NOTE *Surgery*

Treatment of a unicameral bone cyst in a dog using a customized titanium device

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ABSTRACT. A 4-year-old Shih-Tzu, referred for an enlarged left carpus, was diagnosed with a unicameral bone cyst. A customized titanium device was inserted into cystic lesion and fixed by titanium screws. Sufficient strength of the affected bone with the device inserted to maintain limb function was established after resection of contents of cystic lesion. There was no deterioration of the lesion of bone cyst, and acceptable function of the affected limb with no clinical signs of lameness was maintained during 36 months follow-up. The results of this study demonstrated that bone cyst curettage and use of a customized titanium device could provide an effective alternative treatment of huge lesion of unicameral bone cysts with the intent of preventing pathologic fractures.
KEY WORDS: bone cyst, canine, customized titanium device

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A bone cyst is an expansive lesion within the bone marrow cavity that gradually weakens the bone to the point of causing it to fracture [33]. Bone cysts are classified as either unicameral (simple) or aneurysmal. Unicameral bone cysts (UBCs) are benign fluid-filled lesions found in the metaphyseal or diaphyseal regions of long bones and are lined by a thin membrane [5]. In humans, they typically occur in the first two decades of life [5]. Affected dogs are typically less than 18 months of age [30]. Although the exact pathophysiology of UBCs is not well known, it has been theorized that they may be the result of trauma, hematoma formation, osteoclast hyperplasia or venous obstruction, resulting in fluid accumulation within the bone [10, 13, 26]. UBCs are clinically problematic due to the fact that they may result in repetitive pathologic fractures and skeletal deformities during growth of the lesion, because of their proximity to the physis [5]. Bone cysts, while frequently reported in humans, are relatively rare in dogs and other domestic animals [23]. In human medicine, treatment methods vary, each having its advantages and disadvantages in terms of frequency of cyst elimination and degree of invasiveness — no consistent position has been established as to their usefulness; this position is similar in veterinary medicine [5, 17].

A newly developed customized titanium device can, on the basis of 3-dimensional imaging data for joints and bone loss and by means of selective laser melting, be molded as a device that conforms to the site of bone loss [8, 35]. By carrying out selective laser melting, a technique used to prepare the surface and increase its bone affinity, a titanium device of high mechanical and morphological compatibility has been achieved [24]. This device has been shown to be effective for functional reconstruction of lost bone of various shapes; it has been shown to be particularly useful in human maxofacial reconstruction [8, 35]. However, as far as could be ascertained, use of customized titanium devices to treat UBCs has not yet been reported with either humans or domestic animals. This procedure could be employed for prosthesis of partially resected bone defect in cases of tumor treatment for functional limb sparing and has not yet used for huge lesion of UBCs to offer an alternative treatment method for UBCs. The present case report reviews the use of a customized titanium device to treat UBCs in order to prevent pathologic fractures and to provide and maintain limited function of the affected limb in a dog with the distal radial region.

A 4-year-old neutered male Shih Tzu (7.2 kg) was referred to the Fabre Animal Medical Center for an enlarged left carpus. General physical examination showed a body condition score of 5 out of 9 and was otherwise unremarkable [19]. No pain was detected upon palpation of the solid, indurated mass in the distal region of the left antebrachium. Orthopedic evaluation revealed a decreased range of motion in the left carpus. Neurological examination was unremarkable.

Hematologic and serum biochemical analyses variables were within the normal reference range provided. Radiographs of the left thoracic limb revealed enlargement of

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the carpus, thin cortical bone and radiolucent lesions in the medial metaphyseal region of the distal radius (Fig. 1). No periosteal reaction or soft tissue invasion was found. Thoracic radiographs revealed no indication of metastatic lesions. Fourteen days post admission, computed tomography and punch biopsy were performed. Non-contrast computed tomography sections revealed an expansive, radiolucent lesion in the medullary region of the carpus and the neck of the left radius, resulting in cortical thinning. No metastatic lesions were observed in the thoracic cavity. Punch biopsy, using a 4 mm biopsy trephine, was performed. The principal histopathological finding was reactive bone hyperplasia. Most of the bone trabeculae retained a regular arrangement and were well differentiated; no obvious indication of malignancy was observed (Fig. 2). Based on results of the additional diagnostic tests, inflammation, infection, trauma and malignancy were ruled out, and a diagnosis of unicameral bone cyst was made.

Computed tomographic data were used to build a stereolithography model of both thoracic limbs, from the elbow down to the digits. Using these models, a model of the bone-loss region formed by cyst excision was prepared, and the titanium device (100% titanium; designed and molded by Sagawa Printing Co., Ltd., Kyoto, Japan; surface treated by Chubu University) for filling the bone-loss region was designed [8, 24, 35]. A titanium device of high mechanical and morphological compatibility was created by means of selective laser melting, a technique used to prepare the surface and increase bone affinity, so that it conformed to the site of bone loss [8, 24, 35].

A subcutaneous dose of 0.5 mg/kg morphine and 0.05 mg/kg atropine sulfate was administered, and the dog was induced with isoflurane. A lateral surgical approach to the carpus was used. Curettage of the inner cortex of the cyst was performed using a high-speed bur, and tissue samples were submitted for histopathology. A screw-hole was drilled to enable the titanium device to be fixed to the lateral side of the distal radius, where there was remaining cortical bone; and a side-hole was drilled to encourage vascular invasion around the device. Reaming of the ilium was then carried out, and the cancellous and cortical bone samples collected were transplanted inside the titanium device. The device was then fixed to the cortical bone on the medial side of the radius with two 1.5-mm titanium cortical screws made at the time of designing the device. In order to increase fixation strength, a temporary trans-articular internal fixation was performed using a 5-mm-wide bone plate (Advanced Locking Plate System; Kyon Biotech AG, Zurich, Switzerland). The subcutaneous tissue was closed using 3-0 monofilament synthetic absorbable thread (PDS®; Johnson and Johnson, Inc., Tokyo, Japan) in a simple pattern, and the skin was closed by cross suturing using a 3-0 monofilament nylon thread (XX®; Alfresa Pharma Corp., Tokyo, Japan).

Histology of specimens collected during surgery from the inner wall of the cyst revealed hyperplastic bone. In addition, the cyst contents were composed of connective tissue containing abundant mucus. Neither sample revealed any indication of malignancy. Correct positioning of the implants was confirmed on postoperative radiographs (Fig. 2). A dorsal part of the bone cyst, which was not observed intraoperatively, was found to remain on the dorsal surface of the radius (Fig. 2).

The dog returned to full function by week 4, and no signs of lameness were seen during 36 months after surgery. Range of motion in carpal joint of the affected limb was slightly limited due to carpal enlargement. Temporary trans-articular plate was removed on Day 73. Follow-up radiographs over a period of 36 months revealed no signs of progression of bone lesion (Fig. 3). In addition, the cyst found on the dorsal surface of the radius immediately after surgery was resorbed.

Computed tomographic images 36 months postoperatively indicate no loosening of the device. Ill-defined borders between the device and cortical bone and suggesting growth of bone into the device can be seen (Fig. 4). There was no evidence of implant loosening or lysis around the screws.

Bone cysts are benign, tumor-like lesions of bone, resembling primary tumors. Unlike humans, bone cysts that are asymptomatic incidental findings on imaging studies were rarely reported, and clinical signs could often be secondary to progressive expansion of the cyst, at which time dogs present with lameness or enlargement of bone shape of the lesion, which may intensify to severe pain and swelling of surrounding soft tissue if a pathologic fracture is present [2, 4]. The differential diagnosis for this type of lesion includes inflammation, infection, trauma, neoplasia and bone cyst (aneurysmal and unicameral) [1, 15]. Clinical signs and diagnostic imaging methods are helpful in characterizing this type of lesion. However, due to the rarity of bone cysts in animals and the similarity to neoplastic lesions, histologic examination remains mandatory for a definitive diagnosis [1, 12].

The current case was similar to those previously reported, with the exception of age. Radiographic findings essential for diagnosis, including a radiolucent defect with cortical thinning and osseous expansion, were consistent with previous reports from canine veterinary practice [3, 33].

The goal of treatment is the prevention of pathological fracture and skeletal deformities during growth [6]. On the basis of previous reports, nonsurgical treatment of UBCs is considered in asymptomatic cases and includes exercise restriction, analgesic drug administration and coaptation, if a weight-bearing portion of a limb is involved [21]. In human medicine, treatment options include serial percutaneous injection of corticosteroid, autologous bone marrow transplantation, decompression with cannulated screws, intramedullary nailing, open curettage followed by bone grafting and the use of demineralized bone matrix as a graft material [5, 9, 17, 27, 29, 32, 34, 37].

Percutaneous injection of corticosteroids has been reported to have success rates ranging from 50 to 90% [4, 29, 32]. While it is a relatively simple procedure with low morbidity, typically several attempts are necessary to achieve consolidation of the cyst, while a 24% healing rate was reported with a single injection [36]. There has been only one report of similar treatment used in veterinary practice, and in that case, the cystic lesion was remodeled successfully 14 months

Fig. 1. Preoperative radiograph.

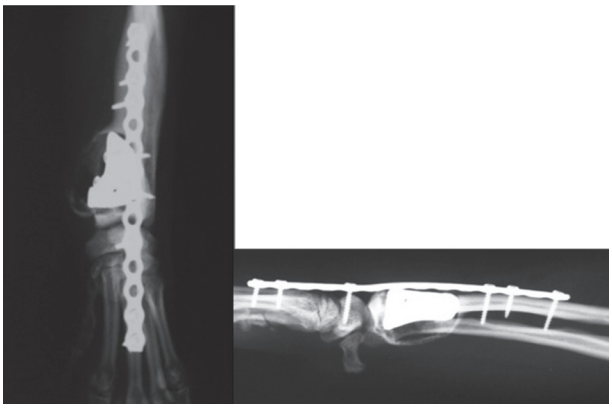

Fig. 2. Postoperative radiograph.

Fig. 3. Follow up radiographs at 36 months postoperatively.

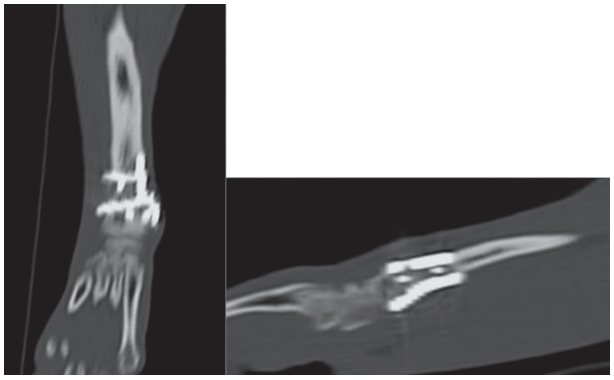

Fig. 4. CT at 36 months postoperatively.

following treatment [22].

Surgical treatment of unicameral bone cysts involves curettage of the cyst lining and filling the cavity with grafted bone [2, 33]. Autologous bone grafts are routinely used, although demineralized bone matrix, bone marrow mononuclear cells and deprotonated bovine cancellous xenografts have recently been used in conjunction with autologous cancellous bone grafts in dogs [5, 11, 18, 36].

The primary consideration in evaluating treatment options in this case was prevention of pathologic fractures. Time to heal was a factor in the consideration of implementing repeated steroid injections due to the lengthy time to recovery reported previously [22]. In addition, the bone cyst in the present case occurred in the radius, which is a load-bearing bone. Treatment solely using post-curettage autologous cancellous bone-grafting was expected to have high probability of fractures due to marked bone loss following cyst resection, resulting in loss of bone strength. The goal of treatment in this case was to establish a spontaneous cure by stimulating osteogenic activity via surgical removal of the wall lining the inner aspect of the cyst. Due to the size of the cyst, ordinary forms of treatment were believed to be less sufficient to prevent possible pathological fractures. If temporary trans-articular internal fixation is implemented, consideration must still be given to the possibility of plate breakage at the bone loss area. An osteoprosthesis method using a titanium implant, as well as curettage of the inner cortex of the cyst, was employed as treatment.

In this case, the customized titanium device that was prepared to fit the bone-loss region formed by curettage of the bone cyst readily fitted to this area. When the device was inserted and fixed to the remaining radial bone using bone forceps, the correct device positioning was achieved readily. This is considered to be a characteristic advantage of the customized titanium device that is adapted in accordance with individual bone-loss regions using selective laser melting. In this case, concomitant internal fixation also enabled early weight bearing of the affected limb, as expected. The authors believe the strength of the bone with the device inserted was also maintained after bone cyst resection, and osteoplasty was achieved as an additional outcome. Furthermore, no recurrence of the bone cyst was observed, and favorable functioning was maintained during the 28 months of follow up.

From these results, we believe that bone cyst curettage and use of a customized titanium device show promise as an effective treatment of unicameral bone cysts with the intent of preventing pathologic fractures and, as such, warrant

further investigation. This treatment could have maintained sufficient limb function as well as halting progression of the bone cyst in a dog with expansive UBCs.

There is also a potential for additional applications of this technique. Asympomatic unicameral bone cysts also occur in metaphyses close to articular surfaces, an area where reconstruction may not be possible, and the only possible treatment includes relief measures, such as amputation or arthrodesis [7]. It is therefore suggested that, even when the condition is asymptomatic, treatment with a customized titanium device in order to prevent pathologic fractures may increase the probability of conserving the affected limb and maintaining its function. The other type of bone cysts, aneurysmal bone cysts, is considered to have poorer prognoses than UBCs, due to a more marked local invasion, more pathologic fractures and a higher post-resection recurrence rate [14, 16, 28]. Therefore, amputation or euthanasia is more frequently selected for these cases [20, 25, 31]. Treatment using a customized titanium device is considered to be effective even with bone loss due to wide-area bone cyst resection and may be applicable even to aneurysmal bone cysts that require vigorous resection. Furthermore, customized titanium devices can be made to fit bone-loss regions of any physical shape, suggesting the potential for their application to bone loss in long bones, which may develop as a result of high-energy injuries or bone tumors and with which reconstruction is currently considered to be difficult.

As the number of veterinary cases increases, further investigation of treatment methods and long-term prognoses for unicameral bone cysts will be needed. It is suggested that this treatment option also be evaluated for the treatment of aneurysmal bone cysts.

REFERENCES

1. Benamou, J., Lussier, B. and Alexander, K. 2012. Use of magnetic resonance imaging and histopathologic findings for diagnosis of an aneurismal bone cyst in the scapula of a cat. *J. Am. Vet. Med. Assoc.* **240**: 69–74. [Medline] [CrossRef]
2. Brady, M. A., Robertson, H. M. and Alsup, J. C. 1998. What is your diagnosis? Simple bone cyst in a dog. *J. Am. Vet. Med. Assoc.* **213**: 957–958. [Medline]
3. Burk, R. L. and Ackerman, N. 1996. pp. 467–468. *In*: Small Animal Radiology and Ultrasonography. W.B.Saunders Company, Philadelphia.
4. Chang, C. H., Stanton, R. P. and Glutting, J. 2002. Unicameral bone cysts treated by injection of bone marrow or methylprednisolone. *J. Bone Joint Surg. Br.* **84**: 407–412. [Medline] [CrossRef]
5. Cho, H. S., Seo, S. H. and Park, S. H. 2012. Minimal invasive surgery for unicameral bone cyst using demineralized bone matrix: a case series. *BMC Musculoskelet. Disord.* **13**: 134. [Medline] [CrossRef]
6. Cho, H. S., Oh, J. H. and Kim, H. S. 2007. Unicameral bone cysts: a comparison of injection of steroid and grafting with autologous bone marrow. *J. Bone Joint Surg. Br.* **89**: 222–226. [Medline] [CrossRef]
7. Choate, C. J. and Arnold, G. A. 2011. Elbow arthrodesis following a pathological fracture in a dog with bilateral humeral bone cysts. *Vet. Comp. Orthop. Traumatol.* **24**: 398–401. [Medline] [CrossRef]
8. Ciocca, L., Fantini, M. and De Crescenzio, F. 2011. Direct metal laser sintering (DMLS) of a customized titanium mesh for prosthetically guided bone regeneration of atrophic maxillary arches. *Med. Biol. Eng. Comput.* **49**: 1347–1352. [Medline] [CrossRef]
9. Cohen, J. 2001. Intramedullary nailing for the treatment of unicameral bone cysts. *J. Bone Joint Surg. Am.* **83-A**: 1279–1280. [Medline]
10. Copete, M. A., Kawamata, A. and Langlais, R. P. 1998. Solitary bone cyst of the jaws: Radiographic review of 44 cases. *Oral Surg. Oral Med. Oral Pathol. Oral Radiol. Endod.* **85**: 221–225. [Medline] [CrossRef]
11. Crovace, A., Fabia, A. and Lactignola, L. 2008. Use of autologous bone marrow mononuclear cells and cultured bone marrow stromal cells in dogs with orthopedic lesions. *Vet. Res. Commun.* **32** Suppl. 1: S39–S44. [Medline] [CrossRef]
12. Degner, D. A. Bone Cysts in Dogs. *In*: Veterinary Surgery Central. (cited on 2013 July 15). Available from: http://www.vetsurgerycentral.com/oncology_bone_cyst.htm.
13. Dueland, R. T. and VanEnkevort, B. 1995. Lateral tibial head buttress plate: use in a pathological femoral fracture secondary to a bone cyst in a dog. *V.C.O.T.* **4**: 31–34.
14. Gibbs, C. P., Hefele, M. C. and Peabody, T. D. 1999. Anuerysmal bone cyst of the extremities. Factors related to local recurrence after curettage with a high-speed burr. *J. Bone Joint Surg. Am.* **81**: 1671–1678. [Medline]
15. Heatley, J. J., Tully, T. N. and Mitchell, M. A. 2004. Trauma-induced aneurismal bone cysts in two psittacine species (Cacutua alba and Nymphicus hollandicus). *J. Zoo Wildl. Med.* **35**: 185–196. [Medline] [CrossRef]
16. Hemmadi, S. S. and Cole, W. G. 1999. Treatment of aneurismal bone cysts with saucerization. *J. Pediatr. Orthop.* **19**: 540–542. [Medline] [CrossRef]
17. Hou, H. Y., Wu, K., Wang, C. T. and Chang, S. M. 2010. Treatment of unicameral bone cyst: a comparative study of selected techniques. *J. Bone Joint Surg. Am.* **92**: 855–862. [Medline] [CrossRef]
18. Innes, J. F. and Myint, P. 2010. Demineralized bone matrix in veterinary orthopedics: A review. *Vet. Comp. Orthop. Traumatol.* **23**: 393–399. [Medline] [CrossRef]
19. Laflamme, D. P. 1997. Development and validation of a body condition score system for dogs. *Canine Pract.* **22**: 10–15.
20. Liu, S. K., Dorfman, H. D. and Patnaik, A. K. 1974. Primary and secondary bone tumours in the cat. *J. Small Anim. Pract.* **15**: 141–156. [Medline] [CrossRef]
21. MacInnes, T. J., Thompson, M. S. and Lewis, D. D. 2005. What is your diagnosis? Benign bone cysts? *J. Am. Vet. Med. Assoc.* **227**: 1561–1562. [Medline] [CrossRef]
22. Miura, N., Fujiki, M. and Miyoshi, Y. 2003. Steroid injection therapy in a feline solitary bone cyst. *J. Vet. Med. Sci.* **65**: 523–525. [Medline] [CrossRef]
23. Palmer, N. 1992. p. 138. *In*: Pathology of Domestic Animals, vol. 1, 4th ed. (Jubb, K. V. F., Kennedy, P. C. and Palmer, N. eds.), Academic Press, New York.
24. Pattanayak, D. K., Fukuda, A. and Matsushita, T. 2011. Bioactive Ti metal analogous to human cancellouse bone: Fabrication by selective laser melting and chemical treatments. *Acta Biomater.* **7**: 1398–1406. [Medline] [CrossRef]
25. Pernell, R. T., Dunstan, R. W. and DeCamp, C. E. 1992. Anuerysmal bone cyst in a six-month-old dog. *J. Am. Vet. Med. Assoc.* **201**: 1897–1899. [Medline]
26. Resnick, D., Kyriakos, M. and Guerdon, D. 1995. Tumors and tumor-like lesions of bone: imaging and pathology of specific

lesions. pp. 3559–3576. *In*: Diagnosis of Bone and Joint Disorders. 3rd ed. (Resinick, D. ed.), WB Saunders Co., Philadelphia.
27. Roposch, A., Saraph, V. and Linhart, W. E. 2000. Flexible intramedullary nailing for the treatment of unicameral bone cysts in long bones. *J. Bone Joint Surg. Am.* **82-A**: 1447–1453. [Medline]
28. Sarierler, M., Cullu, E. and Yurekli, Y. 2004. Bone cement treatment for aneurysmal bone cyst in a dog. *J. Vet. Med. Sci.* **66**: 1137–1142. [Medline] [CrossRef]
29. Scaglietti, O., Marchetti, P. G. and Bartolozzi, P. 1979. The effects of methylprednisolone acetate in the treatment of bone cysts. Results of three years follow-up. *J. Bone Joint Surg. Br.* **61-B**: 200–204. [Medline]
30. Schrader, S. C., Burk, R. L. and Lin, S. 1983. Bone cysts in two dogs and a review of similar cystic bone lesions in the dog. *J. Am. Vet. Med. Assoc.* **182**: 490–495. [Medline]
31. Shimada, A., Yanagida, M. and Umemura, T. 1996. Anuerysmal bone cyst in a dog. *J. Vet. Med. Sci.* **58**: 1037–1038. [Medline] [CrossRef]
32. Spence, K. F. Jr., Bright, R. W. and Fitzgerald, S. P. 1976. Solitary unicameral bone cyst: treatment with freeze-dried crushed cortical-bone allograft. A review of one hundred and forty-four cases. *J. Bone Joint Surg. Am.* **58**: 636–641. [Medline]
33. Stickle, R., Flo, G. and Render, J. 1999. Radiographic diagnosis: Benign bone cyst. *Vet. Radiol. Ultrasound* **40**: 365–366. [Medline] [CrossRef]
34. Tsuchiya, H., Abdel-Wanis, M. E. and Uehara, K. 2002. Cannulation of simple bone cysts. *J. Bone Joint Surg. Br.* **84**: 245–248. [Medline] [CrossRef]
35. Wang, G., Li, J. and Khadka, A. 2012. CAD/CAM and rapid prototyped titanium for reconstruction of ramus defect and condylar fracture caused by mandibular reduction. *Oral Surg. Oral Med. Oral Pathol. Oral Radiol.* **113**: 356–361. [Medline] [CrossRef]
36. Worth, A. J., Thompson, K. G. and Owen, M. C. 2007. Combined xeno/auto grafting of osteolytic lesion in a dog, using a novel bovine cancellous bone biomaterial. *N. Z. Vet. J.* **55**: 143–148. [Medline] [CrossRef]
37. Wright, J. G., Yandow, S., Donaldson, S. and Marley, L. 2008. A randomized clinical trial comparing intralesional bone marrow and steroid injections for simple bone cysts. *J. Bone Joint Surg. Am.* **90**: 722–730. [Medline] [CrossRef]