

# Is precise open excision a more suitable surgical method for osteoid osteoma?

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## Research article

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# Abstract

## Background

The aim of this retrospective study was to evaluate the efficacy of precise open excision surgery to treat osteoid osteoma with C-arm assisted precise localization during the operation.

## Methods

From June 2010 to June 2017, patients with osteoid osteoma of the extremities who had undergone treatment by high speed burr grinding, full scratching with curette, and C-arm assisted lesion localization during the operation were analyzed retrospectively. The preoperative and postoperative pain was assessed by the visual analogue scale (VAS) scoring. The patients were followed up regularly, and the advantages, effects, and complications of the therapeutic technique were analyzed.

## Results

The study consisted of 94 patients (59 males, 35 females; mean age,  $17.6 \pm 8.5$  years) and they were followed up for a mean of 38.9 months (range, 24–72 months). All patients were diagnosed with osteoid osteoma by postoperative pathological examination. Follow-up consisted of imaging reexamination and clinical evaluation. If the patients did not take non-steroidal anti-inflammatory drugs (NSAIDs) before the operation, the mean pre-operative VAS score was 6.7, and the mean VAS score of all patients was 0 one month after operation. The mean time for all patients to resume normal daily activities was 14.3 days (range, 10–21 days). There was no recurrence of pain, infection, vascular or nerve injury, and fracture complications during the follow-up. In only one case of distal femur osteoid osteoma (OO), review X-ray found a suspected recurrence 50 months after the primary surgery and subsequently, the patient underwent a second surgery. Till date, the patient has reported no discomfort following the second surgery.

## Conclusions

For treatment of osteoid osteoma, open incision and minimal resection with C-arm assisted tumor localization is still a suitable method, especially for osteoid osteoma located on the surface of the cortical bone.

## Background

Osteoid osteoma (OO) accounts for 2-3% of primary bone tumors and 10-12% of benign bone tumors. Jeff first described OO in 1935 [1, 2]. About 50% of OO tumors occur in the cortex of the epiphysis of the femur and tibia, among which the proximal femur is the more common site [3]. The incidence in men is

about three times that in women [4, 5]. It is characterized by night-time pain that may be relieved by aspirin or other non-steroidal anti-inflammatory drugs (NSAIDs) [6]. Histologically, nearly 85% of OO tumors have a nidus, which is described as a central hypervascular area surrounded by a hard shell of bone [7, 8]. Although the cause has not been fully elucidated, it is known that a nidus surrounded by reactive scleral bands is usually less than 2 cm in diameter, and is a typical radiological characteristic. The nidus is usually a single lesion, in which the tumor cells are present in dark red tissue with rich blood flow. The peripheral sclerotic reaction zone is composed of osteoblasts, osteoclasts, and dilated capillaries surrounding the nidus. Some cases may also present with atypical manifestations with respect to the nidus type, location, and shape [9, 10]. Since it is difficult to biopsy, the diagnosis of OO mainly depends on clinical manifestations, imaging, and pathological examination. The radiological examination starts with an X-ray, which reveals the substantial thickening of the periosteal cortex and the oval translucent area in the center indicative of OO. Direct radiography is usually supported by computed tomography (CT) or magnetic resonance imaging (MRI) [11]. The nidus looks well defined, round, or oval with low attenuation on CT examination. An area of high attenuation may be seen centrally, representing mineralized osteoid [9]. On MRI scanning, the nidus has low to intermediate signal intensity on T1-weighted images, and variable signal intensity on T2-weighted images. Extensive edema in adjacent bone marrow and soft tissues and joint effusion may additionally be seen [12, 13].

Surgical excision of the nidus is the classic way to treat OO [14]. With development of technology, minimally invasive and rapid recovery concepts have been applied to the treatment of OO. Closed surgery confined to tumor in situ inactivation, such as radiofrequency ablation, freezing, and radiotherapy for OO treatment have been reported with great results [4, 15]. In particular, percutaneous radiofrequency ablation is considered by some scholars as the first-line treatment for majority of OO tumors [16]. However, the above-mentioned methods of in situ inactivation have several limitations that need consideration. This study aimed to evaluate the clinical efficacy of precise open excision treatment of OO along with analysis of the recurrence rate and complications.

## Methods

### *Patients*

From June 2010 to June 2017, 98 consecutive patients with a diagnosis of OO of the extremities were treated at the Xiangya Hospital Bone Tumor Center. The inclusion criteria were as follows: patients who were diagnosed with OO and received treatment consisting of C-arm precise positioning of lesions, high speed burr grinding, full scratching with curette, allogeneic cancellous bone transplantation, and completion of long-term follow-up. The exclusion criteria were latent OO, treatment by other techniques and loss to follow-up. A total of 94 patients met the criteria and were included in the study, the remaining 4 patients were lost to follow-up. Diagnosis was based on pathological results, and X-ray, CT, and MRI were performed to evaluate the tumor. Sex, age, location, lesion type, duration of symptoms, duration of return to normal, lesion size, follow-up duration, and visual analogue scale (VAS) score for pain were recorded (Table 1). The study cohort consisted of 59 men and 35 women, aged 5-50 years (mean 17.6

years). Fifty-five lesions were located in the femur, 28 in the tibia, 2 in the radius, 4 in the ulna, 2 in the talus, and 3 in the fibula. Among them, 71 were cortical (Fig 1a), 20 were periosteal (Fig 1b), and 3 were medullary (Fig 1c). The mean size of the lesions was 0.82 cm (range, 0.4-1.4 cm). The preoperative VAS score ranged from 4 to 9 (mean, 6.7), the mean time for all patients to resume normal daily activities was 14.3 days (range, 10-21 days), and the mean duration of preoperative pain was 8.3 months (range, 2-23 months). The study was approved by the Research Ethics Committee of Xiangya Hospital. The patients and their families were invited to participate and made aware of the risks and benefits of the study before taking informed consent.

## ***Surgical technique***

All operations were performed under general intravenous anesthesia. Usually, the most common surgical approach is selected according to the location of the tumor, and the patient's position, usually supine or prone. It also depends on the anatomical location of the tumor. Preoperative CT and MRI scans can accurately determine the relative position of the nidus and the important peripheral nerves and vessels. They were therefore used to determine the most appropriate surgical approach (Fig 3c and Fig 4c), and to mark the surface projection point of the tumor nest again with the C-arm machine before disinfection. First, the deep subcutaneous fascia of the skin was incised layer by layer to carefully free and protect the important peripheral blood vessels and nerves, and the bones were exposed from the intermuscular space(Fig 2a). Second, the gram needle was used to confirm the nidus location under the perspective of the C-arm, then the high-speed burr was used to carefully grind out the shell of the nidus. Third, the tumor tissue in the nidus was completely eliminated(Fig 2c and Fig 2d), the tumor nest was scraped off thoroughly with a curette(Fig 2b), wiped thoroughly with iodol, and finally, the cavity was irrigated with high- pressure pulsed sterilized water. Lastly, bone grafting was not used for periosteal OO. However, for cortical OO, allogeneic bone graft was harvested to reconstruct the resultant bony defects. Similarly, for medullary OO, autologous bone mass from the bone window was used to reconstruct the cortical defect and allogeneic cortical bone mass was used in patients who did not preserve autologous bone mass (Fig 3d and Fig 4d). Plate internal fixation was used in cases with large fenestration of the cortex. This was followed by careful repair of the soft tissues.

After the operation, the patients were encouraged to undertake continuous passive movements starting on the second postoperative day. Patients were allowed weight-bearing two weeks postoperatively.

## ***Follow-up and evaluation***

The patients were followed up at 6 weeks, 12 weeks, then once every 3 months for the first 2 years, once every 6 months for the next 3 years, and once every year thereafter. The healing, recurrence, and complications (pathological fracture, bone growth restriction, and important neurovascular injury) were recorded. In addition to physical examination, X-ray examination was carried out at each follow-up. If recurrence signs or abnormalities were found on plain film examination, postoperative OO recurrence was

suspected. MRI and CT were subsequently performed in the suspected cases to confirm the recurrence and the nature of the lesions. The degree of postoperative pain relief was assessed by the VAS score.

SPSS version 20 (SPSS Inc., Chicago, IL, USA) was used to analyze the collected data, determine the relationship between different variables, and determine the factors affecting the efficacy of the treatment. The measured data were expressed as mean  $\pm$  standard deviation, and the paired t-test was used to analyze the differences for each factor.  $P < 0.01$  was deemed as statistically significant.

## Results

The diagnosis of OO in this study was confirmed by postoperative pathological examination. There were no operation related complications. The average age of the included 59 men and 35 women was 17.6 years (range, 5–50 years). The mean course of the disease was 8.3 months (range, 2–23 months), and the average diameter of the nidus was 0.82 cm (range, 0.4–1.4 cm). The anatomical tumor sites were as follows: femur(55), tibia 28, radius 2, ulna 4, talus 2, and fibula 3. Follow-up radiographic images revealed that the bone defect had healed stably without pathological fracture or nonunion. All patients were followed up regularly, the minimum follow-up was 24 months with a mean follow-up 38.9 months (24–72 months) (Table 1).

In only one case of distal femur OO, a review X-ray found a suspected recurrence 50 months after the surgery. However, the recurrence location and original location were significantly different (Fig. 5), and there was no pain during the follow-up period. Therefore, it was considered a new tumor, not a recurrence. When the patient underwent a second surgery, the scar of the original operation on the right thigh was incised longitudinally. During the operation, a local protuberance of the bone cortex was seen, with a smooth surface. A large window was opened at the most protuberant point, and a pink tumor with a diameter of 1.0 cm was seen. Subsequently, the nidus and the surrounding reactive sclerotic bone were completely removed with a drill and a bone knife, and allogeneic cancellous bone was implanted in the bone defect. Finally, 6-hole steel plates were placed at the back to ensure that the patient would not have a pathological fracture and poor bone healing (Fig. 5d). The rest of the patients achieved good bone healing, with absence of pain, recurrence, infection, vascular and nerve injury, pathological fracture, and other complications (Fig. 3 and Fig. 4).

All patients with OO are successful in surgical techniques. The key indicator of success was the severity of pain (night pain, day pain, pressure related pain). The VAS evaluation uses 0 (no pain) to 10 (the most imaginable pain), and the patients had permanent pain relief after the surgery. All patients' pain symptoms disappeared one month post-examination. There was no need to take NSAIDs, and the VAS score was 0.

## Discussion

OO can be divided into three types according to its location in the bone: cortical, periosteal, and medullary. Cortical type is the most common and considered classic OO. There were 71 cases of cortical type in our study group (Fig. 1a). Osteolytic tumor nests are located in the bone cortex, surrounded by different degrees of thickening and sclerosing bone, and calcification can be found in the nests. Removal of the tumor might result in a significant decrease in bone strength. Periosteal tumor nests are located under the periosteum, adjacent to the bone cortex, with accompanying periosteal reaction. Removal of the tumor has little effect on bone strength. There were 20 cases of periosteal type in our study group (Fig. 1b). Medullary tumor nests occur in the cancellous bone of the medullary cavity, often in the neck of femoral head and vertebral body, and there is no obvious hyperosteogeny and sclerosis around the tumor nests [17, 18]. We needed to open a window in the cortical bone to remove the tumor. Fortunately, the fenestrated bone can be retained and replanted. There were 3 cases of the medullary type in our study group (Fig. 1c). OO tumor cells produces excessive prostaglandin, which causes widespread bone pain. Therefore, complete pain relief in patients is a sign of complete tumor resection [9].

At present, surgical methods for in situ inactivation treatment of OO have become popular, such as radiofrequency ablation, freezing, and radiotherapy. Radiofrequency ablation is the most recommended method because of the advantages of minimal surgical trauma, short operation time, and short hospital stay [19]. However, the shortcomings of this technique need to be considered. The mechanism of radiofrequency ablation is by thermal destruction of the tumor tissue. It is difficult to accurately control the degree and range of heating during the process, therefore, it is easy to cause damage to important surrounding tissue structures and neurovascular bundles, unlike in an open excision surgery. By performing precise open excision surgery such as in our study, only tumor nests are removed and normal bone loss is minimized. Comparatively, radiofrequency ablation, freezing, or radiation therapy cannot be so precise. In order to ensure effective tumor cell killing, tissue is often included outside the tumor nest, resulting in more damage to the bone and periosteum [20, 21]. Therefore, precise open excision surgery has lesser bone damage and loss than the techniques of tumor in situ inactivation. The recovery in case of bone injury is very slow, which is a key factor for patients to recover and resume their daily activities. Open surgery does cause more soft tissue damage, but this can recover well in two to three weeks. Moreover, since we expose from the intermuscular space, it causes minimal damage to the soft tissue structures. Oc Yunus et al. [22] applied the radiofrequency method to 58 patients and complications were observed in seven patients. Second-degree burns were seen in two patients, and superficial skin infection developed in two patients. In one patient, the probe tip broke and remained within the bone. Intramuscular hematoma was detected in one lesion located in the proximal femur. There was another case of numbness of fingers after the operation, suspected to be caused due to nerve damage. Lassalle et al. [23] additionally reported two cases of peripheral neuropathy after surgery, one case with arm neuropathy from nerve damage, one case with electrode rupture, and one case with muscle hematoma. None of the above complications occurred in our study.

In terms of speed of patient recovery, precise open excision surgery also has advantages. For periosteal OO, there was no significant change in bone strength after resection. Comparatively, in situ inactivation can cause widespread peripheral soft tissue damage and bone cortex damage, with minimal patient

benefit. For OO located in the cortex, following both resection or in-situ inactivation, the bone strength decreases, which may cause a pathological fracture. However, in an open surgery, the loss of bone cortex is smaller, and it can be fully implanted or assisted with internal fixation, decreasing the risk of a pathological fracture. Furthermore, in situ inactivation usually results in widespread cortical necrosis, and therefore, cannot effectively increase the bone strength, resulting in higher incidence of fractures. For medullary OO, it should be the most suitable way for tumor inactivation in situ. However, there are not many such patients. The periosteum and cortex can be preserved when the window of bone is opened by open precise resection. After the tumor is removed, the bone cortex can be replanted, and the healing is very fast. In other studies, pathological fracture and limited bone union were the main complications of the surgical treatment of OO, with an incidence rate of up to 8% [9, 24]. Ruiz et al. [25] reported that among 26 patients with bone tumors treated by radiofrequency ablation, one had symptomatic bone infarction, and another one had a pathological fracture. None of these complications were observed in our study, which additionally confirms the effectiveness of our bone grafting method.

OO as an osteogenic tumor and it usually needs to be differentiated from osteoblastoma, chronic osteomyelitis, and even osteosarcoma [18]. Therefore, the definite diagnosis of OO is significant for deciding the treatment plan and for the estimation of prognosis. However, imaging examination has some limitations in the diagnosis of OO, as it completely depends on the degree of osteosclerosis and periosteal hyperplasia of OO. For OO that occurs under the periosteum or on the surface of the cortex, the degree of sclerosis is relatively light, with periosteal reaction. For OO that occurs in the marrow cavity, because it is away from the inner and outer periosteum, periosteal hyperplasia rarely occurs, and the degree of sclerosis is also relatively light. "Bull's eye sign" is not typical; therefore, the imaging examination is prone to misdiagnosis [9–11]. Consequently, histopathological examination is essential to confirm the diagnosis, and open surgery can obtain pathological specimens to make a diagnosis. In contrast, in situ inactivation cannot obtain effective pathological samples, increasing the risk of misdiagnosis and missed diagnosis [16, 26]. The imaging examination might suggest probable osteoid osteoma in some cases, and the final pathological result reveals osteomyelitis or even osteosarcoma, which was also observed in other studies. Singh et al. [27] reported six cases that were initially misdiagnosed as tuberculous arthritis or osteomyelitis, and finally confirmed as osteoid osteoma by pathological examination. Similarly, Georgiev et al. [28] reported a 12-year-old boy with pain and swelling of the middle phalanx of the ring finger that did not respond to anti-inflammatory drugs for three months. The imaging data was suspicious of osteomyelitis or Ewing's sarcoma, but the pathological examination confirmed osteoid osteoma. Therefore, pathological examination is necessary for the diagnosis of OO, and since all of our patients had been diagnosed with OO by pathological examination, there was no misdiagnosis or missed diagnosis.

Since the recurrence rate is still the key index to judge the efficacy of bone tumor surgery [29–31], our patients were followed up for a mean of 36.9 months. In case of 93 patients, there was no recurrence of pain, and no recurrence was found on X-ray reexamination. Only one patient (1.1%) was found to have suspected recurrence 50 months after the first surgery, but the location of tumor recurrence was not consistent with the original tumor location. In addition, there had been no pain during the follow-up period

of 50 months. The patient remained free of any discomfort after the second operation. Therefore, this patient was considered to have a possible new tumor, rather than a recurrence, but the location was on the same bone. It has not been fully ascertained whether this was a recurrence or a primary tumor, and remains open to discussion. However, in studies on in situ inactivation, the results were not satisfactory. Lindler et al. [19] utilized the radiofrequency technique in 58 patients and reported a recurrence on months 3, 5, and 7, respectively, in three patients (5.2%). Baal Joe et al. [32] reported 71 cases of CT-led radiofrequency ablation therapy, with 10/71 patients (14%) experiencing a symptomatic relapse on an average 21.5 months after surgery. Therefore, the recurrence rate in our study group (1.1%) was significantly lower than reported in other related studies.

Essentially, we compared the precise open excision surgery technique with the in-situ inactivation operation in terms of trauma, bone strength, bone healing, diagnosis, and recurrence rate, and found that the precise open excision surgery is indeed a more reliable choice. On the basis of our experience, we would recommend paying close attention to the following points in the treatment process in order to ensure maximum patient benefit: diagnosis of disease, no detour, no misdiagnosis, no missed diagnosis, clear focus, no deception by imaging, precise treatment, direct to the focus, clear it thoroughly under direct vision, and be careful of recurrence.

Our study had certain limitations. First, we had a relatively short follow-up period for patients with a secondary surgery. Second, intraoperative navigation can be more accurate to find the focus and further reduce the damage. Lastly, our study was mainly retrospective and lacked a direct comparison group or randomized control. However, the overall complication and recurrence rate of our study was lower compared to other reports. All the patients in the study had a great outcome.

## Conclusion

In conclusion, for treatment of OO, although tumor in situ inactivation seems to be minimally invasive, the scope of bone damage is greater, recovery time is longer, and there are more complications. Therefore, it is not a true minimally invasive treatment for patients. Consequently, we think that incision and c-arm guided precise resection of OO is a more suitable treatment.

## Abbreviations

OO: osteoid osteoma; NSAIDs: non-steroidal anti-inflammatory drugs; CT: computed tomography; MRI: magnetic resonance imaging; VAS: visual analogue scale.

## Declarations

### Ethics approval and consent to participate

All patients and their families provided informed consent, at the same time, the consent of the guardian of the minor who participated in this study was obtained (the minor is considered to be anyone under 16

years old), and the study design was approved by the Research Ethics Committee of Xiangya Hospital.

### **Consent for publication**

The data and images in the manuscript have been published with the consent of individuals and their families.

### **Availability of data and materials**

Datasets used in this study can be obtained from the medical record information system of Xiangya Hospital or from the corresponding author on reasonable request.

### **Competing interests**

The authors state that they have no potential conflict of interest in any aspect.

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### **Author contributions**

YHY and WL were in charge of the study design. WL, QL, FL, ZW, HBH and YHY screened patients and collected relevant follow-up data. YHY, QL and FL analyzed the data. The manuscript was written by YHY and WL. WL checked the manuscript.

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## Table

**Table 1** Demographic data for patients with osteoid osteoma

Gender		
M	59(62.8%)	
F	35(37.2%)	
Age(years)	17.6± 8.5	
Localization		
Femur	55(58.5%)	
Tibial	28(29.8%)	
Radius	2(2.1%)	
Ulna	4(4.3%)	
Talus	2(2.1%)	
Fibula	3(3.2%)	
Lesion type		
Cortical	71(75.5%)	
Periosteal	20(21.3%)	
Medullary	3(3.2%)	
Duration of symptom (months)	8.3±4.1	
Duration of resume normal activity(days)	14.3±2.6	
Size(max, diameter, cm)	0.82±0.23	
Follow up time (months)	38.9±10.6	
VAS pain score		
Pre-op VAS	6.7±1.3	p<0.01
Follow-up VAS(1 month post-op)	0	

M: Male; F: Female; Pre-op: preoperative; post-op:postoperative

## Figures

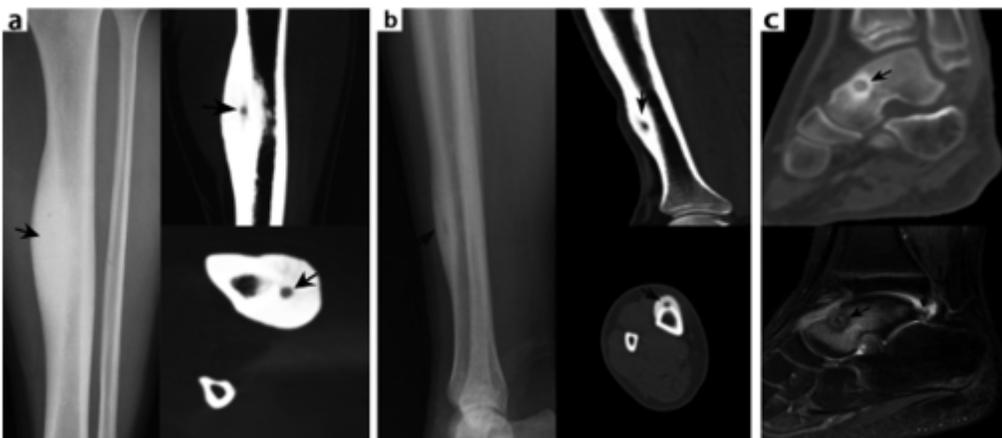
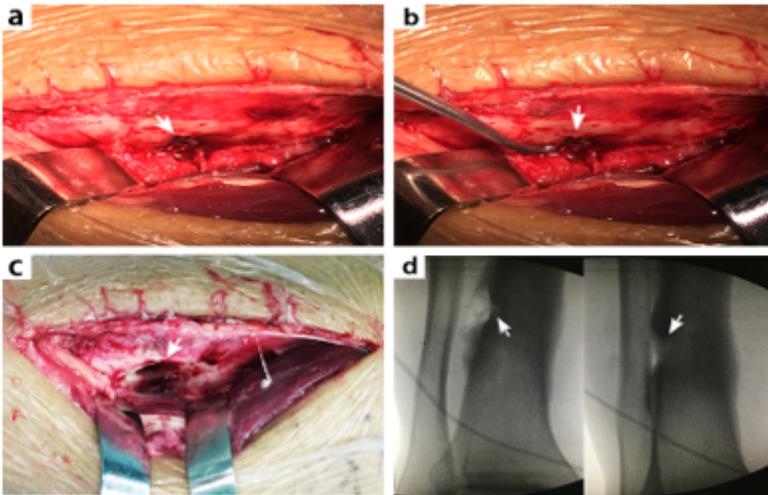


Figure 1

According to the location, osteoid osteoma can be divided into three types. (a) Cortical type: the tumor nest is located in the cortex (arrow), and the removal of the tumor may cause certain damage to the bone cortex, affecting the bone strength. However, good bone healing can be achieved through bone grafting or internal fixation. (b) Periosteal type: The tumor nests are outside the normal cortex (arrow), and the removal of the tumor does not affect the bone strength. (c) Medullary type: the tumor nest is located in the bone marrow (arrow), therefore a window needs to be opened from the cortical bone to remove the tumor, but the fenestrated bone can be preserved for transplantation.



**Figure 2**

Surgical related steps and intraoperative C-arm fluoroscopy. (a) Carefully dissociate and protect the important peripheral blood vessels and nerves to expose the nidus to the intermuscular space. (b) the tumor nest was scraped off thoroughly with a curette. (c,d) Surgical field observation and intraoperative C-arm fluoroscopy showed that the tumor tissue in the focus was completely removed, the bone was well preserved, and there was no obvious damage to the surrounding soft tissue.



**Figure 3**

Typical preoperative and postoperative changes seen in osteoid osteoma of the upper ulna. (a,b) "Bull's eye sign" of high density calcification can be seen (arrow). (c) MRI of the lesion reveals that the nidus is adjacent to the median nerve, T2WI image shows increased intensity in the nidus and extensive surrounding edema (arrow). (d) Postoperative X-ray shows stable healing of the bone defect (arrow).



**Figure 4**

Typical preoperative and postoperative changes observed in osteoid osteoma of the proximal femur. (a-c) Preoperative imaging data reveals that the nidus is well defined and round or oval shaped with low attenuation, and additionally adjacent bone marrow and soft tissue edema can be seen. (d) All patients healed well after the operation, with absence of infection, fracture, and other complications.



**Figure 5**

Preoperative and postoperative imaging changes in a case of suspected recurrence of osteoid osteoma of the distal femur. (a) The patient's first preoperative X-ray reveals the endosteal thickening and demonstrates radiolucency in the cortex. (b) X-ray review after the first surgery shows that the tumor nest was completely cleared. (C) Radiological examination 50 months after the first surgery shows obvious flaky bone mineral density increase at the distal femur along with the nidus showing ground-glass changes, and some periosteal reaction around the periphery, but the location of tumor recurrence is not consistent with the original location. (d) During the second operation, the patient's recurrent lesions were enlarged and curetted, and bone grafting and internal fixation of steel plate were performed to prevent a pathologic fracture or nonunion of bone and other complications.