Osteonecrosis of the femoral head is a progressive disease. Without operative intervention, it most often results in collapse and deterioration of the joint. Many joint-preserving surgeries have been implemented, but no uniform treatment exists. The authors report a modified technique of tantalum rod implantation combined with vascularized iliac grafting for the treatment of osteonecrosis of the femoral head.

Fifty-two patients (56 hips) with osteonecrosis of the femoral head (Association Research Circulation Osseous classification stage II-IV) treated with this technique were retrospectively reviewed. The major steps of this technique included vascularized iliac graft harvested, necrotic lesion excised, and combined interventions implantation. All patients were followed for a mean of 60 months. Seven hips had to be converted to a total hip arthroplasty. The 5-year joint-preserving success rate of entire group was 87.5%, with 95% for Association Research Circulation Osseous stage II hips, 92% for Association Research Circulation Osseous stage III hips, and 63.6% for Association Research Circulation Osseous stage IV hips. The success rate was lower for stage IV hips compared with stage II and III hips. Mean Harris Hip score of the 49 hips improved significantly from 50 to 91 points. Forty-three (76.8%) of 56 hips remained stable on radiographs.

The technique of tantalum rod implantation combined with vascularized iliac grafting may be an effective joint-preserving method for the treatment of intermediate-stage osteonecrosis of the femoral head. A larger group of patients that is compared with a control group is necessary to further research.
Osteonecrosis of the femoral head is a progressive disease characterized by osteocyte necrosis caused by inadequate blood supply to the affected segment of the subchondral bone. It results in articular surface collapse and destructive arthritis if no preventative measures are used. This disease typically affects adults in the third to fifth decades of life and incapacitates patients due to pain and decreased hip range of motion. The effect of conservative treatment for osteonecrosis of the femoral head is poor. In most cases, surgical repair is required.

The primary goal during the early stages of osteonecrosis of the femoral head is to preserve the hip joint, and several techniques have been studied and implemented. Core decompression is commonly used in early-stage (pre-collapse) osteonecrosis, but it cannot be used with more advanced lesions because of the lack of subchondral support. Free vascularized fibular transplantation has been implemented for higher stages of osteonecrosis; however, the donor site complications, longer operative time, and surgical technique challenges for this treatment should be considered. Nonvascularized fibular grafting has also been studied and can shorten the operative time, but vascularized grafts appear to have better clinical results for the prevention of femoral head collapse.

Core decompression combined with the insertion of an intervention implant has been developed. In this method, a porous tantalum rod acts as a fibular graft. However, the outcomes for this treatment are still controversial or unsatisfactory. The current authors hypothesized that the poor outcomes were partly due to the fact that the technique cannot offer adequate blood supply to the affected femoral head. To restore the blood supply of the ischemic femoral head in the current study, vascularized iliac grafting, which the authors reported in previous research, was used as a supplement to tantalum rod implantation and an alternative treatment modality was developed to treat the osteonecrosis.

This article reports the use of tantalum rod implantation combined with vascularized iliac grafting for the treatment of osteonecrosis of the femoral head. The authors retrospectively reviewed 56 patients and evaluated the clinical and radiographic outcomes. All patients were informed that data from their clinical and radiological examinations would be submitted for publication.

**MATERIALS AND METHODS**

Between April and September 2007, fifty-two patients (56 hips) were selected for this study and underwent tantalum rod (Trabecular Metal Technology; Zimmer, Inc, Warsaw, Indiana) implantation combined with vascularized iliac grafting for osteonecrosis of the femoral head (Table 1). Patients included 30 men and 11 women with a mean age of 39 years (range, 20-53 years) at surgery. The etiology of osteonecrosis was idiopathic or unknown in 19 hips, from corticosteroids use in 16 hips, from alcohol abuse in 13 hips, and from a traumatic event in 8 hips. The diagnosis of osteonecrosis of the femoral head was confirmed by clinical and radiographic evidence (plain radiographs and magnetic resonance imaging). According to the Association Research Circulation Osseous (ARCO) classification, 20 hips had stage II, 25 had stage III, and 11 had stage IV osteonecrosis.

The tantalum rod is made entirely of porous tantalum and has a 10-mm-diameter cylindrical shape, a threaded section designed to engage the lateral cortex of the femur, and a hemispherical tip for supporting the subchondral plate.

**SURGICAL TECHNIQUE**

While under general anesthesia, the patient was placed in the supine position with the operative side ilium elevated to 30°. The surgical technique was the same in all patients. A curved skin incision was made along the anterosuperior iliac crest downward to the tip of greater trochanter and then extended vertically approximately 5 cm. The interval between the sartorius muscle and tensor fasciae latae muscle was located and split in the direction of the skin incision. Because the lateral femoral circumflex vessels are beneath the rectus femoris muscle, the ascending branch of the lateral femoral circumflex vessels was identified when splitting the rectus femoris muscle and gluteus medius muscle before exposing the hip capsule. The vessels were isolated along the medial margin of tensor fasciae latae muscle directly to the anterosuperior iliac crest and the tributaries were ligated. An approximately 3.5×2-cm vascularized bone graft with the inner plate of ilium, pedicled with the ascending branch of lateral femoral circumflex vessels, was harvested from the anterosuperior iliac crest. The pedicled bone block was saved in saline-wrapped gauze, and cancellous iliac bone chips were harvested for later use.

The hip joint was approached in the interval between the sartorius and the tensor fasciae latae superficially and between the gluteus medius and the rectus femoris underneath. The anterior aspect of the joint capsule was excised to expose the femoral head and neck. Osteophyte located at the edge of the femoral head, if it existed, was excised because it restrained the hip range of motion. The necrotic lesion was excised and curetted through a 2×3-cm bone window created at the anterior aspect of the femoral head-neck junction. A high-speed abrasive drill was used to remove the lesion in the femoral head as completely as possible until bleeding could be seen.

Next, a technique similar to the core decompression was completed. A guiding needle was drilled from the lateral femoral cortex directly to the original lesion area in the femoral head with the assistance of C-arm radiograph. A bone channel 10 mm in diameter was created using a core reamer over the guiding needle. A suitable tantalum rod was selected by using the analogues. The cancellous bone chips har-
vested from the iliac crest were placed in the excavated region of the femoral head and impacted to elevate the collapsed segment of the femoral head. The vascularized iliac bone graft was then inserted and impacted obliquely into this area.

During insertion, care was taken to not squeeze the soft tissue cuff containing the vessels to the bone graft. The bone graft transplant was completed by exerting some pressure with the impaction instruments. A previously selected porous tantalum rod was then inserted into the bony channel, with its tip impacted to the lower side of the bone graft. Because the implanted cancellous chips were not hard, the hemispherical tip of the tantalum rod could be inserted into the femoral head using a slight force. Last, the hip was moved slightly to confirm that the bone block would not be displaced, and the wound was closed in layers.

Rehabilitation

All patients were instructed to bed rest with continuous light skin traction with the affected leg in a neutral position to prevent additional collapse and decrease the compression between acetabulum and femoral head for 4 weeks postoperatively. Patients were encouraged to do isometric muscular contractions and ankle motions to prevent deep vein thrombosis in the lower extremity. After postoperative week 4, the skin traction was removed, active and passive hip range of motion was allowed under the guidance of the rehabilitation trainer, and ambulation training began with the affected side allowed toe-touch weight bearing while using 2 crutches. Beginning at postoperative week 10, patients were allowed weight bearing with a maximum of 25% of their body weight. Beginning at postoperative week 12, patients were allowed to bear weight with a maximum of 50% of their body weight while using 1 crutch, and then progressive weight bearing was allowed. Full weight bearing was achieved 6 months postoperatively.

Evaluation and Statistical Analysis

All patients underwent clinical and radiographic examinations at 3 and 6 months postoperatively and then at 6-month intervals thereafter. The Kaplan-Meier survival curve was used to illustrate the failure of this treatment.\textsuperscript{16} Failure and endpoint were defined as conversion to a THA. The indication for THA was persistent pain or destructive arthritis. The survival rate was determined and the success rates at every stage were compared. The clinical results were assessed using the Harris Hip Score.\textsuperscript{17} An excellent or good Harris Hip Score was defined as 80 or more points. Plain radiographs and magnetic resonance images were obtained to evaluate the size of the necrotic lesion and the progression of collapse or development of osteoarthritis. The last follow-up was determined by the time to conversion to THA or the longest time of hip survival. All analyses were completed using SPSS version 17.0 software (SPSS, Inc, Chicago, Illinois).

RESULTS

All patients were followed for a mean of 60 months. No postoperative complications, such as infection, deep vascular thrombosis, femoral neck fracture, or subtrochanteric fracture, occurred.

Survival Rate

Seven hips (1 hip in stage I, 2 hips in stage III, and 4 hips in stage IV osteonecrosis) were converted to THA by the last follow-up. Average time between the joint-preserving surgery and conversion to THA was 25 months (range, 11-46 months). The joint-preserving success rate of the entire group was 87.5% at 5 years postoperatively (Figure 1), with 95% for stage II, 92% for stage III and 63.6% for stage IV hips (Figure 2). No difference was found in the success rate between hips with stage II and stage III

| Table 1 Preoperative Patient Demographics |  |
| Demographic | No. |
| Patients (M/F) | 52 |
| Men | 30 |
| Women | 22 |
| Mean age (range), y | 39 (20-53) |
| Etiology |  |
| Idiopathic | 19 |
| Corticosteroids | 16 |
| Alcohol | 13 |
| Trauma | 8 |
| ARCO stage |  |
| Stage II | 20 |
| Stage III | 25 |
| Stage IV | 11 |

Abbreviations: ARCO, Association Research Circulation Osseous.
osteonecrosis ($P > .05$). However, the success rate for hips stage IV osteonecrosis was lower compared with hips with stage II and III osteonecrosis ($P < .05$).

**Harris Hip Score**

Mean preoperative Harris Hip Score for all hips was 49 points, and mean postoperative score was 85 points at last follow-up or before conversion to THA. Mean score for the survival hips improved from 50 to 91 points, with an improvement from 54 to 96 points for hips with stage II osteonecrosis, from 50 to 90 points for stage III, and from 42 to 79 points for stage IV (Table 2). For the survival hips, 89.8% of patients had excellent and good scores (scores of $\geq 80$ points).

**Radiographic Evaluation**

Radiographic progression was found in 3 of 20 hips with stage II osteonecrosis. Signs of arthritis and radiographic progression occurred in 4 of 25 hips with stage III osteonecrosis. Progressive collapse of the femoral head or the apparent joint space narrowing occurred in 6 of 11 hips with stage IV osteonecrosis (Figure 3). Forty-three (76.8%) of 56 hips had no radiographic progression of osteonecrosis (Figures 4, 5). At last follow-up, the iliac bone grafts were well incorporated within the survival hips.

**Discussion**

The natural history of symptomatic osteonecrosis of the femoral head may be progressive. Many pathogenetic mechanism researches have been shown that ischemia was the common pathological pathway leading to death of osteocytes and the bone marrow. Without operative intervention, it most often results in collapse and deterioration of the joint.\textsuperscript{4,5} Total hip arthroplasty may be a good choice for treating osteonecrosis of the femoral head and has excellent clinical results for pain relief and functional improvement. However, the longevity and complication of replacement THA is a major concern, especially for young adults.\textsuperscript{3,18} Therefore, joint preservation is still the primary goal of treatment for osteonecrosis of the femoral head.\textsuperscript{19,20} Many joint-preserving surgeries have been used, such as core decompression\textsuperscript{21,22} and nonvascularized\textsuperscript{23,24} or vascularized bone grafting\textsuperscript{9,11,25} with some successful results. Unfortunately, no uniform treatment exists.

Core decompression has been verified as a commonly successful surgery used appropriately in small-sized and precolapse osteonecrosis, but use of core decompression with more advanced lesions generally deteriorate because of lacking subchondral support.\textsuperscript{8} Alternatively, free vascularized fibular transplantation during core decompression was developed to improve treatment. In addition, this technique can be used for treating larger necrotic lesions than can core decompression.\textsuperscript{9,11} However, free vascularized fibular transplantation has been reported to have donor complications, longer operative time, and blood loss for this technique.\textsuperscript{13}

Porous tantalum is an expanded metal currently being used in several orthopedic procedures. It was found to have excellent biocompatibility and to be safe to use in vivo.\textsuperscript{26} Many studies of biology and biomechanics showed that it had rapid tissue ingrowth and fixation strength;\textsuperscript{27} its modular elasticity was similar to that of subchondral bone;\textsuperscript{28} and its strength, fatigue properties, endurance limits, and initial stability against bone are all superior to natural bone grafts.\textsuperscript{28,29} A recent study done in a model of necrotic femoral head with the porous tantalum implant demonstrated that the implant was similar to a bone graft with regard to its effectiveness in supporting the femoral head.\textsuperscript{30} Augmentation of core decompression

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**Table 2**

<table>
<thead>
<tr>
<th>ARCO Stage</th>
<th>Survival Hips, No.</th>
<th>Mean ± SD (Range)</th>
<th>Excellent and Good Scores, %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Preop HHS</td>
<td>Postop HHS</td>
</tr>
<tr>
<td>II</td>
<td>19</td>
<td>54.1±5.3 (42-62)</td>
<td>95.5±3.4 (86-99)</td>
</tr>
<tr>
<td>III</td>
<td>23</td>
<td>49.6±5.2 (39-60)</td>
<td>90.0±5.0 (78-96)</td>
</tr>
<tr>
<td>IV</td>
<td>7</td>
<td>42.3±5.3 (36-51)</td>
<td>79.1±5.0 (72-88)</td>
</tr>
</tbody>
</table>

*Abbreviations: ARCO, Association Research Circulation Osseous; HHS, Harris Hip Score; postop, postoperative; preop, preoperative.*
with porous tantalum rods has also been explored as a clinical treatment for early stages of osteonecrosis, with some favorable results.\textsuperscript{31-33} However, the tantalum rod implantation used alone was modestly helpful in improving the blood supply to the affected femoral head.

To restore the blood supply of the affected femoral head, the technique of vascularized iliac grafting was introduced as a supplement for the treatment of osteonecrosis in the current study. The iliac graft pedicled with the ascending branch of the lateral femoral circumflex vessels can provide blood supply to the femoral head, like a free vascularized fibular graft. The technique of vascularized iliac grafting has been reported as an alternate for the treatment of osteonecrosis of the femoral head with favorable results.\textsuperscript{15,34,35} However, extended bed rest and nonweight bearing during the early postoperatively period were necessary because of the weak structural stability of the bone graft.

The main problems of a femoral head preservation procedure for the treatment of osteonecrosis are revascularization, reossification, and collapse. Based on these problems and the authors' previous study,\textsuperscript{15} the treatment of osteonecrosis of the femoral head using tantalum rod implantation combined with vascularized iliac grafting was designed. This combined technique offers more beneficial factors for the treatment of osteonecrosis, and the 2 interventions can be an effective supplement to each other. Although the mechanical and biological potencies of this technique were not identified completely, the advantages of the technique include the following: (1) the necrotic lesion could be excised completely through the window made at the head-neck junction, thus the blood barrier was eliminated; (2) the implantation of tantalum rod could facilitate bone growth and provide strong structural support to the subchondral plate via the iliac graft above it; (3) the iliac graft offered not only structural support, but also biologic incorporation because the vascularized iliac graft provides blood supply and promotes reconstruction of the femoral head;\textsuperscript{15,36} (4) with the support of tantalum rod, the iliac graft and the subchondral bone adjoined more tightly to deter further collapse; and (5) the vascularized iliac graft can be harvested and implanted during the same approach, without the need for vascular anastomosis, making the procedure is less time consuming and less technically demanding than free vascularized fibular graft.

The mid-term results of this combined technique should be compared with other joint-preserving techniques because, as noted, the authors did not include a control group. Veillette et al\textsuperscript{31} evaluated the clinical and radiographic outcomes of osteonecrosis of the femoral head treated with porous tantalum implantation and reported that the survival rate of 60 hips was 68% after 48 months. Although having the same follow-up time, Tsao et al\textsuperscript{32} reported a survival rate of 73% of 113 hips at 36 months postoperatively. In contrast to these reports, the current results were better and the follow-up time was longer.

Shuler et al\textsuperscript{33} reported a survival rate of 86%, with 3 of 22 patients having progressive femoral head collapse after 39 months postoperatively; however, most of their hips had stage II osteonecrosis, whereas the majority of hips in the current study had stage II and III osteonecrosis. Shuler et al\textsuperscript{33} concluded that the
treatment of osteonecrosis with porous tantalum implantation had an encouraging success rate, especially in early-stage osteonecrosis. Eisenschenk et al\textsuperscript{13} reported a favorable outcome with a vascularized iliac bone graft; According to the Harris Hip Score, the clinical results were good and excellent in 86.6\% of the patients after an average of 5 years follow-up, which is similar to the current study results. The radiographic appearance remained stable in 56.1\% of their patients\textsuperscript{13} compared with 76.8\% of patients in the current study.

Although comparison among studies is difficult, the results of the current study are also encouraging compared with other joint-preserving methods. In the current study, the clinical and radiographic outcome of the combined technique was encouraging. The success rate of joint preservation was more than 85\% at 5 years postoperatively, with excellent and good Harris Hip Scores in 89.8\% of patients and 43 of 56 hips with no radiographic progressions.

All of the results indicate that the technique of tantalum rod implantation combined with iliac grafting is an effective joint-preserving method for treatment of moderate post-collapse osteonecrosis of the femoral head. The technique was created to deter or postpone the progression of osteonecrosis and delay the need for THA. However, it should to be noted that the success rate of this technique was lower for hips with stage IV osteonecrosis compared with hips with stage II and III osteonecrosis.

CONCLUSION

The current results show that tantalum rod implantation combined with iliac grafting can be used with intermediate stages or moderate collapse osteonecrosis of the femoral head, regardless of the extent of the lesion. However, comparison with a larger group or a control group of patients is necessary to further confirm the effect of this technique.

REFERENCES


