05s ± 0.76s), jig-fixing time (4.25 ± 0.72s), and sawing time (21.10 ± 3.60s) (Fig. 4). However, no difference was observed in the sawing time between the two groups ($P = 0.263$). No complications occurred in either group during the osteotomy process in patients undergoing THA.

Table 1
Characteristics of patients in the Group I and Group II

	Group I(N = 20)	Group II(N = 20)	P value
Gender			0.337
Male	10	7	
Female	10	13	
Mean age(yrs)	62.4(range,27–78)	56.8(range,26–71)	0.154
BMI			0.736
> 25	7	6	
≤ 25	13	14	
Operation side			
Right	9	10	0.752
Left	11	10	
Aetiology of indications			0.527
Femoral head necrosis	11	9	
Primary osteoarthritis	9	11	

A significant improvement in the HHS and VAS score after surgery was observed in the two groups (Table 2). In the oscillating saw group, the mean HHS improved from 44.5 points (SD 4.7, 30 to 52 points) to 82.3 points (SD 2.5, 78 to 90) at the 6-month follow-up examination ($P < 0.001$). In the new osteotomy instrumentation group, it improved from 46.2 points (SD 4.5, 40 to 55 points) to 83.3 points (SD 3.5, 75 to 88 points) at the 6-month follow-up examination ($P < 0.001$). The mean preoperative and postoperative VAS for the oscillating saw group was 5.3 points (SD 0.9, 4.0 to 7.0 points) and 1.4 points (SD 0.6, 0.0 to 2.0 points), respectively. The mean preoperative and postoperative VAS for the new osteotomy instrumentation group was 5.0 points (SD 0.8, 3.0 to 6.0 points) and 1.3 points (SD 0.8, 0.0 to 2.0 points), respectively. There was no significant difference in the VAS and HHS between the two groups ($P = 0.651$, $P = 0.297$). During follow-up, no cases of dislocation or infection were observed in any of the groups.

Table 2
Comparison of the clinical results between Group I and Group II

	Group I(M ± SD)	Group II(M ± SD)	P Value
Pre-OP HHS	44.5 ± 4.7	46.2 ± 4.5	0.246
Post-OP HSS	82.3 ± 2.5	83.3 ± 3.5	0.297
P Value	P < 0.001	P < 0.001	
Pre-OP VAS	5.3 ± 0.9	5.0 ± 0.8	0.361
Post-OP VAS	1.4 ± 0.6	1.3 ± 0.8	0.651
P Value	P < 0.001	P < 0.001	

M: Mean; SD: Standard deviation

Discussion

This present study introduced a novel osteotomy instrumentation (fretsaw, jig, cable passer hook) as a substitute tool while oscillating saw was unavailable in THA. As far as we know, this is the first introduced substitute device that requires low-tech cleaning and sterilization within an acceptable time frame and meets satisfying osteotomy results, as well as the functional requirements, in THA surgery.

Several studies have shown that long operative times are associated with perioperative complications. Prolonged operation time can increase the risk of blood loss and periprosthetic joint infection (PJI), which may be associated with extended hospital, financial hardship, and even hazard of mortality for patients [11–13]. In this study, the average osteotomy time was a little longer in the new osteotomy instrumentation group than it in the oscillating saw group, yet there was no significant difference in the total operation time between two groups. This osteotomy instrumentation was an efficient tool as an oscillating saw and did not prolong the entire operation time. Thus, this fully functional, detachable, and flexible instrumentation could be the ideal choice rather than the chisel for osteotomy when the oscillating saw is deactivated. Besides, complications have occasionally been reported during THA, which includes bleeding, soft tissue damage, and fractures [14]. The major sources of bleeding in THA are the ischiofemoral ligament and posterior labrum, bleeding may occur if the surgeon performs an aggressive femoral neck osteotomy using an oscillating saw [15]. The inadvertent penetration of the oscillating saw into the soft tissue leading to neurovascular branch damage may cause postoperative pain and neural and vascular complications, although the reported rate of severe damage is rather low [16]. Unlike the oscillating saw, which requires a force toward the bone and the tissues from above, the fretsaw is placed around the bone and directed away from the adjacent soft tissue through the bone. Thus, there is no risk of overshooting or surrounding tissue and trochanter damage during the osteotomy. In addition, this instrumentation resulted in a flat osteotomy surface with no risk of notch generation and fracture of the trochanter or contralateral femoral neck. Therefore, it may offer a safe method of femoral neck osteotomy with a reduced risk of trapping soft tissue and periprosthetic femoral fracture.

The major objectives of THA include postoperative improvement of self-reported physical functioning, pain relief, and quality of life [17]. In this study, improvement in the HHS and VAS was observed in both groups. There was no significant difference in the postoperative HSS and VAS between the oscillating saw group and the new osteotomy instrumentation group at the 6-month follow-up ($P > 0.05$). These results demonstrated that the new osteotomy device could be used as a novel osteotomy technique in THA, which had no influence on physical rehabilitation and pain subsided.

Besides, there are still great challenges for surgeons to deal with complicated hip joint disease caused by congenital disease, rheumatic disease, and other serious diseases [18]. In these cases, the fused hips are difficult to dislocate and reconstruct accurately. The surgeon may encounter a struggle with an inconvenient osteotomy position and a higher risk of neurovascular branch damage during the cutting process, which can prolong the entire operation time. With our newly designed instrumentation, the femoral head does not have to be dislocated prior to osteotomy, since the fretsaw could easily surround the femoral neck through the cable passer hook. In this case, the osteotomy can easily be performed in situ with no need to excessively release the soft tissues, which results in less bleeding, enhanced stability, and faster rehabilitation [19].

Over the decades, many researches have been conducted to explore and advance for THA. In the thousands of study topics in this therapeutic method, surgical methods, postoperative outcomes, and materials remain the major focus [20]. However, so far as we know, this study is the first to focus on the femoral neck osteotomy tool and introduces and evaluates whether this novel osteotomy instrumentation could accomplish the accurate femoral neck osteotomy during THA surgery. Our clinical data and follow-up outcomes show that the collaboration of the fretsaw, jig, and cable passer hook can accomplish a safe, minimally invasive, efficient, and precise femoral neck osteotomy.

Nevertheless, this study had several limitations. First, the small sample size of the study resulted in low credibility of conclusions. Second, the jig could not fix the femoral neck well, which required a reformative jig with acumination. Finally, patients with severe hip ankylosis, femoral neck fracture or deformity of the femoral neck were excluded.

Therefore, the study conclusions still require further verification. Osteotomy instrumentation needs to be modified to fit the surgery. Randomized controlled trials with larger sample sizes, higher quality, and a longer follow-up will be conducted to confirm the results. Third, the osteotomy tools in both groups were only used in patients with a relatively normal femoral neck. Patients with more severe deformity of the femoral neck or hip ankyloses were not included in this study.

Conclusions

This study demonstrated that the innovative osteotomy instrumentation was equal to the conventional oscillating saw in THAs in terms of operation time and postoperative physical function. Besides, this osteotomy instrumentation had a lower risk of neurovascular and soft tissue damage during surgery than the conventional oscillating saw, thus making it an ideal substitute tool for femoral neck osteotomy in THA, especially when the oscillating saw is unavailable or malfunctional. Furthermore, studies with modified tools, larger samples, and long-term results are required in the future.

Abbreviations

THA, total hip arthroplasty; HHS, Harris Hip Score; ONFH, osteonecrosis of the femoral head; DDH, developmental dysplasia of the hip; PJI, periprosthetic joint infection

Declarations

Ethics approval and consent to participate

This study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Institutional Review Board of Shanghai Ninth People's Hospital, Shanghai Jiaotong University School of Medicine (protocol code SH9H-2021-T84-1 and date of approval 26 March 2021). The requirement for informed consent was waived due to the retrospective study design.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and/or analysed during the current study available from the corresponding author on reasonable request.

Competing of interests

The authors have no conflicts of interest to declare.

Funding

This study was supported by the Shanghai Clinical Medical Center (2017ZZ01023); Shanghai Municipal Key Clinical Specialty (shslczdzk00402, shslczdzk07001); Science & Technology Innovation Fund of Shanghai Ninth People's Hospital, Shanghai Jiaotong University School of Medicine (CK2019002); The Youth Doctor Collaborative Innovation Team Project of Shanghai Ninth People's Hospital, Shanghai Jiaotong University School of Medicine (QC201903).

Acknowledgements

Not applicable.

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Authors' contributions

Conceptualization, YH.H. and ZJ.Z.; methodology, YH.H.; software, JW.Z.; validation, ZY.S, DG.Y. and YH. H.; formal analysis, JW.Z.; investigation, ZY.S; resources, JW.Z.; data curation, DG.Y.; writing—original draft preparation, YH.H.; writing—review and editing, YH.H; HW.L.; visualization, ZA.Z.; supervision, MN.Y.; project administration, ZJ.Z.; funding acquisition, YQ.M. All authors have read and agreed to the published version of the manuscript.

References

1. Learmonth ID, Young C and Rorabeck C. The operation of the century: total hip replacement. Lancet 2007; 370: 1508–1519.
2. Pivec R, Johnson A J, Mears S C, et al. Hip arthroplasty[J]. Lancet, 2012, 380(9855):1768-1777.
3. Zeng Chao,Lane Nancy E,Englund Martin et al. In-hospital mortality after hip arthroplasty in China: analysis of a large national database. [J]. Bone Joint J, 2019, null: 1209-1217.
4. Zhen, Tan, Guorui, et al. Total hospital cost, length of stay, and complications between simultaneous and staged bilateral total hip arthroplasty: A nationwide retrospective cohort study in China. [J]. Medicine, 2019.
5. Abrasive water jet cutting as a new procedure for cutting cancellous bone—In vitro testing in comparison with the oscillating saw[J]. Journal of Biomedical Materials Research Part B: Applied Biomaterials, 2004, 71b.
6. Sun X, Zhao X, Zhou L, et al. Direct anterior approach versus posterolateral approach in total hip arthroplasty: a meta-analysis of results on early post-operative period[J]. Journal of Orthopaedic Surgery and Research, 2021, 16(1).
7. Minnaard J, Kleipool R P, Baars W, et al. A new bone-cutting approach for minimally invasive surgery[J]. Medical Engineering & Physics, 2021, 87(3):56-62.
8. Mahomed N N , Arndt D C , Mcgrory B J , et al. The Harris hip score: comparison of patient self-report with surgeon assessment. [J]. Journal of Arthroplasty, 2001, 16(5):575-580.
9. Carlsson A M. Assessment of chronic pain. I. Aspects of the reliability and validity of the visual analogue scale. [J]. Pain, 1983, 16(1):87-101.

10. Lima F D, Fernandes D A, Melo G, et al. Effects of total hip arthroplasty for primary hip osteoarthritis on postural balance: A systematic review[J]. Gait & Posture, 2019, 73.
11. Maca M M A C. Risk Factors for Periprosthetic Joint Infection Following Primary Total Hip Arthroplasty: A 15-Year, Population-Based Cohort Study[J]. JBJS, 2020, 102.
12. Ryan, R, Thacher, et al. The Impact of Running, Monofilament Barbed Suture for Subcutaneous Tissue Closure on Infection Rates in Total Hip Arthroplasty: A Retrospective Cohort Analysis - ScienceDirect[J]. The Journal of Arthroplasty, 34(9):2006-2010.
13. Malik Azeem T, Jain Nikhil, Scharschmidt Thomas J et al. Does Surgeon Volume Affect Outcomes Following Primary Total Hip Arthroplasty? A Systematic Review. [J] J Arthroplasty, 2018, 33: 3329-3342.
14. Pincus D, Jenkinson R, Paterson M, et al. Association Between Surgical Approach and Major Surgical Complications in Patients Undergoing Total Hip Arthroplasty[J]. JAMA The Journal of the American Medical Association, 2020, 323(11):1070.
15. Guild G N, Runner R P, Castilleja G M, et al. Efficacy of Hybrid Plasma Scalpel in Reducing Blood Loss and Transfusions in Direct Anterior Total Hip Arthroplasty[J]. Journal of Arthroplasty, 2017, 32(2):458.
16. Herregodts Stijn, Verhaeghe Mathijs, Paridaens Rico et al. Soft-tissue penetration of the oscillating saw during tibial resection in total knee arthroplasty. [J]. Bone Joint J, 2020, null: 1324-1330.
17. Peters Rinne M, van Steenbergen Liza N, Stewart Roy E et al. Which patients improve most after total hip arthroplasty? Influence of patient characteristics on patient-reported outcome measures of 22,357 total hip arthroplasties in the Dutch Arthroplasty Register. [J]. Hip Int, 2020, undefined: 1120700020913208.
18. Peng-fei Lei, Shi-long Su, Ling-yu Kong, et al. Mixed Reality Combined with Three-Dimensional Printing Technology in Total Hip Arthroplasty: An Updated Review with a Preliminary Case Presentation[J]. Orthopaedic Surgery, 2019, 11(5).
19. Schneider A K, Pierrepont J W, Hawdon G, et al. Clinical accuracy of a patient-specific femoral osteotomy guide in minimally-invasive posterior hip arthroplasty[J]. Hip International, 2018:1120700018755691.
20. Zhang W, Tang N, Li X, et al. The top 100 most cited articles on total hip arthroplasty: a bibliometric analysis[J]. Journal of Orthopedic Surgery and Research, 2019, 14.

Figures

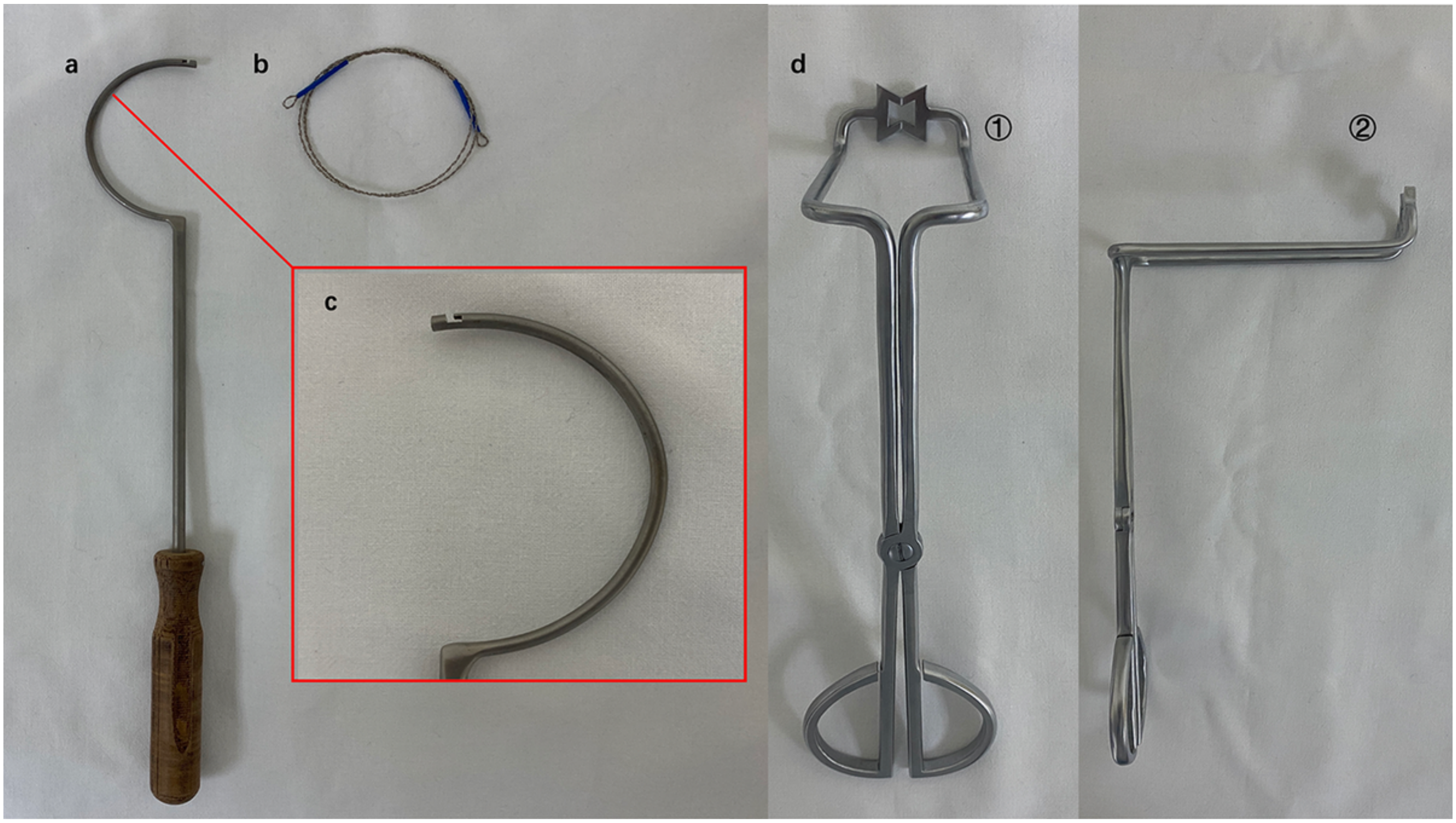

Figure 1

Femoral neck osteotomy instrumentation a: the cable passer hook. b: fretsaw. c: special fillister at the distal end. d: anterior view of the jig (①) and lateral view of the jig (②).

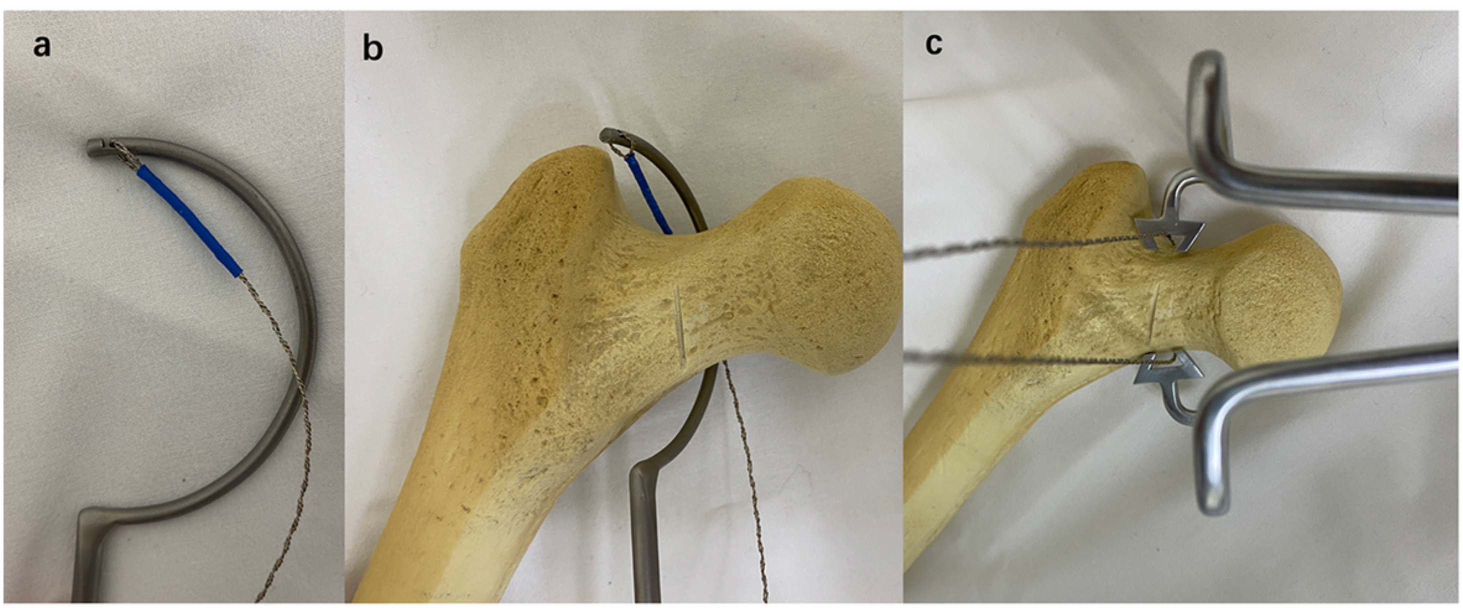

Figure 2

Photograph of the osteotomy instrumentation as a femoral neck osteotomy tool in vitro model a: the fretsaw hooking on the terminal of the cable passer hook. b: basic principle of the fretsaw placement around the femoral neck demonstrated. c: the jig fixing the fretsaw in place for osteotomy.

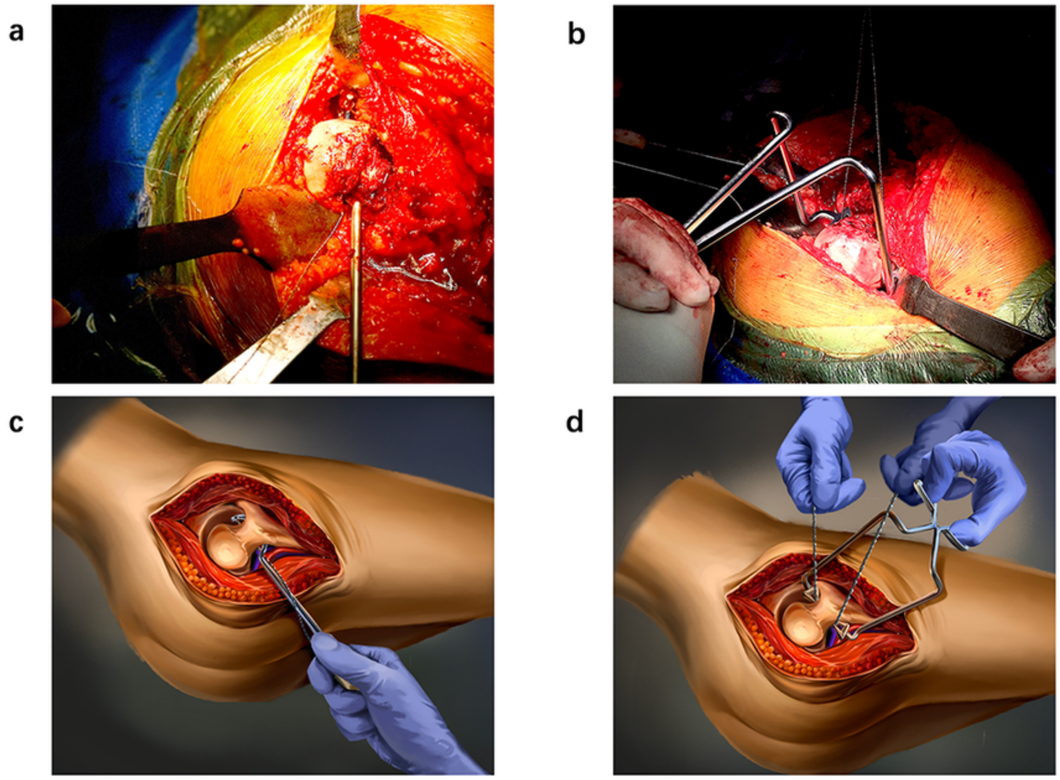

Figure 3

Intraoperative photographs were obtained for the patients during the surgery. a, b: Intraoperative photographs of our new osteotomy instrumentation group. c, d: the diagrams of the osteotomy using new osteotomy instrumentation.

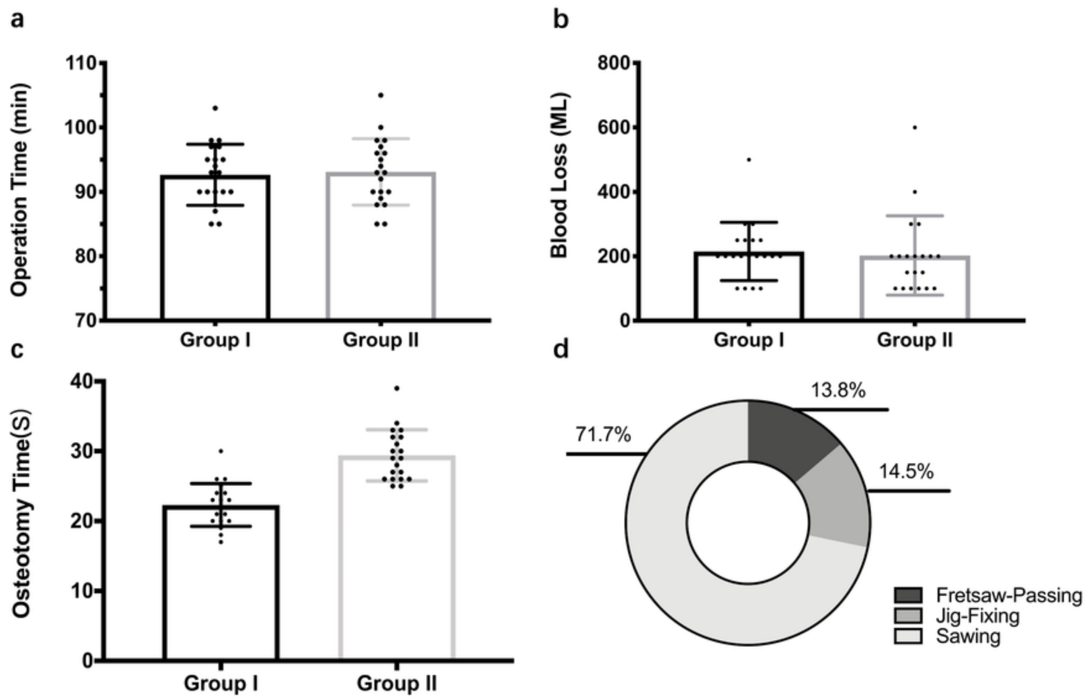

Figure 4

Intraoperative evaluation of two groups. a: total operation time of two groups. b: blood-loss in the surgery of two groups. c: osteotomy time of two groups. d: timeline of sectioning motion conducted on the osteotomy in Group II.