Original article

A modified technique of bone grafting pedicled with femoral quadratus for alcohol-induced osteonecrosis of the femoral head

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Keywords: *osteonecrosis of femoral head; titanium mesh; pedicled with quadratus femoris; strut bone grafting; deliquesce prop*

Background Quadratus femoris pedicled bone grafting has yielded satisfactory long-term clinical outcome for osteonecrosis of the femoral head (ONFH) in pre-collapse ONFH without extensive lesion. However, for pre-collapse ONFH with extensive necrotic area, it is still challenging to preserve the femoral head. The current study aimed to introduce a new technique of deliquesce strut with titanium mesh containing bone grafting pedicled with the femoral quadratus and to evaluate its short-term outcomes.

Methods From January 2008 to December 2008, 10 ONFH patients (12 hips) underwent operations by a new technique of deliquesce strut with titanium mesh containing bone grafting pedicled with the femoral quadratus (group A). According to the ARCO classification system, there were two hips in stage II B and 10 hips in stage II C. Also in the same period, 12 ONFH patients (16 hips) underwent operations by the conventional procedure of quadratus femoris pedicled bone grafting (group B). There were 6 hips in stage II B and 10 hips in stage II C. All patients were males and suffered from alcohol induced ONFH. For the new technique, the necrotic area was evaluated, and a titanium mesh piece of the same size (range from 2.5 cm×2.8 cm to 2.8 cm×3.4 cm) was obtained and shaped to match the contour of the head. The cancellous bone was first placed underneath the subchondral bone and was densely impacted (about 1 to 2 mm thick). Then the titanium mesh piece was inserted. The length of the decompressive trough was measured. A titanium cylinder mesh cage with a diameter of 1.6 cm of the same length was obtained, with a "U" shaped window in the wall being created to make room for the muscle pedicle. The muscle pedicle bone was inserted into the titanium mesh cage to form a bone graft-titanium cage complex and, then the complex was inserted. The hundred percent score method was used for outcome evaluation. Clinical and radiographic outcomes were compared between group A and group B.

Results The average operative time was 150 minutes (130 to 185 minutes) in group A, with an average of 130 minutes (120 to 180 minutes) in group B. The mean blood loss was 400 ml (300 to 500 ml) in group A and 350 ml (250 to 500 ml) in group B. Group A patients were followed up for an average of 19.2 months (14 to 24 months), with an average of 18.5 months (12 to 24 months) for Group B. Full weight bearing was allowed 5 to 7 months postoperatively. Pain and function were obviously improved. For group A, pain score improved from a mean of 9.8 points preoperatively to an average of 24.6 points postoperatively, and function score improved from a mean of 9.0 points preoperatively to an average of 17.4 points postoperatively. In group B, pain score improved from a mean of 9.5 points preoperatively to an average of 24.2 points postoperatively and function score improved from a mean of 9.2 points preoperatively to an average of 17.2 points postoperatively. The range of motion changed the least, with score improvement from a preoperative mean of 13.9 points to postoperative 16.8 points for group A and from a preoperative mean of 13.7 points to postoperative 16.5 points for group B. Radiographic score improved from preoperative 31 points to postoperative 38 points for group A, in comparison with an improvement from preoperative 31 points to postoperative 37 points for group B. At the latest follow up, 11 hips were rated as excellent and 1 hip was better for group A, with 14 hips being rated as excellent and 2 hips being better in group B. There was no statistically significant difference between groups A and B in clinical and radiographic outcomes.

Conclusion For ONFH in stage ARCO IIC, satisfactory clinical outcome can be achieved by the new technique in the short-term period while the long-term clinical outcome has yet to be determined.

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Osteonecrosis of the femoral head (ONFH) is often seen in young patients. Due to the limited life of artificial hip arthroplasty, it is an important objective for the young patients to choose an effective head-preserving method to delay or avoid joint replacement.[1,2] Vascularized bone grafting procedures with powerful support are optimal head-preserving methods.[1-3] Quadratus femoris pedicled bone grafting has long been practiced in our institution and has yielded satisfactory long-term clinical outcome for ONFH in pre-collapse ONFH without

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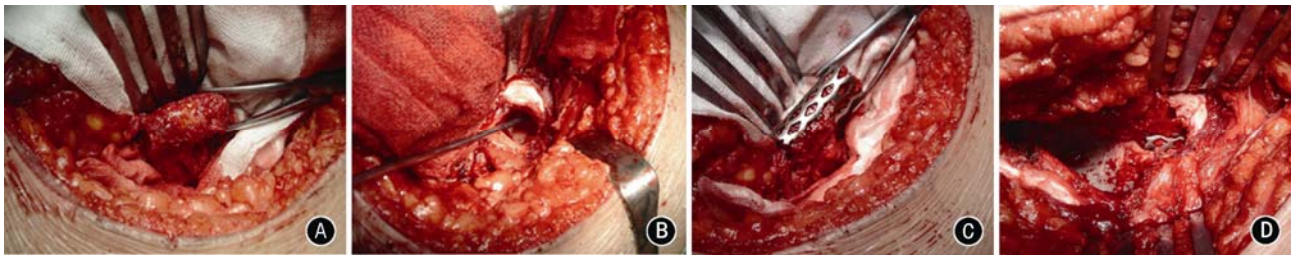

Figure 1. A: Bone graft pedicled with femoral quadratus; **B:** decompression window through which necrotic bone was removed; **C:** complex formed by titanium cage containing bone graft pedicled with femoral quadratus; **D:** insertion of the complex into the femoral head.

extensive lesion. However, for pre-collapse ONFH with extensive necrotic area, it is still challenging to preserve the femoral head.[4,5] In an attempt to improve the clinical outcome for ONFH with an extensive necrotic area lesion, we had modified the traditional procedure and designed a new technique of deliquesce strut with a titanium mesh containing bone grafting pedicled with the femoral quadratus. From January 2008 to December 2008, a series of ONFH cases, mostly in stage ACRO II C, underwent surgery using the new technique. The current study was to report the short-term clinical and radiographic outcomes of the new technique, and to compare it with the conventional procedure of quadratus femoris pedicled bone grafting.

METHODS

Patients

From January 2008 to December 2008, 10 ONFH patients (12 hips) underwent operations by a new technique of deliquesce strut with titanium mesh containing bone grafting pedicled with the femoral quadratus (group A). All patients were males and suffered from alcohol-induced ONFH. The average age was 30.1 years (21 to 42 years). According to the ARCO classification system,[6] there were two hips in stage II B and 10 hips in stage II C. In the same period, 12 ONFH patients (16 hips) underwent operations by the original procedure of quadratus femoris pedicled bone grafting (group B). All patients were males and got alcohol-induced ONFH. The average age was 29.8 years (20 to 41 years). According to the ARCO classification system,[6] there were six hips in stage II B and 10 hips in stage II C.

Surgical technique

The patient was placed in lateral decubitus position. The posterior aspect of the hip was exposed using the Moore approach. After the posterior intertrochanteric area with the insertion of the quadratus femeris was indentified, a rectangular block of bone pedicled with the quadratus femeris muscle was obtained, usually 1.6 cm×1.6 cm×(3.5–5.0) cm (Figure 1A). Then the cancellous bone graft pieces were taken from the greater trochanteric area through the window made by removing the above pedicled bone graft. A window of 1.6 cm×1.6 cm in size was made near the cartilage margin in the posterior aspect of the neck. Through this window, the necrotic bone, usually in the anterior-superior-lateral part of the femoral head, was thoroughly removed to the depth of the subchondral bone (Figure 1B). For the conventional procedure, the cancellous bone was densely impacted underneath the subchondral bone and lateral walls. Then the strut graft bone was trimmed to fit the redisual decompressive trough and was inserted. During the whole procedure, the muscle pedicle and the strut bone were protected from damage.

For the new technique, the necrotic area was evaluated, and a titanium mesh piece of the same size (range from 2.5 cm×2.8 cm to 2.8 cm×3.4 cm) was obtained and shaped to match the contour of the head. The cancellous bone was first placed underneath the subchondral bone and was densely impacted (about 1 to 2 mm thick). Then the titanium mesh piece was inserted. The length of the decompressive trough was measured. A titanium cylinder mesh cage, 1.6 cm in diameter and of the same length was obtained, with a U-shaped window in the wall being created to make room for the muscle pedicle. The muscle pedicle bone was inserted into the titanium mesh cage to form a bone graft-titanium cage complex (Figure 1C). When the complex was inserted, the position of the muscle pedicle was checked to avoid compression or too much tension (Figure 1D). The residual room was filled with cancellous bone graft pieces.

After the operation, the patient was restricted to bed. Partial weight bearing was allowed after three to four months when the bone union of the bone grafts was confirmed by radiography. Full weight bearing was allowed two to three months later if there was no radiographic change of the height of femoral head at follow up.

Follow-up

During the first six months postoperatively, the patient was followed up monthly. During the second six months postoperatively, the patient was seen every two months. Over the next 12 months, follow-up was done every three months. The patients were instructed to see their physician in a timely manner whenever they felt discomfort. In the first postoperative year, the patients met the doctor in the clinic. After one year, the patients were either seen or contacted by telephone. The patients were evaluated clinically and radiographically at each visit.

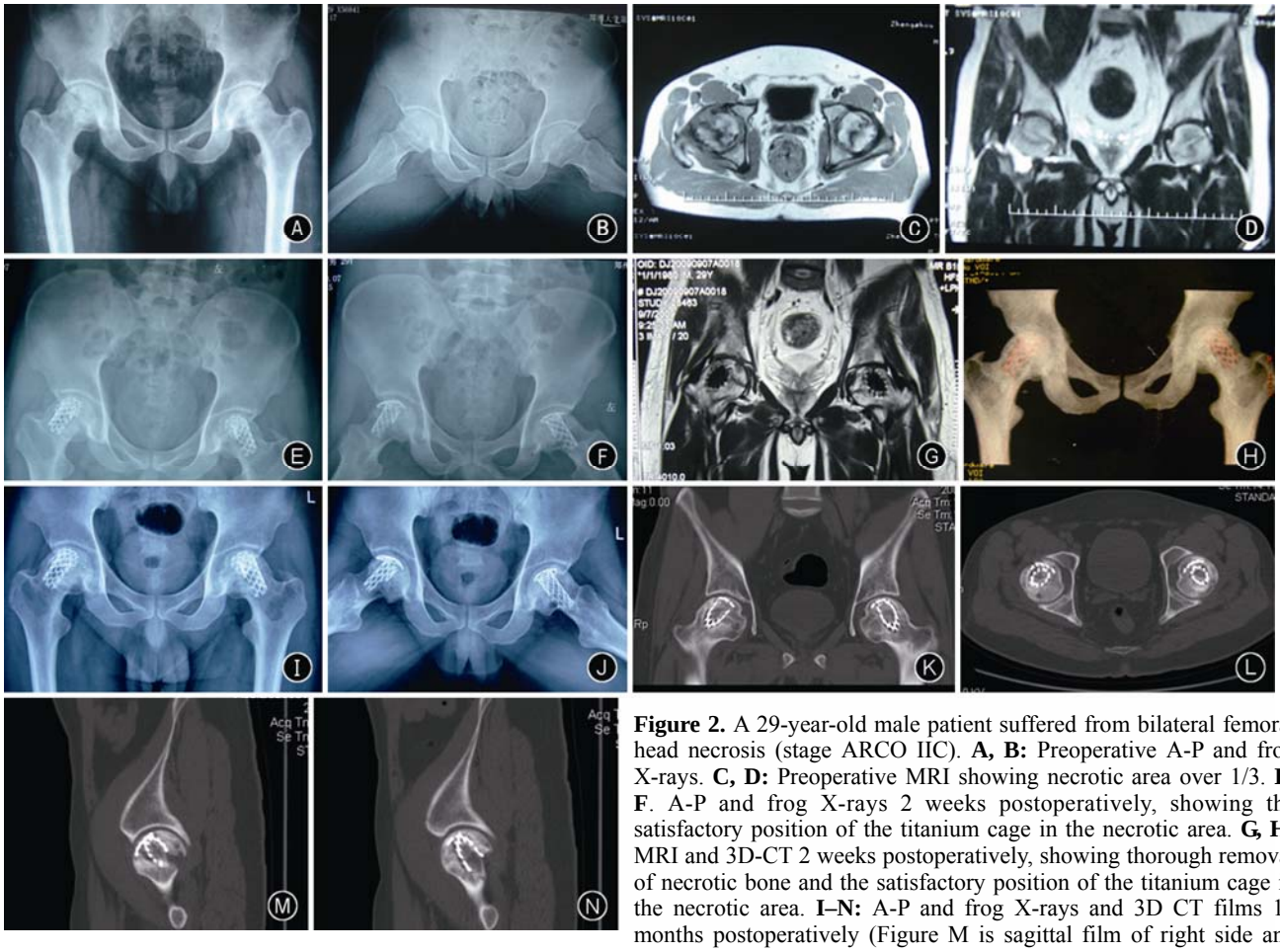

Figure 2. A 29-year-old male patient suffered from bilateral femoral head necrosis (stage ARCO IIC). **A, B:** Preoperative A-P and frog X-rays. **C, D:** Preoperative MRI showing necrotic area over 1/3. **E, F**. A-P and frog X-rays 2 weeks postoperatively, showing the satisfactory position of the titanium cage in the necrotic area. **G, H:** MRI and 3D-CT 2 weeks postoperatively, showing thorough removal of necrotic bone and the satisfactory position of the titanium cage in the necrotic area. **I–N:** A-P and frog X-rays and 3D CT films 12 months postoperatively (Figure M is sagittal film of right side and Figure **N** is sagittal film of left side), showing union of the bone graft with the host bone and intact of the position of the titanium cage in the necrotic area.

Evaluation standard

A 100-point rating score system was used.[7] It consists of a 60-point clinical part and a 40-point radiographic part. The clinical part includes 25 points for pain, 18 points for function, and 17 points for range of motion (ROM) of the joint. The outcome was rated as excellent (≥90 points), good (75 to 89 points), moderate (60 to 74 points), and poor (<60 points).

Statistical analysis

The Wilcoxon rank test was applied for comparison of clinical and radiographic outcomes between groups A and B using SPSS 11.5 software. A P value <0.05 was considered statistically significant.

RESULTS

For group A, the operative time averaged 150 minutes (130 to 185 minutes). The mean blood loss was 400 ml (300 to 500 ml). For group B, the operative time averaged 130 minutes (120 to 180 minutes). The mean blood loss was 350 ml (250 to 500 ml). All incisions healed uneventfully. Anticoagulation treatment was not regularly used. No deep vein thrombosis was noted.

Group A patients were followed up for an average of 19.2 months (14 to 24 months), with an average of 18.5 months (12 to 24 months) for patients in Group B. Full weight bearing was allowed five to seven months postoperatively. Pain and function were both improved. For group A, the pain score improved from a mean of 9.8 points preoperatively to an average of 24.6 points postoperatively, and function score improved from a mean of 9.0 points preoperatively to an average of 17.4 points postoperatively. In group B, the pain score improved from a mean of 9.5 points preoperatively to an average of 24.2 points postoperatively and the function score improved from a mean of 9.2 points preoperatively to an average of 17.2 points postoperatively.

The ROM changed the least, with score improvement from a preoperative average for group A of 13.9 points to a postoperative average of 16.8 points and from a preoperative average for group B of 13.7 points to a postoperative average of 16.5 points. For group A the radiographic score improved from a preoperative average of 31 points to a postoperative average of 38 points. By comparison, group B showed an improvement from a preoperative average of 31 points to a postoperative average of 37 points. At the last follow up for group A, 11 hips were rated as excellent and one hip was better and in group B 14 hips were rated as excellent with two hips

being better. There were no statistically significant differences between groups A and B in clinical and radiographic outcomes (P >0.05).

Clinical evaluation

Pain

All preoperative local pain disappeared or was relieved within four to seven days after surgery. When weight bearing was allowed three to four months after surgery, 9/10 patients in group A were fully free of preoperative pain, and 10/12 patients in group B were fully free of preoperative pain. One patient in group A and two patients in group B experienced slight hip pain when they were allowed weight-bearing. The pain disappeared gradually one to three weeks later.

Function

When weight bearing was allowed, 9/10 patients in group A were free of preoperative limbing, and 10/12 patients in group B were free of preoperative limbing. They could move freely with a nearly normal gait. The three patients, who continued to experience hip pain, had improved mobility after surgery. They were taught to use crutches and to apply heat to the area of pain. When the pain disappeared they gradually walked with a normal gait.

ROM

ROM was improved to a varying degree for all patients. However, the figure-of-four test was still positive in most of the patients. At the latest follow up, all patients could achieve hip flexion of more than 100 degree, abduction of 20 to 30 degree, and internal and external rotation of 15 to 20 degree.

Radiographic evaluation

At the latest follow up, the normal height of the femoral head was maintained in 10 of 12 hips in group A and in 13 of 16 hips in group B. Bone graft healing without cyst lesion was seen in their X rays and three dimensional CT. Five patients in each group had slightly depressed height of the femoral head 8 to 10 months at postoperative follow up. The depressed height was kept on X-ray film at the latest follow up. No ossification was found in any case among the patients (Figure 2).

The optimal position of the titanium mesh piece should be within 2 mm of the subchondral bone and supporting the whole necrotic area. Usually, the titanium mesh piece supports the weight-bearing area on frog radiographic film. In this series, optimal position was obtained in 11 hips. In one hip, the titanium mesh piece was slightly off laterally from the weight-bearing area on frog radiographic film. The optimal position of the titanium cage-graft bone complex should be in the central line of the femoral neck or in line with the compressive trabecular when seen on anterior-posterior radiographic films (all hips obtained the optimal position), and support the weight-bearing area on frog radiographic film (11 hips were in the optimal position with one hip slightly off medially from the weight-bearing area). At the latest follow up, the position of the titanium cage was kept intact in 11 hips. For the one hip with femoral head collapse in group A, the titanium cage shifted down along the central line of the femoral neck.

DISCUSSION

The optimal joint-preserving procedure should meet the following requirements: removing all necrotic bone and replacing the excavated area with viable bone graft, revascularization of the involved area, and sufficient support. Among all bone grafting procedures, vascularized bone grafting was the most promising option.[1,2,3,8,9] Vascularized bone grafting mainly includes free vascularized fibular bone grafting, local iliac bone grafting and quadratus femoris pedicle bone grafts.[10] Long-term satisfactory clinical outcome has been reported for various vascularized bone grafting procedures for ONFH with pre-collapse and not extensive lesions. However, for extensive or post-collapse ONFH, the long-term success rate is still low.[4,5,11-13]

In a long-term follow-up series of 2600 cases of ONFH treated by free vascularized fibular grafting, Aldridge et al[14] reported that there was an 88% success rate if there was no collapse of the femoral head; the success rate decreased to 78% if there was any degree of subchondral fracture or collapse. The success rate for patients with an articular step-off between 1 mm and 3 mm decreased even lower to 68% at the five-year mark. Wang et al[4] treated 186 cases (206 hips) of ONFH with double strut bone grafting pedicled with the quadratus femoris. In a mean followup of 10.5 years (5 to 16 years), the results showed that the success rates for stage ARCO II B and II C were 83.3% and 80% respectively, and it decreased to only 40% in post-collapse ONFH cases.

Although the stage of ONFH was the important factor affecting the clinical outcome, surgical technique was also a key factor. It took a long time for Aldridge et al[14,15] to gain extensive experience in free vascularized fibular grafting for ONFH. Therefore, good understanding the pros and cores of different vascularized bone grafting techniques and improvement of surgical technique are important to improve the clinical outcome of joint preserving methods.

The advantages of quadratus femoris pedicle bone grafting

Of all the joint-preserving procedures, the main advantages of vascularized bone grafting lies in its providing new blood supply. However, it is not easy to protect the blood supply of the bone graft from any damage during the process of bone graft harvest and placement. In the long term practice of free vascularized fibular grafts for ONFH, Aldridge et al[14,15] have identified many factors that can affect the blood supply of the fibular graft; such as the length of pedicle vessels,

anastamosis technique, the position of pedicle vessels in the decompression trough of the femur, and inflammatory edema after operation. In the report on vascularized iliac bone grafting for ONFH from Zhao et al[16] the author showed that pedicle vessel stripping may occur if not carefully protected during the procedure. In contrast to these technically demanding procedures, quadratus femoris pedicle bone grafting had several advantages. The muscle pedicle is large and protects the blood vessels in it from being easily damaged, the blood supply is rich, and the surgical procedure is relatively easy to perform.[4,5]

In addition, due to the fact that necrotic bone is usually in the anterior-lateral-superior area of the femoral head, the posterior approach of quadratus femoris pedicle bone grafting made it easy to clearly visualize the necrotic area and thoroughly remove the necrotic bone. On the other hand, with the anterior approach of vascularized iliac grafting it is not easy to clearly visualize the necrotic area. In free vascularized fibular grafting, whether the necrotic bone was extracted thoroughly is determined by intraoperative fluoroscopy. This may cause inadequate decompression because of such factors as the three dimensional aspect of the femoral head, radiographic magnification and indirect visualization. Thorough decompression is the basic element in joint preserving treatment for ONFH. In the experience of Aldridge et al,[14] to restore the normal height of the femoral head, effective decompression requires removal of necrotic bone to less than 4 mm from the subchondral plate for precollapse lesions, and to within 2 to 3 mm of the subchondral plate for postcollapse cases. In retrieval analysis of failed tantalum osteonecrosis implants, Tanzer et al[17] found that implants should be within 5 mm of the subchondral bone, and be enough larger in diameter in order to provide the support necessary to prevent collapse.

The importance of increasing the support strength and area

Preventing collapse of the avascular femoral head is the basic objective for joint preserving surgical procedures. Therefore, sufficient mechanical support must be provided by the structural bone graft. Zhao et al[16] reported the difference between the clinical success rate (more than 90%) and radiographic success rate (76%), suggesting that insufficient mechanical support may be an important factor affecting the long term clinical outcome. Yang et al[18] used core decompression with autogenous bone grafting augmented with a porous screw, for precollapse ONFH and achieved short-term satisfactory results.

It was true that the supporting strength of the quadratus femoris pedicle bone graft was not as strong as a fibular graft. In order to increase the supporting strength of the quadratus femoris pedicle bone graft, the current author has revised the technique and used a titanium mesh cage filled with a pedicle bone graft for treatment of 20 patients (22 hips) with ONFH. There were 15 hips in ARCO stage IIA, five hips in ARCO stage IIC, and two hips in ARCO stage IIIA. The short-term evaluation showed excellent results with 20 hips with a better result in only one hip that was in ARCO stage IIIA.[19]

In addition to supporting strength, the supporting area was also important for providing sufficient support to prevent collapse of the subchondral bone. The retrieval analysis of failed tantalum osteonecrosis implants[17] also suggested that in order to adequately support the subchondral bone, a large area of the necrotic femoral head should be supported. Otherwise, the unsupported necrotic subchondral bone can collapse. The current study design was a modification of the traditional quadratus femoris pedicle bone grafting procedure.[20] The new modification of the traditional technique was as follows: A large piece of mesh cage was placed underneath the necrotic area. It was then supported by a mech cage filled with the quadratus femoris pedicle bone graft. This design produced an umbrella-shape strut support and the supporting area was greatly increased. The supporting area was usually more than 2.5 cm × 2.6 cm with the maximal area being 2.8 cm × 3.4 cm. The current new technique may provide strong mechanical support necessary to prevent collapse in the long run.

The combination of graft bone with titanium in this new technique had more advantages. It not only protects the graft bone from damage when the graft bone was inserted into the femoral head, but also makes it easy to adjust the position of the muscle pedicle to avoid being compressed or twisted. What is more, before the graft bone was placed into the titanium cage, the length of the mesh cage can be predetermined to match the decompressed trough. This not only makes it easier to put the graft bone in place, but also ensured that the graft bone is reliably fixed in case the length of bone strut is short. The surgical trauma of the new technique was not much increased when compared with the traditional quadratus femoris pedicle bone grafting procedure. The extension of operation time averaged 20 minutes and the increase of the blood loss averaged 50 milliliters. Although there was no statistical significance between groups A and B in clinical outcomes, it may be due to the fact that the number of cases was small and the follow up period was short. Whether the new technique had advantages over the original procedure is still to be determined in the long run.

In summary, the new technique not only retained the merits of the traditional quadratus femoris pedicle bone grafting procedure, but also enhanced the supporting strength and made it easier to protect the blood supply from being damaged. The objective of the current technique was to design treatment for ONFH with an extensive necrotic area or slight post-collapse lesion. Therefore, when performed for ONFH in stage ARCO II C, the new technique may have advantages. On the other hand, the surgical trauma was slightly increased, and the long-term clinical and radiographic outcome have yet to

be studied.

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