



The minimally invasive endoscopic technique for the treatment of symptomatic benign bone lesions: Preliminary results from a retrospective study



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ABSTRACT

Objective: The present study aimed to evaluate the short-term clinical feasibility and efficacy of the minimally invasive endoscopic technique (MIET) for the treatment of symptomatic benign bone lesions.

Materials and methods: This single-institution retrospective study investigated 34 patients with symptomatic benign bone lesions from December 2015 to June 2017. Patients involved in this study presented with definite indications for surgical intervention. All procedures were performed under endoscopic guidance for direct visualization followed by complete curettage of tumor tissue. There were 19 males and 15 females, with a mean age of 33.3 ± 12.7 years (range, 17–68 years). The lesions were located in the upper extremities (20, 58.8%), lower extremities (9, 26.5%) and pelvis (5, 14.7%). Primary outcomes were measured before and after intervention using the visual analog scale (VAS), the Musculoskeletal Tumor Society (MSTS) stage and the 36-item Short-Form Health Survey (SF-36) scoring system.

Results: Of the 34 patients included in this study, all completed follow-up examinations, with a mean follow-up duration of 22.4 ± 7.6 months (range, 13–35 months). Significantly improved VAS, MSTS and SF-36 scores were observed at 3 months after the initial treatment ($P < 0.001$), suggesting enhanced pain relief and improved functional recovery and quality of life following surgery. All procedures were technically successful, with the exception of 3 cases (8.8%) manifesting access site numbness; these patients recovered within the follow-up period through symptomatic treatment alone. Only 2 patients (5.9%; one osteblastoma and one enchondroma) experienced local recurrence and underwent standard open curettage within the follow-up period. All patients showed functional stability without any major complications.

Conclusion: The MIET is an effective and safe alternative treatment for symptomatic benign bone lesions. The short-term efficacy of MIET was favorable and associated with improved pain palliation, quality of life and functional recovery.

1. Introduction

Each year, millions of patients suffer from symptomatic benign bone lesions, including benign bone tumors and nonneoplastic lesions, representing a substantial challenge for orthopedic oncology surgeons due to the lack of evidence-based therapeutic strategies [1,2]. With the

rapid development of musculoskeletal imaging and interventional radiology, an increasing number of benign bone tumors and non-neoplastic lesions are being detected at the early stage [3,4]. Clinically, regular follow-ups and dynamic imaging observations may be suitable for asymptomatic patients with minor bony lesions [5]. However, for patients with a refractory limp, pain or potential pathologic fracture,

Abbreviations: MIET, Minimally invasive endoscopic technique; MDT, Multidisciplinary team; CT, Computed tomography; MRI, Magnetic resonance imaging; STIR, Short tau inversion recovery; MWA, Microwave ablation; PKP, Percutaneous kyphoplasty; PVP, Percutaneous vertebroplasty; PPSF, Percutaneous pedicle screw fixation; RFA, Radiofrequency ablation; SF-36, 36-item Short-Form Health Survey; MSTS, Musculoskeletal Tumor Society; VAS, Visual analog scale; GCTB, Giant cell tumor of bone; ABC, Aneurysmal bone cyst

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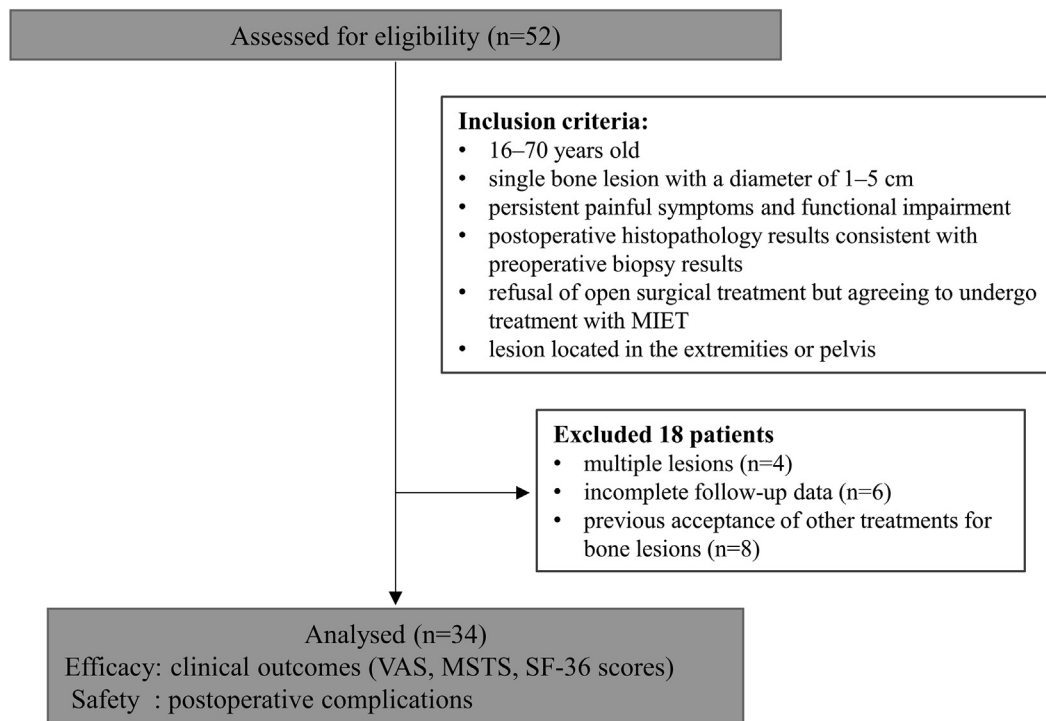


Fig. 1. STROBE diagram of the study.

surgical resection and curettage may be considered the mainstay treatment to prevent lesion progression [6]. Nonetheless, conventional open surgery generally involves high risks of complications, is extremely invasive to the soft tissue and the bone/cartilage, and may greatly compromise the overall efficacy of surgery in the long term [7,8]. In recent years, minimally invasive surgical techniques have been widely used to treat both benign and malignant bone lesions, which are thought to be associated with a less invasive operation, resulting in decreased intraoperative blood loss, a shorter hospital stay, early pain palliation and reduced complication rates [9]. More importantly, the number of treated bone lesions and the availability of various techniques are increasing because of the development of more advanced minimally invasive surgical instruments and approaches [5,10]. Accumulating evidence shows that various methods, including radiofrequency ablation (RFA), microwave ablation (MWA), endoscopic techniques, percutaneous pedicle screw fixation (PPSF), percutaneous vertebroplasty (PVP) and percutaneous kyphoplasty (PKP), are being widely and successfully applied in the treatment of symptomatic bone lesions [8,11–16].

Among these methods, the minimally invasive endoscopic technique (MIET) is a well-established approach that is prevalent throughout orthopedics, principally in sports and spinal surgery [17–20]. Regardless, the role of MIET in the management of symptomatic benign bone lesions is controversial, and early guidelines do not recommend MIET for symptomatic benign bone lesions because of a lack of evidence [21–23]. However, compared with other minimally invasive surgical strategies, MIET provides direct visualization of the operative field to avoid damage to adjacent anatomical structures, which allows safe tumor removal [24]. Moreover, another distinct advantage of MIET is that it provides an excellent opportunity for trainees and medical students to observe every step of the operation on a video screen, which is especially beneficial for expansion of this technique into the field of orthopedic oncology. Although limited evidence is available, some studies have shown that the MIET produces an excellent profile of efficacy for the treatment of benign bone tumors, such as giant cell tumors of the tendon sheath, simple bone cysts, aneurysmal bone cysts and chondroblastomas [24–30]. In China, however, few studies have evaluated

this therapeutic modality, with most studies published to date comprising case reports that do not report comprehensive outcome measures (including VAS, MSTs and SF-36 scores) [31]. One common reason is that the application of MIET for symptomatic benign bone lesions has not been comprehensively evaluated in the literature. Overall, for patients with impaired motor function and progressive pain, especially in cases caused by disease progression, it would be advantageous to perform surgery using MIET, which is associated with minimal tissue damage [16].

Based on the above background, we performed this retrospective study to better verify the feasibility and efficacy of MIET for the treatment of symptomatic benign bone lesions. We hypothesized that the application of MIET would alleviate pain and increase stability for better function in patients with symptomatic benign bone lesions. To test this hypothesis, we systematically evaluated the preliminary results of MIET by observing patients' functional outcomes, quality of life, pain scores and complications at a single tertiary referral institution in China.

2. Materials and methods

2.1. Ethical approval and consent to participate

Prior to testing, all participants and/or their parents were informed of the technique itself, associated risks, and the possible benefits of participation, and they provided written informed consent for the procedure. All procedures involving human participants were performed in accordance with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. The present study was retrospective, and the local ethics committee waived formal consent for this type of study.

2.2. Patient characteristics

From our institutional database, we initially identified 52 patients with histologically verified symptomatic benign bone lesions who underwent MIET between December 2015 and June 2017. Eighteen

patients were subsequently excluded, resulting in a study population of 34 patients. The patients included 19 males and 15 females, with a mean age of 33.3 ± 12.7 years (range, 17–68 years). The STROBE diagram of the study is shown in Fig. 1. The inclusion criteria for this study were as follows: (1) 16–70 years old; (2) single bone lesion with a diameter of 1–5 cm; (3) persistent painful symptoms and functional impairment; (4) postoperative histopathology results consistent with preoperative biopsy results; (5) refusal of open surgical treatment but agreeing to undergo treatment with MIET; and (6) lesion located in the extremities or pelvis. The exclusion criteria were as follows: (1) multiple bone lesions; (2) severe bleeding tendency, a platelet count $< 50 \times 10^9/L$, or a prolonged prothrombin time > 3 s; (3) previous acceptance of other treatments for bone lesions; and (4) incomplete follow-up data. The most important criterion for inclusion in this study was clinical symptomatology: persistent painful and functional impairment symptoms present a good indication for surgical intervention with the goals of pain palliation, recovery of motor function, and prevention of a potential pathological fracture and/or local lesion recurrence.

The diagnosis of benign bone tumors and nonneoplastic lesions was established based on clinical findings and imaging data. For patients with an uncertain diagnosis based on imaging findings, computed tomography (CT)-guided percutaneous core biopsy or open biopsy was performed to determine a definitive diagnosis before surgery, as we described in our previous study [32]. The most common lesion location included the lower extremities (20, 58.8%), followed by the upper extremities (9, 26.5%) and pelvis (5, 14.7%). The primary lesions consisted of enchondromas (14, 41.2%), osteblastomas (2, 5.9%), osteofibrous dysplasia (2, 5.9%), simple bone cysts (6, 17.6%), degenerative cystic lesions (7, 20.6%) and nonossifying fibroma (3, 8.8%). According to our center's electronic medical record system and pathological reporting systems, we recorded and summarized the relevant clinical characteristics for the study cohort (Table 1). A multidisciplinary team

Table 1
Patient and lesion characteristics.

Parameter		Value	Percentage (%)
Patient characteristics (n = 34)			
No. of men		19	55.9
No. of women		15	44.1
Age (years)	Mean \pm SD (years)	33.3 ± 12.7	
	Range	17–68	
Initial symptom at admission	Pain	20	58.8
	Limp	8	23.5
	Both	6	17.6
Lesion characteristics (n = 34)			
Lesion pathology	Enchondroma	14	41.2
	Osteoblastoma	2	5.9
	Osteofibrous dysplasia	2	5.9
	Simple bone cysts	6	17.6
	Degenerative cystic lesion	7	20.6
	Non-ossifying fibroma	3	8.8
Lesion location	Upper extremity	9	26.5
	Lower extremity	20	58.8
	Pelvis	5	14.7
Lesion diameter	Mean \pm SD (cm)	3.6 ± 0.9	
	Range	1.9–4.8	
Surgical management	MIET alone	5	14.7
	MIET + artificial bone graft	7	20.6
	MIET + autogenous bone graft	22	64.7
	Follow-up (months)	Mean \pm SD (months)	22.4 ± 7.6
	Range	13–35	

MIET: Minimally invasive endoscopic technique.

(MDT) meeting was held with our experienced histopathologists, radiologists and orthopedic oncology surgeons to thoroughly evaluate patient treatment options based on the imaging findings (i.e., X-rays, CT images and magnetic resonance images) before any surgical intervention was performed.

2.3. Surgical procedures (Figs. 2 and 3)

All surgical procedures were conducted on an inpatient basis under general or epidural anesthesia and strict surgical asepsis. All of these procedures were performed by the same team with at least 3 years of experience in interventional bone oncology. In addition, the surgical procedure was conducted with the aid of an inflatable tourniquet. For patients in which a tourniquet was not suitable (e.g., lesions located in the pelvis or proximal femur), epinephrine (approximately 3–3.5 mg/L) was injected to control blood loss. The access path used for MIET and the surgical program was planned under the guidance of X-ray fluoroscopy, which provides real-time imaging localization. Specifically, we used fluoroscopy to localize the lesion (Fig. 2A), and access to the target site was given priority to the shortest skin-to-target and safest route while avoiding major blood vessels and vital anatomical structures.

By making an approximately 1–3 cm incision in the skin, the dilating catheter was inserted step by step through a hook wire, and the soft tissue was bluntly separated until reaching the bone surface of the target area. Subsequently, the dilating catheter was preferably placed at the thinnest points of the affected cortical bone. The cortical bone was pierced with a paragon bone biopsy system (Paragon Bone Biopsy Systems, Sterylab, Italy) through tubular retractor systems (Fig. 3A–B), and specimens were obtained and sent to the laboratory. When the working cannula was well established, a high-speed burr was used for cortical bone fenestration over the area of the lesion. The endoscope was then placed and confirmed by X-ray fluoroscopy. Under endoscopic visualization, the lesion could be curetted using variously angled curettes (Fig. 3C) and rongeurs (Fig. 3D). After all of the visible lesion was removed (Fig. 2A–C), the cavity was burred with a high-speed burr (Fig. 2D) and washed abundantly with normal saline until normal bone was observed in the medullary cavity, which indicated that all pathologic tissue had been thoroughly removed. Following curettage of the bone lesion, bone grafting was performed using an artificial bone graft (Osteolink Biomaterial Co., Ltd., Hubei, China) or an autogenous bone graft under fluoroscopic guidance (Fig. 2E). Postoperatively, patients with upper limb or nonload-bearing bone lesions were able to gradually increase their mobility, with the exception of high-energy activities. In the case of lower extremity lesions, partial weight-bearing was maintained for at least 1 month with crutches. Full weight-bearing was allowed after the radiological confirmation of bone healing, which usually occurred at 3 months after surgery.

2.4. Postoperative follow-up and efficacy evaluation

The follow-up radiological assessment, including standard radiography and CT or MRI, was performed before and at 1 month after surgical intervention, every 3 months for the first years, every 6 months for the second year, and then annually thereafter. The general condition, curative effect, disease recurrence and complications after MIET were assessed. Specifically, pain improvement was evaluated via an ordinal visual analog scale (VAS) scoring system ranging from 0 to 10, where 0 refers to no pain and 10 to the worst possible level of pain. Improvements in functional status before and after surgery were evaluated using the Musculoskeletal Tumor Society (MSTS) score, which is widely applied for the assessment of physical function in patients with musculoskeletal lesions [33]. The obtained value is usually a percentage of normal function, with a maximum score of 30/30 corresponding to 100% normal function. The 36-item Short-Form Health Survey (SF-36) was employed to measure health-related quality of life. These assessments were performed preoperatively and at 3 months

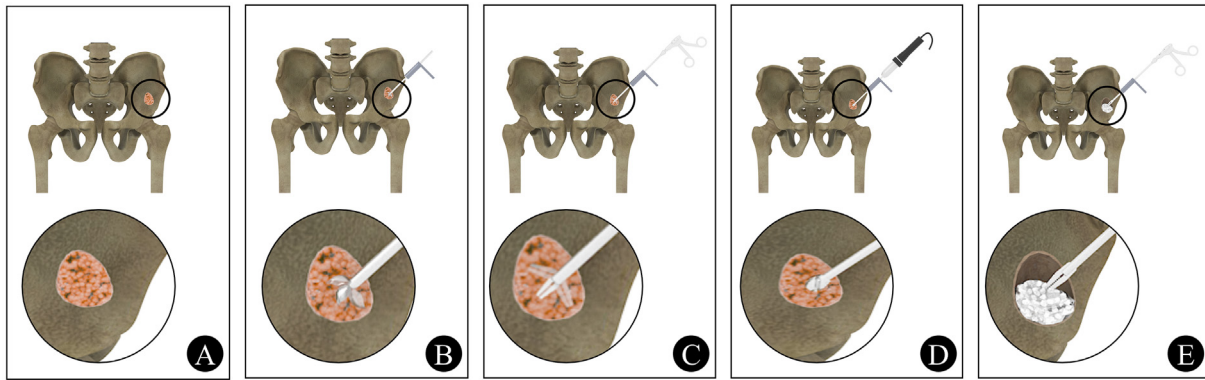


Fig. 2. Schematic diagram of the use of MIET for the curettage and bone grafting of symptomatic benign bone lesions (A-E). A-D Tumor curettage using curettes (B), rongeurs (C), and high-speed burring (D). E Endoscopy-guided bone grafting.

postoperatively. Any complications related to the procedure were recorded within one month after treatment.

2.5. Statistical analysis

All descriptive statistics are presented as the means ± standard deviations (SD) for continuous variables. Qualitative variables are expressed as numbers and percentages. A paired *t*-test was used to compare preoperative and postoperative data, including VAS, MSTS and SF-36 scores. Statistical significance was defined as *P* < 0.05. All statistical analyses were performed using R software, version 3.5.3.

3. Results

3.1. General characteristics

During the study period, follow-up was completed by 34 patients (100%), with a mean follow-up period of 22.4 ± 7.6 months (range, 13–35 months). MIET was successfully performed for all patients, who completed postoperative clinical follow-up examinations (without loss) via a standardized telephone questionnaire or outpatient rechecks. The mean operative duration was 174.3 ± 36.6 min (range, 112–235 min), with an average intraoperative bleeding volume of 140.3 ± 82.9 mL (range, 58–340 mL). The mean hospital length of stay was 8.6 ± 2.5 days (range, 5–13 days). Among the 34 patients, the majority were treated with MIET and bone grafting (29, 85.3%), followed by MIET alone (5, 14.7%) depending on the size of the lesion. The

patient and lesion characteristics are summarized in Table 1.

3.2. Follow-up and clinical outcomes

The VAS scores at 3 months postoperatively were lower than the values observed preoperatively (4.9 ± 1.4 vs 0.3 ± 0.5) for all patients, and the differences between the 2 time points were statistically significant (*P* < 0.001). In addition, the mean MSTS functional scores improved significantly from 17.8 ± 2.8 preoperatively to 25.5 ± 1.9 at 3 months postoperatively (*P* < 0.001). Additionally, MSTS functional scores at the final follow-up were excellent in all 34 (100%) patients (mean 27.6 ± 1.8, range 25–30). Moreover, the preoperative and 3-month postoperative SF-36 scores of the patients were 61.1 ± 6.2 and 79.7 ± 5.5, respectively (*P* < 0.001). Relevant surgical outcomes are presented in Table 2 and Fig. 4. During the follow-up period, the surgical outcome was satisfactory with good pain control and functional improvement, except in 2 patients (5.9%; one osteoblastoma and one enchondroma) with tumor recurrence who underwent standard open curettage and had reached subclinical severity at the subsequent follow-up. No other recurrence or symptom worsening was observed during follow-up. Representative surgical procedures and complete images during follow-up, including preoperative imaging, intraoperative imaging, and postoperative imaging, are shown in Figs. 5 and 6.

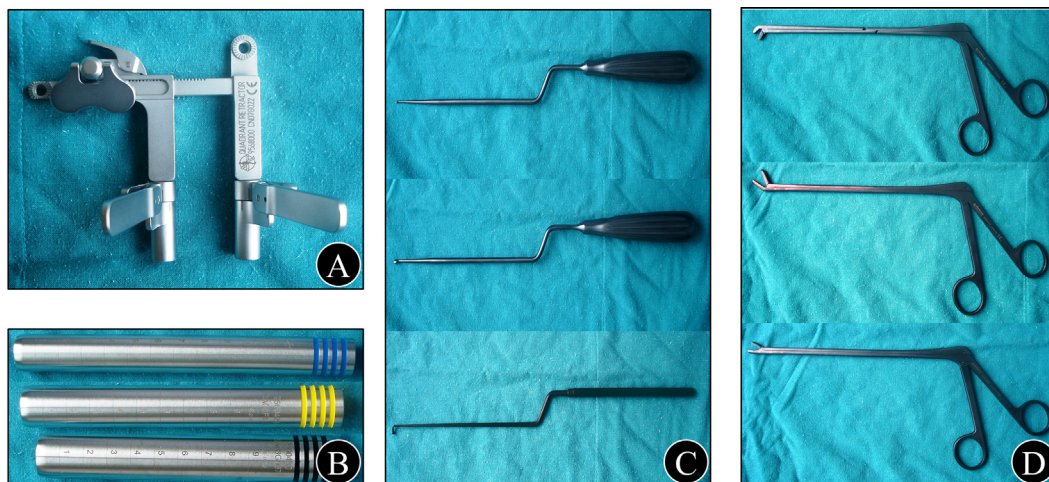


Fig. 3. Surgical devices used for MIET (A-D). A-B A tubular retractor system that permits a minimally invasive surgical access portal to allow biopsy, curettage and grafting. C-D Various angled curettes (C) and rongeurs (D) used for curettage.

Table 2

Preoperative and postoperative data regarding surgical efficacy according to the VAS, MSTs and SF-36 scores.

	Pre	Pos	t value	P value
VAS score	4.9 ± 1.4	0.3 ± 0.5	18.6053	< 0.001
MSTS score	17.8 ± 2.8	25.5 ± 1.9	-20.0909	< 0.001
SF-36 score	61.1 ± 6.2	79.7 ± 5.5	-26.6391	< 0.001

Pre: Preoperatively, Pos: Postoperatively, VAS: Visual analog scale, MSTs: Musculoskeletal Tumor Society, SF-36: 36-item Short-Form Health Survey.

3.3. Complications and side effects

No deaths occurred among our study population. Surgical mortality or other serious procedure-related complications (e.g., major neurovascular injury, hemorrhage, secondary fracture or infection) were not observed during or after treatment in any patient. Seventeen patients (45.9%) experienced mild or moderate incision pain, which ranged in duration from 3 to 7 days. Minor complications, such as local skin numbness in the region of the access site, occurred in 3 patients (8.8%). The symptoms significantly alleviated by symptomatic treatment alone and had disappeared at the 3-month follow-up.

4. Discussion

The present study demonstrates good postoperative outcomes in a series of 34 patients with symptomatic benign bone lesions following treatment with MIET. Pain, functional status, and quality of life were significantly improved; the complication rate was acceptable (8.8% minor complications), and recurrence was observed in only two patients (5.9%) during the 22.4 ± 7.6 months of follow-up. Specifically, our results confirm that this minimally invasive procedure provides acceptable clinical efficacy and can significantly reduce patient pain, improve patient functional recovery and enhance patient quality of life. A significant difference in these outcomes in terms of VAS, MSTs and SF-36 scores was noted between the preoperative and 3-month postoperative time points.

4.1. Advantages of MIET for the treatment of benign bone lesions

Over the past several decades, the treatment for benign bone lesions has consisted mostly of open curettage and packing the lesion cavity with an autograft, allograft, or bone substitute, which remains the mainstay of therapeutic modalities [34,35]. The application of open surgery is relatively simple and easy to learn, but some authors do not recommend it as the initial treatment due to concerns of delayed union, bleeding, or iatrogenic fracture [36]. Clinical evidence for the utility of the MIET in the treatment of benign bone tumors has been limited to some small case series. In 1995, Stricker et al. [29] first reported the successful execution of endoscopic curettage and bone grafting in 3 patients with chondroblastomas. During the follow-up period, all three tumors healed without recurrence, with no complications related to the approach. Similarly, Lui et al. [37] described this technique for the treatment of enchondroma and reported excellent functional recovery and local tumor control. Collectively, MIET can provide the advantage of accurately assessing lesion curettage through direct visualization of the bone cavity for complete removal. In addition, direct visualization avoids blind spots or excessive curettage, which may result in intraoperative fracture or cartilage damage. Recently, in a retrospective study, Aiba et al. [27] reported the use of MIET to treat 30 patients with aneurysmal bone cysts (ABCs). Good postoperative functional recovery was achieved in all patients following the procedure. In general, the MIET is typically performed in patients with bone lesions located in the extremities or pelvis, and a potential explanation for this finding is that this technique is able to maintain the structural integrity and periosteal sleeve of the involved bones, significantly reducing cortical bone degradation and increasing bone healing. Moreover, MIET enables avoiding more extensive soft tissue dissection while still permitting complete evaluation and bone grafting of benign bone lesions [38]. Based on these studies, the MIET is associated with a minimal risk of local soft tissue injury and thus provides early pain relief and improved functional recovery, showing potential applications in the field of oncologic orthopedical surgery.

In addition to good local lesion control, an improvement in extremity function and the quality of life would be the critical goals for most patients, particularly young patients, who are often good surgical candidates. In a retrospective study, Farouk et al. [38] reported the successful treatment of 26 benign bone lesions with the MIET.

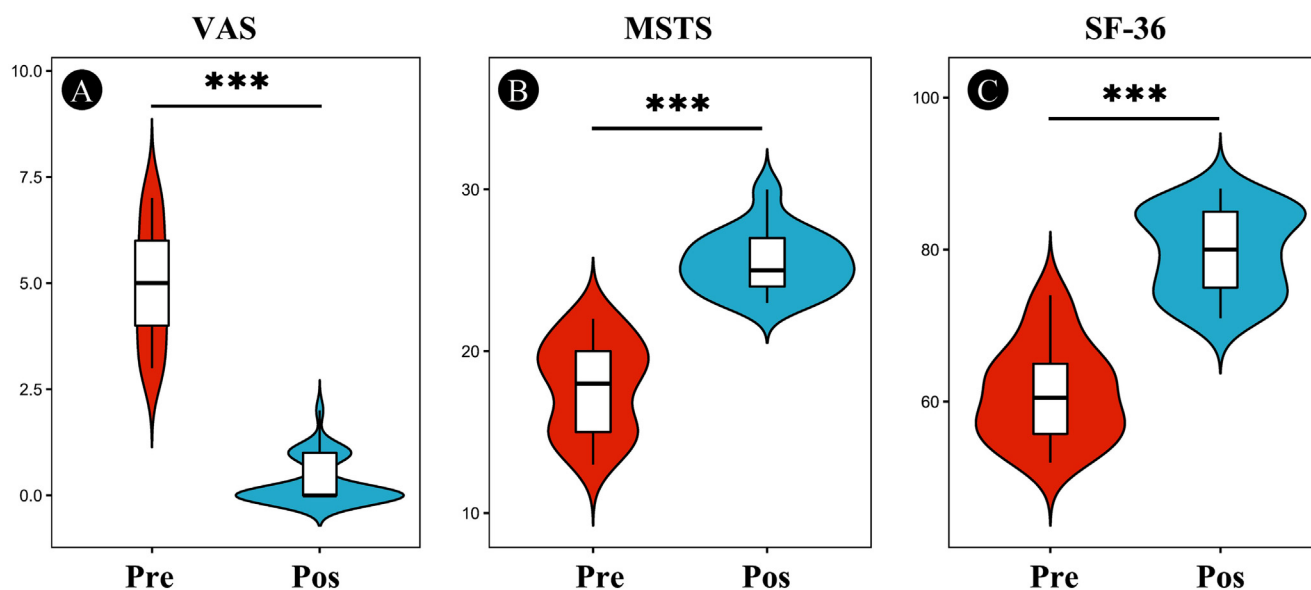


Fig. 4. A-C Graphs were generated for a visual comparison of preoperative and postoperative test scores. VAS (A), MSTs (B) and SF-36 (C) scores measured preoperatively and 3 months postoperatively for all patients are shown. VAS, visual analog scale; MSTs, Musculoskeletal Tumor Society; SF-36, 36-item Short Form Health Survey; Pre, preoperative; Pos, postoperative (3 months postoperatively) follow-up visit. ***P < 0.001.

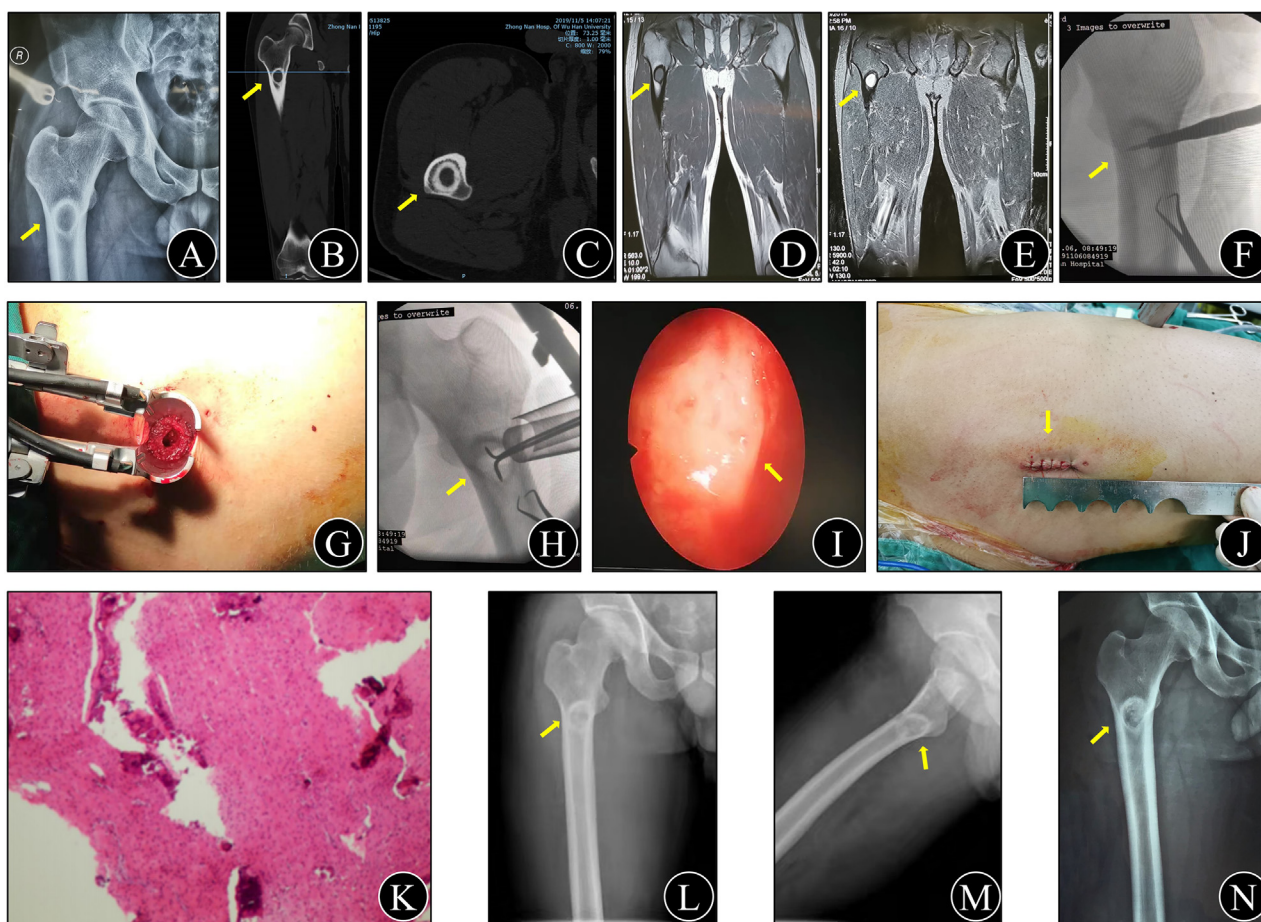


Fig. 5. A 29-year-old man with osteofibrous dysplasia of the right proximal femur. A Preoperative anteroposterior plain radiographs indicate a neoplastic lesion with a benign sclerotic rim (yellow arrow). B-C Preoperative coronal (B) and axial (C) CT images (using bone windows) demonstrate a regular and sclerosing lesion in the bone marrow cavity (yellow arrow). D-E Preoperative coronal T1-weighted (D) and coronal short tau inversion recovery (STIR) (E) sequence images show a central lesion with low signal intensity on T1WI and homogeneous high signal intensity on STIR sequences (yellow arrow). F-H Intraoperative X-rays show the needle targeted within the lesion (yellow arrow). Subsequently, endoscopic curettage and bone grafting of the lesion were performed under the guidance of direct visualization (yellow arrow). I Endoscopic images in the affected bone marrow cavity show the lesion (yellow arrow). The process is shown in the video in the supplementary materials. J-K Postoperative gross observation shows the incision appearance, and histopathological results (hematoxylin and eosin, original magnification $100\times$) diagnosed the bone lesion as osteofibrous dysplasia. L-M At the 6-month follow-up visit, a solid, bony union at the proximal femur without progression of the lesion was observed (yellow arrow). N At the 15-month follow-up visit, good bony union was observed at the proximal femur, without progression of the lesion (yellow arrow). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Twenty-five patients (96.2%) achieved completed functional recovery at a period of 8–12 weeks, and the mean functional scores increased from 20.2 to 28.6/30 postoperatively, indicating promising functional outcomes. In another study, Miyamoto et al. [39] introduced an endoscopic technique combined with a bone substitute for the treatment of a unicameral bone cyst of the proximal femur. The authors concluded that a sufficient initial strength after curettage is achieved by injecting calcium phosphate cement under the guidance of endoscopy. They also reported improved functional outcomes and no major complications. These results are largely attributed to the advantage of minimally invasive surgery in terms of less surgical trauma and preservation of the cortical integrity [37]. The results of the present study are in line with those of the aforementioned previous study and further confirm the excellent curative potential of MIET, with early pain reduction, enhancement of functional recovery and improvement of quality of life observed in almost 100% of the patients, which is maintained at the final follow-up visit.

4.2. Complications

Rather than performing an open surgical technique, MIET is used to gain adequate surgical access through a smaller incision. Nevertheless,

the smaller surgical exposure may increase the risk of inadequate visualization and poor surgical site access, which may present an increased risk of complications. Regardless, our study did not reveal any major complications related to MIET, including secondary fracture, neurovascular injury or cartilage damage, though three minor complications (8.8%) related to local skin numbness in the region of the access site were observed. Similar results have been obtained in other recent and mostly retrospective studies, indicating a relatively low rate of complications associated with the MIET [26,38]. Indeed, Aiba et al. [26] recently showed that endoscopic curettage has the advantages of a minimally invasive procedure for the treatment of simple bone cysts; complications occurred in 3 patients (8.1%) (one transient radial nerve palsy and two postoperative fractures). In a multicenter retrospective study, Sadick et al. [24] successfully treated 36 benign forehead lesions using the endoscopic approach. In their series, no hematomas, infections, scalp numbness, contour irregularities, temporal branch paralysis, or tumor recurrence occurred, except in one patient with a prolonged area of alopecia that resolved on its own. To reduce the complications associated with MIET, the application of a tourniquet and epinephrine is administered to provide adequate clarity of the visual field. In addition, for lesions located in poor soft tissue envelopes and challenging anatomic locations, such as the proximal tibia or

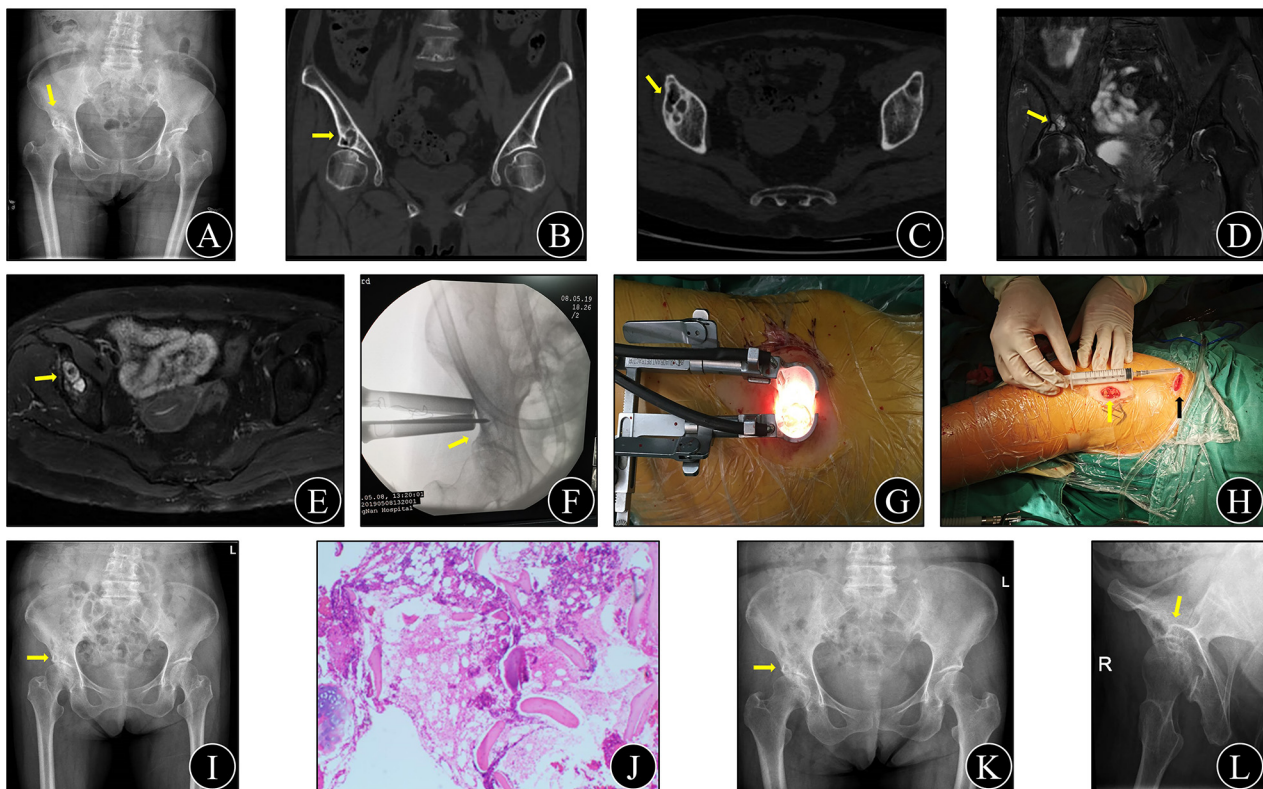


Fig. 6. A 65-year-old woman with a benign bone lesion of the right acetabulum. A Preoperative anteroposterior plain radiographs show irregular cystic lesions with osteolytic destruction in the right acetabulum (yellow arrow). B-C Preoperative coronal (B) and axial (C) CT images (using bone windows) demonstrate multiple small cystic changes without surrounding soft tissue swelling and involvement (yellow arrow). D-E Preoperative coronal (D) and axial (E) STIR sequence images show heterogeneous high signal intensity on STIR sequences (yellow arrow). F Intraoperative X-rays confirm the needle and dilator targeted within the lesion (yellow arrow). The working cannula was well established (G). H Postoperative gross observation shows the incision appearance (yellow arrow: incision for endoscopic curettage, black arrow: incision for the autogenous iliac bone graft). I-J At the 9-month follow-up visit, a solid, bony union at the acetabulum without progression of the lesion was observed (yellow arrow), and histopathological results (hematoxylin and eosin, original magnification $40\times$) diagnosed the bone lesion as a degenerative cystic change. K-L At the 19-month follow-up visit, good bony union was observed at the right acetabulum, without progression of the lesion (yellow arrow). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

acetabulum, MIET may be considered a good choice that can prevent open wound-related complications and provide adequate surgical exposure to bone lesions. Furthermore, as a percutaneous minimally invasive technique, MIET has potential advantages associated with a minimal risk for cartilage injury caused by excessive curettage, even though some scholars suggest that endoscopic techniques may impair cartilage during tumor excision [28,29]. Indeed, early endoscopy-guided surgery may have had inherent disadvantages due to limitations with visualization and devices. In the current study, MIET permitted a minimally invasive surgical access portal to allow for curettage and grafting utilizing several instruments, such as scopes, curettes and rongeurs, and enabled the surgeon to make the necessary adjustments to ensure adequate visualization for lesion excision; thus, our results also suggest the important value of MIET in the treatment of symptomatic benign bone lesions, reducing the aggressiveness of treatment and its unavoidable complications.

4.3. The risk of lesion recurrence

Recognizing the issue of possible recurrence with intralesional curettage, numerous published medical studies have proposed that intralesional curettage combined with high-speed burring and pulse lavage or chemical treatment may improve the effectiveness of curettage, resulting in a relatively low rate of local recurrence, especially for aggressive benign bone tumors such as chondroblastomas and giant cell tumors of the bone (GCTB) [40,41]. In this work, we performed MIET using various angled curettes, rongeurs, and high-speed burring to

eliminate small pockets of the residual tumor in the cavity and reduce the likelihood of tumor recurrence. Moreover, MIET can provide proper direct exposure of the entire bone lesion with careful assessment of the adequacy of curettage and is thus associated with a low risk of recurrence. According to our experience, a detailed preoperative examination (i.e., X-rays, CT images and MRI) is helpful for precise planning of the surgical routes, which is important because the lesion area may be ignored during surgery, making it impossible to evaluate the sufficiency of lesion removal in the deeper area. Taken together, our results are consistent with the findings of previous studies reporting that the MIET is a safe treatment for benign bone tumors and is associated with a low recurrence rate and an improvement in satisfactory outcomes. Recently, Errani et al. [28] reported their experience with the treatment of chondroblastoma involving the knee joint and suggested that the application of MIET provides surgeons with direct visualization of the residual tumor. After 12 months of follow-up, no recurrence or malignant transformation was observed in any of the cases.

4.4. Limitations

Our results indicate only our practice of using MIET for the treatment of symptomatic benign bone lesions in a small population of Chinese patients. Some potential limitations must be acknowledged when interpreting the findings of this study. First, the lesions were heterogeneous (i.e., different lesion types, sizes, and locations). However, our primary goal was to demonstrate the short-term clinical feasibility and efficacy of MIET in the treatment of symptomatic benign

bone lesions. A higher level of evidence might be achieved by performing a prospective, multicenter trial in the future. Second, our current study does not constitute a comparative study, as no other minimally invasive techniques (e.g., PKP, PVP, and percutaneous thermal ablation) were performed due to the limited sample size. Because this study was not designed to establish the superiority of MIET compared to other minimally invasive techniques, studies with a larger sample size and longer follow-up should be performed to demonstrate that MIET is a safe and effective technique and to support this technique as an alternative for treating symptomatic benign bone lesions. Finally, this series probably underestimates recurrence rates because the lesions were small (1.9–4.6 cm); in addition, the majority of the lesions were enchondromas and degenerative cysts (21/34, 61.8%), and fewer lesions associated with high rates of recurrence were treated, such as chondroblastoma, GCTB and ABC. Follow-up was also limited, as these tumors are very slow-growing, which may again cause underestimation of recurrence and late pathological fractures. Regarding these issues, more randomized studies and long-term follow-up of the patients will be conducted to clarify the aforementioned results

5. Conclusions

In conclusion, our study suggests that a minimally invasive technique using endoscopic guidance is an effective and safe procedure for the treatment of symptomatic benign bone lesions. Our patients recovered without any major complications and achieved improved pain palliation as well as good functional recovery and quality of life. Nevertheless, further studies with a long-term follow-up period are necessary to validate our results.

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Author' contributions

MW and LX performed the studies, participated in collecting the data, and helped draft the manuscript. CZ and JL performed the data analysis, participated in the study design, and drafted the manuscript. ZD conceived of the study and participated in the study design and coordination. All authors read and approved the final manuscript.

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Appendix A. Supplementary data

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References

- X. Niu, H. Xu, C.Y. Inwards, Y. Li, Y. Ding, G.D. Letson, M.M. Bui, Primary bone tumors: epidemiologic comparison of 9200 patients treated at Beijing Ji Shui Tan Hospital, Beijing, China, With 10 165 patients at Mayo Clinic, Rochester, Minnesota, *Arch. Pathol. Lab. Med.* 139 (9) (2015) 1149–1155.
- J.M. Nogueira Drumond, Efficacy of the enneking staging system in relation to treating benign bone tumors and tumor-like bone lesions, *Rev. Bras. Ortop.* 45 (1) (2010) 46–52.
- P. Scheitza, M. Uhl, O. Hauschild, J. Zwillingmann, H. Bannasch, C. Kayser, N.P. Südkamp, G.W. Herget, Interobserver variability in the differential diagnosis of benign bone tumors and tumor-like lesions, *Rofo* 188 (5) (2016) 479–487.
- T.C. Kwee, J.M.H. de Klerk, M. Nix, B.G.F. Heggelman, S.V. Dubois, H.J.A. Adams, Benign bone conditions that may be FDG-avid and mimic malignancy, *Semin. Nucl. Med.* 47 (4) (2017) 322–351.
- A. Barile, F. Arrigoni, L. Zugaro, M. Zappia, R.L. Cazzato, J. Garnon, N. Ramamurthy, L. Brunese, A. Gangi, C. Masciocchi, Minimally invasive treatments of painful bone lesions: state of the art, *Med. Oncol.* 34 (4) (2017) 53.
- H. Fritzsche, K.D. Schaser, C. Hofbauer, Benign tumours and tumour-like lesions of the bone: General treatment principles, *Orthopade* 46 (6) (2017) 484–497.
- R.A. Reeves, M.C. DeWolf, P.J. Shaughnessy, J.B. Ames, E.R. Henderson, Use of minimally invasive spine surgical instruments for the treatment of bone tumors, *Expert Rev. Med. Devices* 14 (11) (2017) 881–890.
- M.H. Wu, L.F. Xiao, F.F. Yan, S.L. Chen, C. Zhang, J. Lei, Z.M. Deng, Use of percutaneous microwave ablation for the treatment of bone tumors: a retrospective study of clinical outcomes in 47 patients, *Cancer Imaging* 19 (1) (2019) 87.
- R.L. Cazzato, X. Buy, R.F. Grasso, G. Luppi, E. Faiella, C.C. Quattrocchi, F. Pantano, B. Beomonte Zobel, G. Tonini, D. Santini, J. Palussiere, Interventional Radiologist's perspective on the management of bone metastatic disease, *Eur. J. Surg. Oncol.* 41 (8) (2015) 967–974.
- M.P. Hartung, S.M. Tutton, E.J. Hohenwarter, D.M. King, J.C. Neilson, Safety and efficacy of minimally invasive acetabular stabilization for periacetabular metastatic disease with thermal ablation and augmented screw fixation, *J. Vasc. Interv. Radiol.* 27 (5) (2016) 682–688 e1.
- K. Yu, B. Liang, Y. Zheng, A. Exner, M. Kolios, T. Xu, D. Guo, X. Cai, Z. Wang, H. Ran, L. Chu, Z. Deng, PMMA-Fe3O4 for internal mechanical support and magnetic thermal ablation of bone tumors, *Theranostics* 9 (14) (2019) 4192–4207.
- M. Stangenberg, L. Viezens, S.O. Eicker, M. Mohme, K.C. Mende, M. Dreimann, Cervical vertebroplasty for osteolytic metastases as a minimally invasive therapeutic option in oncological surgery: outcome in 14 cases, *Neurosurg. Focus* 43 (2) (2017) E3.
- A.N. Hage, J.F.B. Chick, J.J. Gemmete, J.J. Grove, R.N. Srinivasa, Percutaneous radiofrequency ablation for the treatment of osteoid osteoma in children and adults: A comparative analysis in 92 patients, *Cardiovasc. Intervent. Radiol.* 41 (9) (2018) 1384–1390.
- A. Hamad, L. Vachtsevanos, A. Cattell, M. Ockendon, B. Balain, Minimally invasive spinal surgery for the management of symptomatic spinal metastasis, *Br. J. Neurosurg.* 31 (5) (2017) 526–530.
- J.D. Baal, J.S. Pai, W.C. Chen, G.B. Joseph, R.J. O'Donnell, T.M. Link, Factors associated with osteoid osteoma recurrence after CT-guided radiofrequency ablation, *J. Vasc. Interv. Radiol.* 30 (5) (2019) 744–751.
- L. Bahamonde, J. Catalan, Bone tumors around the knee: risks and benefits of arthroscopic procedures, *Arthroscopy* 22 (5) (2006) 558–564.
- H. Song, W. Hu, Z. Liu, Y. Hao, X. Zhang, Percutaneous endoscopic interlaminar discectomy of L5–S1 disc herniation: a comparison between intermittent endoscopy technique and full endoscopy technique, *J. Orthop. Surg. Res.* 12 (1) (2017) 162.
- J.-E. Kim, D.-J. Choi, M.-C. Kim, E.J. Park, Risk factors of postoperative spinal epidural hematoma after biportal endoscopic spinal surgery, *World Neurosurg.* 129 (2019) e324–e329.
- J.K. Shin, M.S. Youn, Y.J. Seong, T.S. Goh, J.S. Lee, Iatrogenic dural tear in endoscopic lumbar spinal surgery: full endoscopic dural suture repair (Youn's technique), *Eur. Spine J.* 27 (Suppl. 3) (2018) 544–548.
- C.H. Liu, W.L. Yeh, P.J. Tsai, K.F. Fan, H.W. Cheng, J.M. Chen, A novel implant removal technique by endoscopy, *J. Orthop. Surg. Res.* 13 (1) (2018) 74.
- M.S. Rosario, K. Hayashi, N. Yamamoto, A. Takeuchi, S. Miwa, Y. Taniguchi, H. Tsuchiya, Functional and radiological outcomes of a minimally invasive surgical approach to monostotic fibrous dysplasia, *World J. Surg. Oncol.* 15 (1) (2017) 1.
- P.K. Wu, C.F. Chen, C.M. Chen, S.W. Tsai, Y.C. Cheng, M.C. Chang, W.M. Chen, Grafting for bone defects after curettage of benign bone tumor - Analysis of factors influencing the bone healing, *J. Chin. Med. Assoc.* 81 (7) (2018) 643–648.
- H.W. Schreuder, E.U. Conrad 3rd, J.D. Bruckner, A.T. Howlett, L.S. Sorensen, Treatment of simple bone cysts in children with curettage and cryosurgery, *J. Pediatr. Orthop.* 17 (6) (1997) 814–820.
- H. Sadick, M. Huber, S.W. Perkins, H.H. Waters, G.S. Hamilton 3rd, A.G. O'Reilly, H.G. Gassner, Endoscopic forehead approach for minimally invasive benign tumor excisions, *JAMA Facial Plast. Surg.* 16 (5) (2014) 352–358.
- S.H. Tsai, H.H. Wu, C.Y. Cheng, C.M. Chen, Full endoscopic interlaminar approach for nerve root decompression of sacral metastatic tumor, *World Neurosurg.* 112 (2018) 57–63.
- H. Aiba, M. Kobayashi, Y. Waguri-Nagaya, H. Goto, J. Mizutani, S. Yamada, H. Okamoto, M. Nozaki, H. Mitsui, S. Miwa, M. Kobayashi, K. Endo, S. Saito, T. Goto, T. Otsuka, Treatment of simple bone cysts using endoscopic curettage: a case series analysis, *J. Orthop. Surg. Res.* 13 (1) (2018) 168.
- H. Aiba, M. Kobayashi, Y. Waguri-Nagaya, H. Goto, J. Mizutani, S. Yamada, H. Okamoto, M. Nozaki, H. Mitsui, S. Miwa, M. Kobayashi, K. Endo, S. Saito, T. Goto, T. Otsuka, Treatment of aneurysmal bone cysts using endoscopic curettage, *BMC Musculoskelet. Disord.* 19 (1) (2018) 268.
- C. Errani, F. Traina, M. Chehrassan, D. Donati, C. Faldini, Minimally invasive technique for curettage of chondroblastoma using endoscopic technique, *Eur. Rev. Med. Pharmacol. Sci.* 18 (22) (2014) 3394–3398.
- S.J. Stricker, Extraarticular endoscopic excision of femoral head chondroblastoma, *J. Pediatr. Orthop.* 15 (5) (1995) 578–581.
- K.H. Lu, Arthroscopic excision of juxta-articular giant-cell tumor arising from the patellar tendon sheath, *Arthroscopy* 20 (5) (2004) eE35–8.
- Y.-J. Liu, Y. Wang, Z.-L. Li, Z.-G. Wang, M. Wei, X. Cai, J. Xue, M. Zhou, H.-P. Li, J.-L. Zhu, The value of arthroscopic minimally invasive surgery in diagnosis and

- treatment of benign bone and joint tumors, *Zhonghua yi xue za zhi* 87 (11) (2007) 751–753.
- [32] M.H. Wu, L.F. Xiao, H.W. Liu, Z.Q. Yang, X.X. Liang, Y. Chen, J. Lei, Z.M. Deng, PET/CT-guided versus CT-guided percutaneous core biopsies in the diagnosis of bone tumors and tumor-like lesions: which is the better choice? *Cancer Imag.* 19 (1) (2019) 69.
- [33] W.F. Enneking, W. Dunham, M.C. Gebhardt, M. Malawar, D.J. Pritchard, A system for the functional evaluation of reconstructive procedures after surgical treatment of tumors of the musculoskeletal system, *Clin. Orthop. Relat. Res.* 286 (1993) 241–246.
- [34] P.I. Carvallo, A.M. Griffin, P.C. Ferguson, J.S. Wunder, Salvage of the proximal femur following pathological fractures involving benign bone tumors, *J. Surg. Oncol.* 112 (8) (2015) 846–852.
- [35] W.A. Ebeid, B.Z. Hasan, I.T. Badr, M.K. Mesregah, Functional and oncological outcome after treatment of chondroblastoma with intralesional curettage, *J. Pediatr. Orthop.* 39 (4) (2019) e312–e317.
- [36] A.D. Sung, M.E. Anderson, D. Zurakowski, F.J. Hornicek, M.C. Gebhardt, Unicameral bone cyst: a retrospective study of three surgical treatments, *Clin. Orthop. Relat. Res.* 466 (10) (2008) 2519–2526.
- [37] T.H. Lui, Endoscopic curettage and bone grafting of the enchondroma of the proximal phalanx of the great toe, *Foot Ankle Surg.* 21 (2) (2015) 137–141.
- [38] H.A. Farouk, M. Saladin, W.A. Senna, W. Ebeid, All-endoscopic management of benign bone lesions; a case series of 26 cases with minimum of 2 years follow-up, *SICOT-J.* 4 (2018) 50.
- [39] W. Miyamoto, M. Takao, Y. Yasui, S. Miki, T. Matsushita, Endoscopic surgery for symptomatic unicameral bone cyst of the proximal femur, *Arthrosc. Tech.* 2 (4) (2013) e467–e471.
- [40] M. Wu, K. Xu, Y. Xie, F. Yan, Z. Deng, J. Lei, L. Cai, Diagnostic and management options of osteoblastoma in the spine, *Med. Sci. Monit.* 25 (2019) 1362–1372.
- [41] C. Errani, P. Ruggieri, M.A. Asenzio, A. Toscano, S. Colangeli, E. Rimondi, G. Rossi, A. Longhi, M. Mercuri, Giant cell tumor of the extremity: A review of 349 cases from a single institution, *Cancer Treat. Rev.* 36 (1) (2010) 1–7.