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IDEAS AND INNOVATIONS
Experimental

A Novel Rat Model of Intramedullary Tibia Fracture Fixation Using Polyetheretherketone Threaded Rod

Zhe Jin, MD*
Yu Sun, MS*
Yuheng Guan, MS†
Guibo Yu, BS†

Background: The rat fracture fixation models have been widely adopted, but current implant designs suffer from operational difficulty, massive soft-tissue dissection, and radiological intervention. The authors developed a new tibia fracture-healing model using minor invasive intramedullary fixations with polyetheretherketone (PEEK) threaded rods, which have excellent x-ray translucency and no magnetic resonance artifact.
Methods: Tibia fractures of 6 adult male Sprague-Dawley rats were fixed with intramedullary PEEK threaded rods. X-ray examination was performed at 0, 4, and 8 weeks postoperatively. Histological analysis was conducted via hematoxylin-eosin staining of nondecalcified tissue sections.
Results: Radiological fracture healing was observed at 8 weeks postoperatively. Histology demonstrated fracture gap bridging and bone ingrowth adjacent to PEEK.
Conclusion: This innovative model is simple and effective, providing a new selection in future biomedical research. *(Plast Reconstr Surg Glob Open 2015;3:e417; doi: 10.1097/GOX.0000000000000386; Published online 11 June 2015.)*

The rat fracture fixation model is highly effective and time saving, having been widely adopted in biomedical research of musculoskeletal diseases, tissue engineering, and biomaterials.[1–6] As rat is better genetically defined than large animals, it allows detailed investigation of molecular mechanisms during fracture healing.[5,7,8] In combination with current imaging modalities designed for small animals, such as micro–computed tomography, magnetic resonance imaging, and positron emission tomography, researchers could also obtain accurate radiological data correlated with histological sections and continual noninvasive monitoring of in vivo cellular and tissue reactions.[9–14]

However, current fixation techniques for rat have severe drawbacks, such as high risk of infection, operational complexity, and massive tissue dissection.[5,9,15–18] Furthermore, involvement of metal materials leads to radiological artifact and interruption. Thus, there are several issues to consider in developing fracture models: (1) the model should exhibit biological healing process;(2) complication rates should be lowered by decreasing surgical time, tissue damage, and infection; and (3) nonmetallic,

*From the *Department of Joint Surgery and Sports Medicine, First Hospital of China Medical University, Shenyang, China; and †Department of Radiological Diagnosis and Interventional Treatment, First Hospital of China Medical University, Shenyang, China.*

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radiological intervention-free materials are favored. To the authors' knowledge, there still lacks a rat model meeting all above requirements.

The authors' purpose is to introduce a new rat model of tibia fracture fixation with polyetheretherketone (PEEK) threaded rod, combining the advantages of simple operation procedure, good tissue protection, and excellent translucency without radiological artifact.

MATERIALS AND METHODS

PEEK threaded rods were 2 mm in diameter and 100 mm in length with standard pitch (0.4 mm), which were, rinsed ultrasonically twice in 70% ethanol for 24 hours and underwent ethylene oxide sterilization (**see Fig. 1, Supplemental Digital Content 1**, which displays a PEEK threaded rod, ***http://links.lww.com/PRSGO/A101***). Experiment protocols were approved by the ethical committee at the authors' institution. Six skeletally mature male Sprague-Dawley rats (300–350 g) provided by the institutional animal center were kept in plastic cages (2 per cage) with free access to food and water, at constant room temperature with a 12-hour day/night cycle.

Before operation, animals received intraperitoneal injections of 50 mg/kg pentobarbital sodium (Merck, Darmstadt, Germany) for general anesthesia. The left hind leg was shaved and disinfected. A 3-cm longitudinal anteromedial skin incision was made to expose the left knee joint and tibia. The patella was released laterally, and a 2-mm diameter bone tunnel was drilled from proximal tibial plateau with a depth of 20 mm, followed by another reaming step with PEEK threaded rod (Fig. 1). The level of osteotomy was at the proximal third of tibia. After transverse osteotomy, a 20-mm PEEK threaded rod was inserted by a press-fit maneuver, and care was taken to ensure rigid fixation without extra bone damage (Fig. 1). Then, the wound was irrigated with normal saline, and the muscle fascia and skin were sutured interruptedly. Intraoperative lateral radiographs were obtained after wound closure using standard imaging module of an x-ray unit (Arcadis; Siemens, Muenchen, Germany). Postoperative plain films were obtained at 4 and 8 weeks to monitor healing status.

After 8 weeks, all animals were euthanized and bilateral legs were harvested without implant removal. Gross appearance was observed to exclude local infection or fracture nonunion. The samples were immersed in 10% buffered formalin for 48 hours, and then, longitudinal 30-μm sections were made from each specimen using hard-tissue slicing equipment (Exakt, Norderstedt, Germany). Sections were stained with hematoxylin and eosin to assess the general morphology at the fracture site. Images were taken using a digital microscope (Eclipse 80i; Nikon, Tokyo, Japan).

RESULTS

All animals returned to full weight bearing after 48 hours. There were no postoperative wound complications. Radiological fracture healing was

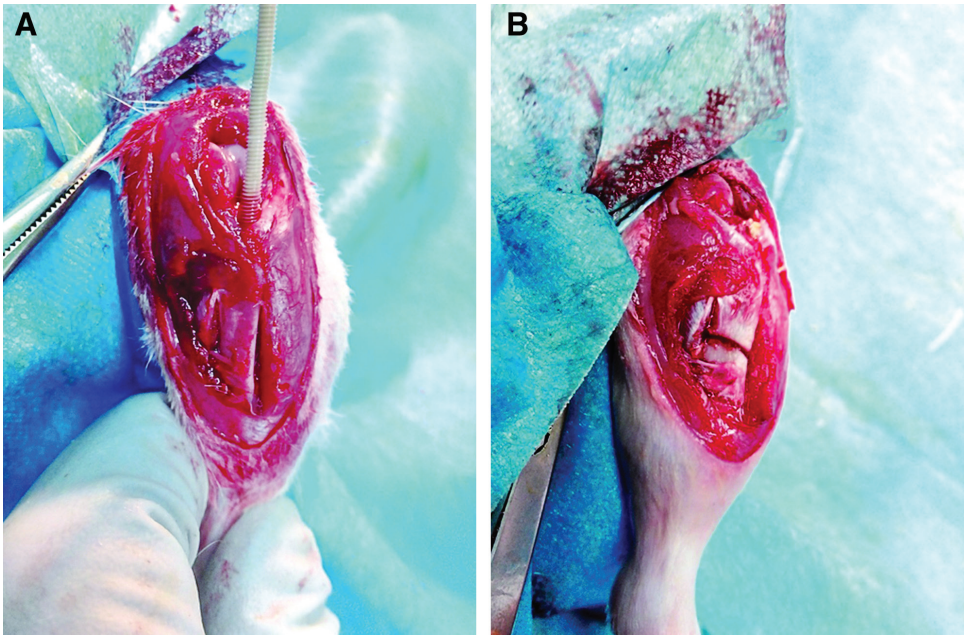

Fig. 1. A, Surgical procedure: bone tunnel reaming with PEEK threaded rod. B, Surgical procedure: fracture fixation with anatomical alignment and compression.

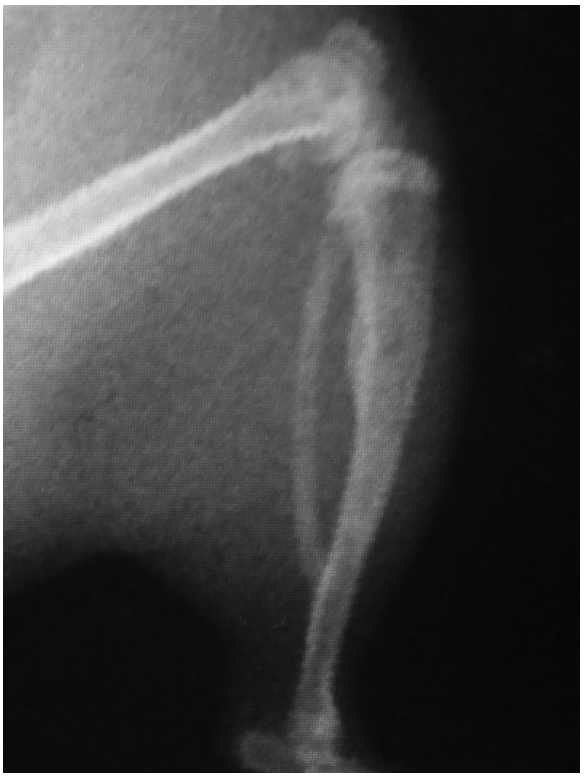

Fig. 2. Postoperative plain film at 8 weeks showing fracture healing.

achieved at 8 weeks (Fig. 2), with no visible continuous osteotomy line. Macroscopic examination of the specimen showed that the fracture ends were united by newly formed bone tissue, and qualitative morphological examination of hard-tissue sections revealed new bone ingrowth surrounding PEEK rods (Fig. 3) (**see Fig. 2, Supplemental Digital Content 2**, which displays a macroscopic examination, ***http://links.lww.com/PRSGO/A102***).

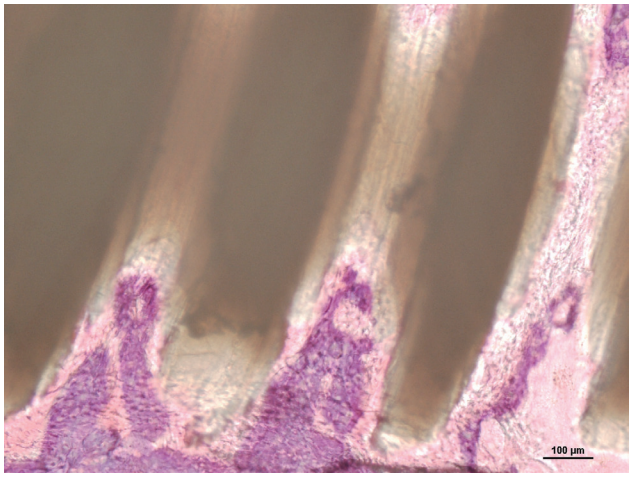

Fig. 3. Microscopic examination: bone ingrowth adjacent to PEEK threaded rod.

DISCUSSION

It has been reported that more than one third of animal fracture research in leading orthopedic journals used the rat model[19] but favored metal implants to radiological artifact and image interruption.[5,15,16,18,20] PEEK was demonstrated chemically stable and nontoxic in animal research, with excellent mechanical strength, ideal elastic modulus similar to cortical bone, and radiological translucency.[21,22] But previous PEEK plates developed for rat are used in combination with metal screws.

The authors machined thread on PEEK rods to provide press-fit compression fixation with good stability and used intramedullary implantation without excessive periosteal stripping to reduce infection risk and peripheral dissection. Future quantitative biomechanical and radiological analyses of this fixation technique in large animals are applicable to provide further information.

CONCLUSIONS

This study introduced a simple and effective intramedullary fixation model of rat fracture. Future application in combination with noninvasive imaging modalities will allow tracking soft tissue and bone cell activity in vivo and correlate the findings with histological results, providing useful information on early diagnosis of fracture nonunion and other disorders, such as inflammation, infection, and tumor recurrence.

Yu Sun
Department of Joint Surgery and Sports Medicine
First Hospital of China Medical University
155 Nan Jing Bei Street Heping District
Shenyang, China 110001
E-mail: sunyu@mail.cmu.edu.cn
sunyulovesit@163.com

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