Original Article

Clinical Characteristics and Treatment of Spontaneous Osteonecrosis of Medial Tibial Plateau: A Retrospective Case Study

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Abstract

Background: In a small proportion of cases, spontaneous osteonecrosis of the knee (SONK) involves the medial tibial plateau (MT). Here, we introduced the clinical characteristics of spontaneous osteonecrosis of the MT and unicompartmental knee arthroplasty (UKA) as the favorable treatment for this situation based on a retrospective case study.

Methods: Patients with spontaneous osteonecrosis of the MT, confirmed by magnetic resonance imaging (MRI) at Guangdong Provincial Hospital of Chinese Medicine (China) from March 2015 to June 2016, were included as a case serial and analyzed retrospectively. All patients underwent Oxford Medial UKA. The characteristics of their lesions, corresponding treatment, and results of follow-up were presented. The lesion scores and grade were determined according to the criteria of Ficat and Arlet.

Results: In total, 22 patients (5 men, 17 women; mean age, 64.1 years) with spontaneous osteonecrosis of the MT were analyzed. The lesion stages assessment showed that 3 (14%) were Stage II, 10 (45%) were Stage III, 7 (32%) were Stage IV, and 2 (9%) were Stage V. In the sagittal plane, 7 (32%) were in the anterior region (MTa) and 15 (68%) were central (MTc). The lesion volume averaged 2.24 ± 0.79 cm^3 (range: 1.57–3.08 cm^3). Seventeen patients (77%) had Level III posterior medial meniscus root tears (MMRTs). All the patients underwent UKA. Average follow-up was 30.0 ± 6.4 months with a range of 23.0–38.0 months. The visual analog scale score was 7.78 ± 0.67 before surgery while decreased to 2.22 ± 1.09 at the final follow-up ($P < 0.001$). The Hospital for Special Surgery scores of pre-/post-surgery were 65.67 ± 5.45 and 84.10 ± 4.20, respectively ($P < 0.001$).

Conclusions: SONK often occurs in the anterior and central tibial plateau due to abnormal stresses. Most of the patients had Level III posterior medial meniscus root tears. MRI is recommended for suspected cases to identify SONK at an early stage. The use of the Oxford Medial UKA for SONK of the MT is reliable both immediately and at follow-up.

Key words: Knee; Spontaneous Osteonecrosis; Unicompartmental Knee Arthroplasty

Introduction

Spontaneous osteonecrosis of the knee (SONK) was first reported in 1968 by Ahlback.[1] It was defined as a distinct clinical entity with characteristic findings including a subchondral lesion in the weight-bearing region of a single condyle. The exact etiology of SONK is not clear.[2] Evidence suggests that chronic stress, insufficient blood supply, or minor trauma may result in a weakened subchondral bone plate, which could present as subchondral insufficiency fracture of the knee or focal subchondral osteonecrosis.[3] SONK is prevalent in middle-aged women (usually >55 years old, male: female ratio approximately 1: 3).[3] Its main symptom is acute pain in the involved knee, which is often confined to the medial knee. The lesions of SONK usually involve the medial femoral condyle, although rare cases may involve the tibial plateau especially the medial tibial plateau (MT).[4]

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SONK is a progressive disease. Conservative treatment is recommended in the early stage of the disease. The advanced stages are generally treated more invasively with surgery such as drilling, osteochondral grafts, high tibial osteotomy with or without autogenetic bone grafts, or unicompartmental or total knee arthroplasty.

The clinical characteristics of spontaneous osteonecrosis of the MT have not been well described and are poorly understood. In this study, we surveyed the clinical features and treatment of SONK of the MT in a single tertiary center in China. This work described the clinical presentation, imaging findings, and unicompartmental knee arthroplasty (UKA) as the main treatment for SONK of the MT.

Methods

Ethical approval

The study was approved by the Ethics Committee of Guangdong Provincial Hospital of Chinese Medicine, China (No. Z2017-161-01). As a retrospective study and the fact that data analysis were performed anonymously, this study was exempt from informed consent from patients.

Subjects

From March 2015 to June 2016, 22 patients (5 men and 17 women), who met the diagnostic criteria for SONK of the MT, were evaluated at Guangdong Provincial Hospital of Chinese Medicine, China. The patients consulted orthopedic surgeons because of sudden-onset knee pain. The diagnosis was confirmed by using X-ray and magnetic resonance imaging (MRI). The following clinical characteristics were collected from the medical records of all patients: gender, age, symptoms, medical history, lesion location and stage, and treatment. All patients underwent Oxford Medial UKA.

Diagnostic criteria

SONK is diagnosed in patients with typical manifestations when the MRI or radiographic imaging findings are compatible with the disease and other causes of pain and bony abnormalities are unlikely or have been excluded by appropriate testing.

Plain X-rays may show a radiolucent lesion with a surrounding sclerotic halo, together with subtle flattening of the involved femoral condyle. In advanced cases with significant subchondral collapse, secondary degenerative changes may be evident along with loss of joint space, sclerosis in the MT, and osteophyte formation.

MRI without a contrast agent continues to be the gold standard for diagnosis in symptomatic and asymptomatic patients especially in early-stage disease. In cases of SONK, T1-weighted imaging shows a discrete low-signal intensity area, often surrounded by an area of intermediate signal intensity, while T2-weighted images typically show high-signal intensity at the lesion edge in the region of bone marrow edema.[5]

Inclusion and exclusion criteria

Patients, who met the following criteria, were included in the study: (1) a confirmed diagnosis of SONK, which was (2) in the acute phase when diagnosed.

Patients were excluded for any of the following reasons: (1) necrosis of the knee secondary to trauma, inflammation, joint instability, or knee osteoarthritis secondary to congenital diseases; (2) a history of long-term use of hormones or alcohol or metabolic bone disease; (3) suspected or confirmed joint tuberculosis or tumor; or (4) severe heart, lung, or brain disease.

Protocol

First, we collected the patients' general demographic and clinical information, including whether they had a history of knee injury, any long-term use of hormones or excessive drinking, and the treatment applied to the affected knee. Then, we reviewed the plain X-rays, bone scans, and MRI scans of all patients. Using the imaging studies, lesion stage, location, and meniscus injury were assessed, and lesion size was measured. Finally, we followed up the patients and assessed their pain using a visual analog scale (VAS), and knee function according to the Hospital for Special Surgery (HSS) score.

Only those undergoing Oxford Medial UKA were included. At the time of surgery, all patients had intact cruciate ligaments, correctable varus deformity, and full preservation of the thickness of the articular cartilage in the lateral and patellofemoral compartments, consistent with the selection criteria for Oxford UKA. The surgical technique was as previously described for the Oxford UKA, using the minimally invasive approach (The Oxford Phase 3 Unicompartmental Knee, Manual of the Surgical Technique, Biomet-Merck Ltd).

Lesion stages assessment

According to the Ficat-Arlet classification (modified version),[6,7] the lesion stages are classified as follows: Stage I lesions have normal plain X-rays, but can be identified by characteristic changes on MRI and bone scans; Stage II lesions show sclerotic or cystic changes on plain radiographs, identified by radiodensities in the distal femur or proximal tibia; Stage III lesions exhibit subchondral collapse, evidenced by a characteristic "crescent sign" on plain radiographs; Stage IV lesions reveal articular collapse, joint space narrowing, degeneration on both sides of the joint, and possible osteophyte formation; and Stage V lesions manifest osteoarthritis, "ivory bone," and bone cysts, based on plain radiographs.

Subdivision of knee joint

To locate necrotic lesions, the knee joint was subdivided according to the whole-organ MRI score.[8] In the coronal position, the knee lesions were all located at the MT, which was subdivided into equal anterior (MTa), central (MTc), and posterior (MTp) regions on the sagittal plane [Figure 1].

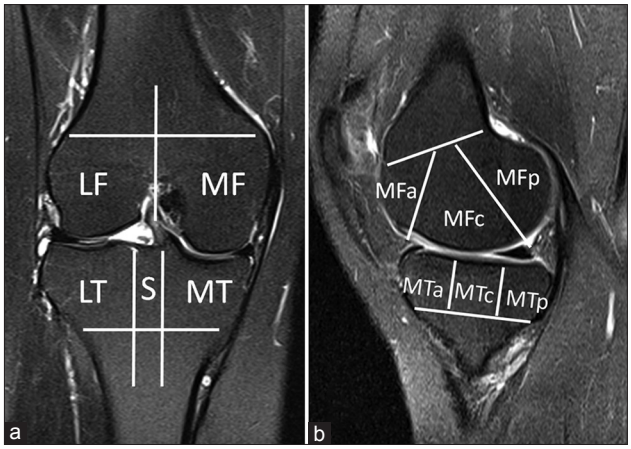

Figure 1: Subdivision of the knee joint on MRI. (a) Subdivision of the knee joint on coronal position MRI. MF: Medial femoral condyle; LF: Lateral femoral condyle; MT: Medial tibial plateau; LT: Lateral tibial plateau; S: Subspinous nonarticulating portion of the tibial plateau beneath the tibial spines. (b) Subdivision of the knee joint on sagittal position MRI. The MF was subdivided into anterior (MFa), central (MFc), and posterior (MFp) regions. The MT was also subdivided into equal anterior (MTa), central (MTc), and posterior (MTp) regions. MRI: Magnetic resonance imaging.

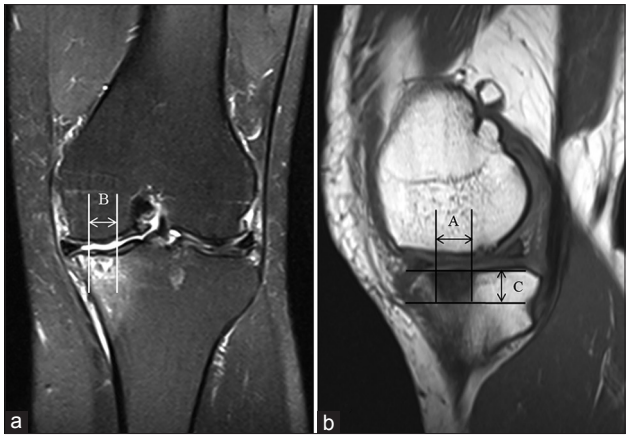

Figure 2: Calculation of SONK lesion size. (a) The mediolateral (B) diameters of the osteonecrosis lesions were measured on the coronal position MRI scan. (b) The anteroposterior (A) and superoinferior (C) diameters of the osteonecrosis lesions were measured on the sagittal position MRI scan. MRI: Magnetic resonance imaging; SONK: Spontaneous osteonecrosis of the knee.

Lesion size

The anteroposterior (a), mediolateral (b), and superoinferior (c) diameters of the lesions were measured on MRI images, and the ellipsoidal volume was calculated using the formula volume = 4/3× π × (a/2 × b/2 × c/2) [Figure 2].

Classification of meniscus injury

The meniscus injury was classified from Level 0 to Level III, as follows: 0, normal MRI signal; I, a spherical signal that did not touch the joint surface; II, a linear horizontal signal that did not extend to the joint surface; and III, a signal extending to the joint surface.[9,10]

Clinical evaluation

To evaluate patient function, the VAS and HSS function scores were determined before and after treatment. The HSS scores were rated as excellent (≥85), good (70–84), intermediate (60–69), or poor (<60).

Statistical analysis

Statistical analysis will be performed using PASW Statistic 18.0 software (IBM SPSS Inc., Armonk, New York, USA). Demographic and clinical characteristics and outcomes will be descriptively reported. Descriptive statistics will be presented as the mean, range, and standard deviation or the percentage in the outcome variables. The paired *t*-test was performed to compare the difference of continuous variables between before and after treatment. A *P* value <0.05 was considered statistically significant.

Results

General information

This study included 22 patients (5 men, 17 women) with spontaneous osteonecrosis of the MT. Their average age was 64.1 ± 9.2 years (range: 53.0–78.0 years). One patient also underwent a total hysterectomy and the removal of thyroid cancer after a radical prostatectomy.

Image evaluation

The lesion stages assessment showed that three patients (14%) were Stage II, ten (45%) were Stage III, seven (32%) were Stage IV, and two (9%) were Stage V. All of the lesions were on the MT.

In the sagittal plane, seven (32%) were in the anterior region (MTa), and 15 (68%) were central (MTc). The lesion volume averaged 2.24 ± 0.79 cm^3 (range: 1.57–3.08 cm^3).

We can diagnose the meniscus injury in the help of MRI. Seventeen patients (77%) had Level III posterior medial meniscus root tears (MMRTs) [Figure 3]. A signal extending to the joint surface on the posterior medial meniscus supported the diagnosis of Level III MMRTs. For medial meniscus tears, three patients were Level II, and two with Level I; for lateral meniscus tear, 12 patients were Level 0, seven with Level I, and three with Level II; and none had a Level III lateral meniscus tear.

Clinical evaluation

Among the patients, the history of knee pain ranged from 1 to 36 months. The patient with the longest history had the most severe lesion of the knee (Stage V). All the patients underwent UKA. No knees had undergone revision for either infection or loosening. Average follow-up was 30.0 ± 6.4 months with a range of 23–38 months. All patients were satisfied with the results of their surgery.

The VAS score was 7.78 ± 0.67 before surgery while decreased to 2.22 ± 1.09 at the final follow-up, with significant difference (t = 31.858, P < 0.001). Similarly, the HSS scores of pre-/post-surgery were 65.67 ± 5.45 and 84.1 ± 4.20, respectively, which showed a significant increase in scores of final follow-up compared to that of presurgery (t = −36.693, P < 0.001).

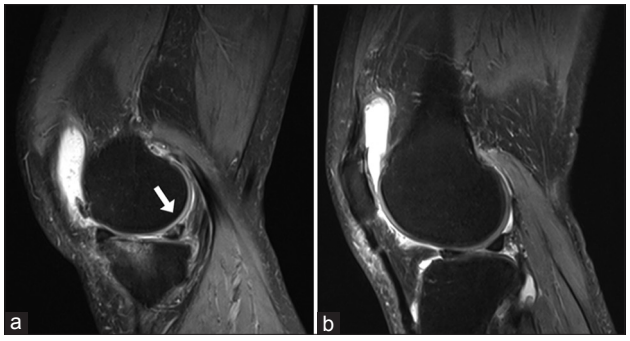

Figure 3: Posterior medial meniscus root tears exit in SONK. (a) A Level III posterior MMRT. A signal extending to the joint surface on the posterior medial meniscus root tears (arrow). (b) Although degeneration of the lateral meniscus also occurs, none of our patients had a Level III lesion. MMRTs: Medial meniscus root tears; SONK: Spontaneous osteonecrosis of the knee.

Discussion

Classically, SONK is described as a focal lesion occurring in the medial femoral condyle, and in the tibial plateau in a small proportion of cases. Its etiology is uncertain. Women older than 55 years are susceptible to this disease. SONK in the tibial plateau manifests similarly to that in the medial femoral condyle. Its' typical symptom is sudden-onset severe pain in the affected knee, which is confined mostly to the lesion location. The pain is aggravated by weight-bearing and alleviated by rest, and nocturnal resting pain is common. Excessive alcohol use, long-term corticosteroid use, and hematological diseases can also lead to osteonecrosis and should be excluded before making a diagnosis of SONK.

The prevalence of early-stage SONK in patients over 65 years of age, with pain in the medial knee and no history of trauma, was 9.4% in a study by Pape *et al*.[11] When elderly patients present with normal conventional radiographs after sudden-onset severe pain in the knee, and when the pain continues for more than 6 weeks, MRI should be performed to rule out early SONK. A diagnosis of SONK may avoid unnecessary arthroscopy. In our series, the patient with the shortest history of knee pain was a 75-year-old female (Case 1) who presented with a 4-week history of sudden-onset severe knee pain and no history of trauma. Plain X-rays showed a localized translucent area surrounded by a band in the subchondral region of the MT. MRI clearly showed necrotic changes [Figure 4]. Therefore, we believe that MRI is necessary to identify the early SONK.

The pathogenesis of SONK of the medial femoral condyle remains unclear, although subchondral bone microfracture and local circulation disorders are widely accepted as common causes. SONK mostly affects elderly females. This population commonly has underlying osteoporosis. Thus, even mild trauma might lead to microfracture of the weak subchondral bone. In one patient (Case 1), MRI clearly showed a subchondral fracture. The T1-weighted image showed a linear, low-intensity signal in the subchondral bone, while the T2-weighted image showed high-signal intensity surrounding the subchondral fracture line [Figure 4]. Takao suggested that after a subchondral fracture, joint fluid moves into the bone through subchondral cracks, which lead to local edema and, eventually, local osteonecrosis.[12] The other patients in our series suffered from pain for more than 6 months. Therefore, we found only focal subchondral osteonecrosis on the MRI rather than a typical subchondral fracture line [Case 2; Figure 5].

The development of SONK is also associated with inappropriate weight bearing and stress on the knee. In our series, seven cases of SONK (32%) involved the anterior tibial plateau (MTa) and 15 (68%) involved the central tibial plateau (MTc), but none involved the posterior tibial plateau (MTp) [Figures 4 and 5]. This may be due to the difference between anatomical structure and function. When humans walk, the load on the tibial plateau is mainly transmitted to the MTa and MTc, while the MTp is stressed only during extreme buckling or a complete squat. Elderly populations primarily walk, rather than performing squatting or other activities that involve extreme buckling due to limited joint mobility. Therefore, osteonecrosis caused by abnormal stress often occurs in the anterior and central regions of the tibial plateau.

A recent study found MMRTs in 80% of patients with SONK, suggesting an association between meniscal tears and SONK.[5] In our series, 17 patients (77%) had a Level III posterior MMRT [Figures 3 and 4]. Although degeneration of the lateral meniscus also occurs, none of our patients had a Level III lesion [Figure 3]. Meniscal tears and injury may increase the mechanical load on the affected condyle, resulting in subchondral fracture. In clinical practice, it is important to recognize the characteristics of SONK to avoid ignoring tibial and femoral bone lesions. Simply explaining the clinical symptoms as being due to a meniscus injury, rather than differentiating them from SONK, could result in the incorrect treatment.

Juréus *et al*.[13] evaluated the natural course and long-term consequences of SONK, regarding the need for major knee surgery, by following 40 patients for an average of 9 years (range: 1–27 years). Of these, 17 underwent surgery and, of those with large lesions (>40%), six patients underwent surgery immediately after the diagnosis of SONK was confirmed. None of the 10 patients with a lesion <20% underwent surgery at any point. In our series, the lesion volume averaged 2.24 ± 0.79 cm^3 (range: 1.57–3.08 cm^3). During follow-up, we found that the pain was relieved, and knee function recovered, after unicondylar knee arthroplasty. Compared with baseline, the HSS and VAS scores improved significantly at follow-up. Juréus *et al*.[13] believed that the size of the osteonecrotic lesion predicted the outcome. Early appearance of the signs of osteoarthritis and a large area of osteonecrosis, both indicate the need for surgery.

SONK is a progressive disease. If not diagnosed and treated in a timely manner, the illness can gradually worsen.[14] Conservative treatment is recommended in the early stage

Figure 4: A typical case of early diagnosed SONK on MT. (a) Plain X-rays showed a localized translucent area surrounded by a band in the subchondral region of the MT (the white arrow). (b) On plain radiographs, the trabecular bone of her right knee is clear (the black arrow). (c-f) The T1-weighted image showed a linear, low-intensity signal in the subchondral bone, while the T2-weighted image showed high-signal intensity surrounding the subchondral fracture line. (g and h) Postoperative radiographs demonstrated the affected knee after unicompartmental arthroplasty. SONK: Spontaneous osteonecrosis of the knee; MT: Medial tibial plateau.

of the disease including the use of lateral-wedge insoles, protected weight bearing, anti-inflammatory drugs, and bisphosphonates.[15] Yates *et al*.[16] reported that the resolution of symptoms in all 20 patients with Stage I SONK lesions treated with protected weight-bearing or activity restriction, and oral analgesics as needed at a mean of 5 months (range: 3–8 months) following the onset of symptoms. At Stage II, when the articular cartilage is still relatively intact, drilling can be performed. Drilling has achieved good results in such cases due to the functions of mesenchymal stem cells and subsequent reduction in intraosseous pressure.

The advanced stages are generally treated more invasively with surgery, such as osteochondral grafts, high tibial osteotomy with or without autogenetic bone grafts, or unicompartmental or total knee arthroplasty, with good clinical results.[17-20] Appropriately selected patients may be managed through HTO to preserve the joint.[21] Although this option is typically reserved for younger, active patients, HTO relieves the affected femoral condyle by shifting the weight-bearing axis laterally. In a study on 10 patients managed either through HTO (n = 6) or nonoperatively (n =4), Marti *et al*.[22] found that HTO was associated with greater improvements in lesional appearance on follow-up MRI (83% vs. 25%) and a higher frequency of symptom improvement (100% vs. 50%).

Depending on patient factors, lesion characteristics, and the condition of the remainder of the joint, unicompartmental arthroplasty may be utilized. Unicompartmental arthroplasty is an effective treatment method for those with disease isolated to a single femoral condyle or tibial plateau, with the benefit of preserving the patient's bone stock and functioning cruciate ligaments.

Bruni *et al*.[23] reported the long-term survival rate of UKAs in a larger group of patients with spontaneous osteonecrosis of the knee; they retrospectively evaluated all 84 patients with late-stage spontaneous osteonecrosis of the knee who had a medial UKA from 1998 to 2005. Ten-year survival rate was 89%. Ten revisions were performed; the most common reasons were subsidence of the tibial component (four) and aseptic loosening of the tibial component (three). The authors suggest that spontaneous osteonecrosis of the knee may be

Figure 5: A typical case of late diagnosed SONK on MT. The patients in our series suffered from pain for more than 6 months (Case 2). Therefore, we found only focal subchondral osteonecrosis on the MRI rather than a typical subchondral fracture line. SONK involved the anterior tibial plateau (MTa). (a and b) Plain X-rays showed osteoarthritis changes. (c-f) MRI clearly showed necrotic changes. (g and h) Postoperative radiographs demonstrated the affected knee after unicompartmental arthroplasty. SONK: Spontaneous osteonecrosis of the knee; MT: Medial tibial plateau; MRI: Magnetic resonance imaging.

an indication for UKA. In the study of Heyse *et al*.,[24] data showed that spontaneous osteonecrosis of the knee (SONK) could successfully be treated with UKA at a good mid- to long-term follow-up.

There are some limitations of our study. We retrospectively analyzed the clinical and radiological results of UKA in SONK without a control group of other treatment options. In addition, the sample size of our study was small. These are mainly limited by the epidemiology. The cases of SONK in the tibial plateau are relatively scarce. The majority of SONK occurred in the medial femoral condyle. Despite that the quality of evidence of case series is low, this work demonstrated the clinical characteristics of SONK in MT and outcome of UKA, which will be the necessary foundation for further study.

In conclusion, clinicians should be aware of spontaneous osteonecrosis of the MT. MRI is recommended for suspected cases to identify SONK at an early stage. SONK often occurs in the anterior and central tibial plateau due to abnormal stresses. Furthermore, SONK is typically accompanied by meniscal tears and should be recognized to avoid misdiagnosis. The use of the Oxford Medial UKA for spontaneous osteonecrosis of the MT is reliable in the short-to-medium term.

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Conflicts of interest

There are no conflicts of interest.

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膝关节胫骨平台自发性骨坏死的临床特征及治疗方法探讨

摘要

背景：膝关节自发性骨坏死常常无法早期诊断出来。膝关节自发性骨坏死晚期，常需要行关节置换术。在一小部分病例中，膝关节自发性骨坏死涉及胫骨内侧平台。本文在回顾性病例研究的基础上，介绍了发生于胫骨内侧平台的自发性骨坏死的临床特点，及利用单髁置换术进行治疗该疾病的临床疗效。

方法：从2015年3月至2016年6月，在广东省中医医院就诊，利用磁共振成像检查证实，诊断为胫骨内侧平台的自发性骨坏死患者被纳入研究，并进行回顾性分析。所有患者都接受牛津内侧单髁置换术。该部分病人的病变特点、治疗方法及随访结果均被记录和评估。利用Ficat and Arlet分期对坏死部分的分期和评分。

结果：本研究共纳入了22例诊断为胫骨内侧平台自发性骨坏死的患者，其中男性5例，女性17例，平均年龄64.1岁。坏死分级：II级3例(13.64%),III级10例(45.45%)，IV级7例(31.82%)，V级2例(9.09%)。所有坏死灶均位于胫骨内侧平台。在矢状位上，坏死灶位于胫骨平台前1/3者7例(31.82%)，坏死灶位于胫骨平台中1/3者15例(68.18%)。坏死灶平均体积2.24 ± 0.79 cm^3 (范围：1.57 - 3.08 cm^3)。有17例(77.27%)患者合并了内侧半月板后角III度损伤，没有1例患者合并了外侧半月板后角III度损伤。所有患者均行内侧单髁置换术，没有感染、松动等并发症发生，平均随访时间30.0 ± 6.4月（23-38月）。所有患者对手术的疗效评价满意。VAS评分从术前7.78 ± 0.67分下降到末次随访时2.22 ± 1.09；HSS评分从术前65.67 ± 5.45分到末次随访时84.1 ± 4.20分；两者前后比较均有统计学意义（P<0.001）。

结论：由于应力异常，发生于胫骨内侧平台的自发性骨坏死，常常在胫骨前部和中部出现；该部分患者常合并内侧半月板后角损伤。对于该病的诊断和鉴别，建议尽早行MRI检查。利用牛津单髁置换术治疗胫骨内侧平台的自发性骨坏死的早中期疗效满意。