

# Computed tomographic features and surgical treatment of equine mandibular aneurysmal bone cysts with $\beta$ -tricalcium phosphate in a multicenter case series

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## OBJECTIVE

To describe clinical and imaging features and surgical treatment of equine mandibular aneurysmal bone cysts (ABCs) with  $\beta$ -tricalcium phosphate (TCP).

## ANIMALS

3 horses (cases 1, 2, and 3) and 1 pony (case 4) with histologically confirmed ABC.

## CLINICAL PRESENTATION

All cases had mandibular swelling with intact adjacent skin. Cases 1 to 3 had a body condition score of 3/5 and case 4 had 2/5 and showed quidding during mastication and, at oral examination, large interdental spaces and loose elements adjacent to the swelling. Radiography or CT was performed in all cases. In cases 1, 3, and 4, an expansile septate cystic space-occupying lesion with mass effect on the adjacent cortices and teeth was seen without compact bone destruction. Case 2 showed a heterogeneous osteolytic mass with multifocal cortical lysis and interruption. Case 4 had severe dental abnormalities of deciduous and precursors of permanent teeth. ABCs were surgically treated and filled with only TCP (case 3) or in combination with autologous bone marrow (cases 1, 2, and 4).

## RESULTS

Cases 1 through 3 showed an uneventful reduction in ABC size with increased opacity/attenuation. In case 4, a surgical site infection occurred. After removal of TCP remnants, the ABC healed satisfactorily, but remaining dental abnormalities necessitated dietary adjustments to maintain an acceptable body condition score.

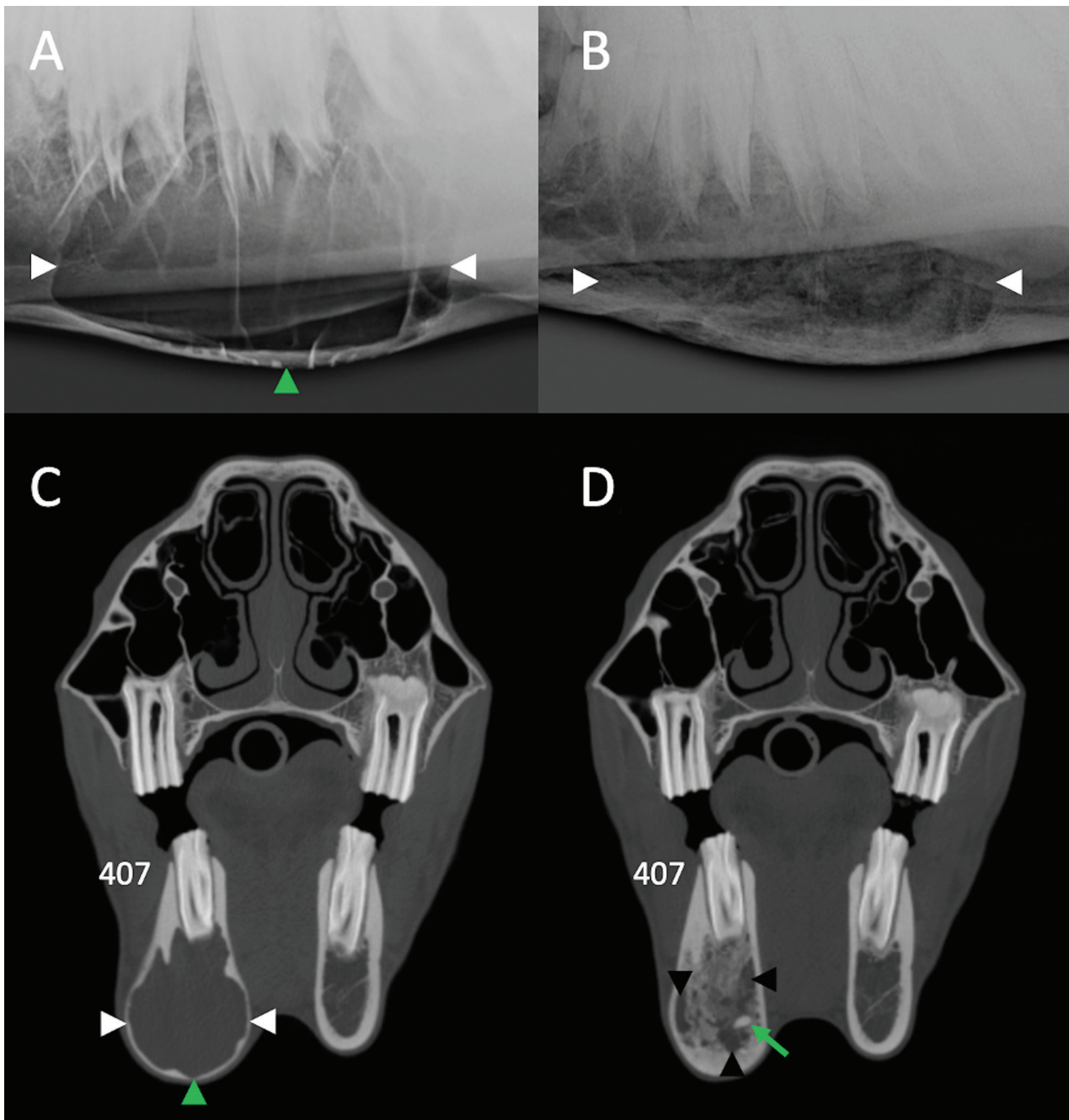
## CLINICAL RELEVANCE

Treatment of ABCs with TCP had a favorable outcome and good long-term prognosis. In young specimens, the expansile effect on the development and eruption of neighboring teeth can influence and determine final functionality of the diseased dental quadrant.

**A**neurysmal bone cysts (ABCs) are encountered in humans and animals alike and are classified by appearance and development.<sup>1</sup> They are believed to be benign; however, they can be locally destructive due to their expansile nature<sup>2</sup> and appear as osteolytic, multilocular lesions, surrounded by a thin periosteum. The lesions can have solid areas but in general consist of multiple blood-filled cavities divided by septa. The septa are made of loosely arranged spindle cells that contain hemosiderin-containing macrophages and multinucleate giant cells. Radiographically, these septa

give the lesion a soap-bubble appearance (**Figure 1**).<sup>3,4</sup> Although their clinical appearance is typical, only histopathological examination of biopsies allows for the definite diagnosis of an ABC.<sup>1</sup> ABCs are believed to develop from disturbances in the vasculature of bone marrow.<sup>5</sup> They can be congenital or the result of a pre-existing bone lesion (eg, trauma, neoplasia, hematoma, or fracture).<sup>5,6</sup>

Equine ABCs are rare, and in recent decades, only 17 cases have been reported. In 9 cases, the localization varied; 6 were reported in long bones, of which



**Figure 1**—Presurgical (A and C) and 6-month postsurgical (B and D) oblique radiographs and transverse CT images of case 1 at the level of the aneurysmal bone cyst (ABC) of the right mandible. Left ventral right dorsal oblique radiographs are shown and rostral is to the left of the radiographs. The transverse CT images are all in bone settings at the level of element 407, and left is to the right of the CT images. A—Oblique radiograph performed before surgery. There is a particularly well-defined area of geographic osteolysis (between white and green arrowheads) showing multiple osseous septa as a soap-bubble appearance, ventral to elements 407, 408, and 409. Also note the marked thinning and ventral deviation of the right mandibular cortex caused by mass effect from the ABC (green arrowhead). Blunting and shortening of the roots of elements 407 and 408 is also suspected. B—Oblique radiograph performed 6 months after surgery. Note the decreased volume; heterogeneous increased mineral opacity of the lesion, which is now more ill defined (white arrowheads); and the improvement of the ventral deviation and thinning of the mandibular cortex. C—Transverse CT image performed before surgery. Note the increased volume and abnormal shape of the right mandible with thinning and lateral and ventral deviation of the mandibular cortex caused by mass effect from the ABC (white and green arrowheads). Also note the blunting and shortening of the roots of element 407 when compared with the other side. D—Transverse CT image performed 6 months after surgery. Note the decreased volume and heterogeneous increased mineral attenuation of the lesion. Also note the multiple areas of lesser attenuation (black arrowheads) and small well-defined mineral focus (green arrow) that was not present before surgery. The most ventral area of decreased attenuation (most ventral black arrowhead) has a fluid attenuation.

3 were in the metatarsus,<sup>3,6,7</sup> 1 in the radius,<sup>8</sup> and 2 in the metacarpus.<sup>9,10</sup> Three were located in the maxilla and/or premaxilla.<sup>11,12</sup> The other 8 ABCs occurred in the most common location: the mandible.<sup>4,13–18</sup>

Treatment of mandibular ABCs generally consists of surgical curettage and flushing.<sup>15,16</sup> In addition to curettage and flushing, some report packing the cyst with povidone-iodine gauze or placing cancellous or corticocancellous bone grafts.<sup>13–16</sup> More recently, a combination of an autogenous bone graft with a nonresorbable collagen-hydroxyapatite (CHA) was used in one horse<sup>4</sup> and percutaneous doxycycline sclerotherapy in another.<sup>18</sup> The aims of this case series were to describe clinical and imaging features of 4 horses with a histologically confirmed diagnosis of ABC and the use of bioresorbable and osteoconductive  $\beta$ -tricalcium phosphate (TCP), until now only evaluated in horses in experimental orthopedic models,<sup>19–21</sup> as a treatment and to evaluate the long-term evolution of these ABCs after surgical treatment.

## Methods

### General case description

Case records from 2009 to 2021 were reviewed, and those with a histologically confirmed diagnosis of ABC and that were treated with TCP were included. This resulted in 4 cases from 3 different equine referral hospitals. Case 1 was from a private clinic in the Netherlands; cases 2 and 3 were from the Vetsuisse Faculty, University of Zurich, Switzerland; and case 4 was from the Faculty of Veterinary Medicine, Utrecht University, The Netherlands. Follow-up varied and for cases 1, 2, 3, and 4 was 28 months, 8 months, 2 months, and 48 months, respectively. Within this postoperative period, repetitive clinical (all), radiographic (case 2), and CT (cases 1, 3, and 4) examinations were recorded.

## Results

### Case 1

A 9-year-old Dutch Warmblood mare was referred with a large, hard, slightly painful swelling approximately 20 X 6 X 8 cm (length-width-height [LWH]), halfway from the right mandible. The swelling was first noticed 9 months earlier and grew slowly. Previous treatment by the referring veterinarian with antimicrobials and nonsteroidal anti-inflammatory substances (drugs and dosages unknown) had no effect. At referral, the horse was bright and alert and had a body condition score (BCS) of 3/5.<sup>22</sup> Radiography showed an ovoid area of geographic lysis with multiple osseous septa ventral to elements 407, 408, and 409 (Figure 1). There was also thinning and ventral and lateral deviation of the adjacent mandibular cortex and suspicion of blunting and shortening of the roots of teeth 407 and 408. CT (4-slice helical scanner; Philips Medical Systems; scanning parameters were 120 kVp, 250 mA, 1.3-mm slice thickness, 0.6-mm reconstruction interval, matrix size of 512 X 512 pixels, and field of view of 500 mm) under general

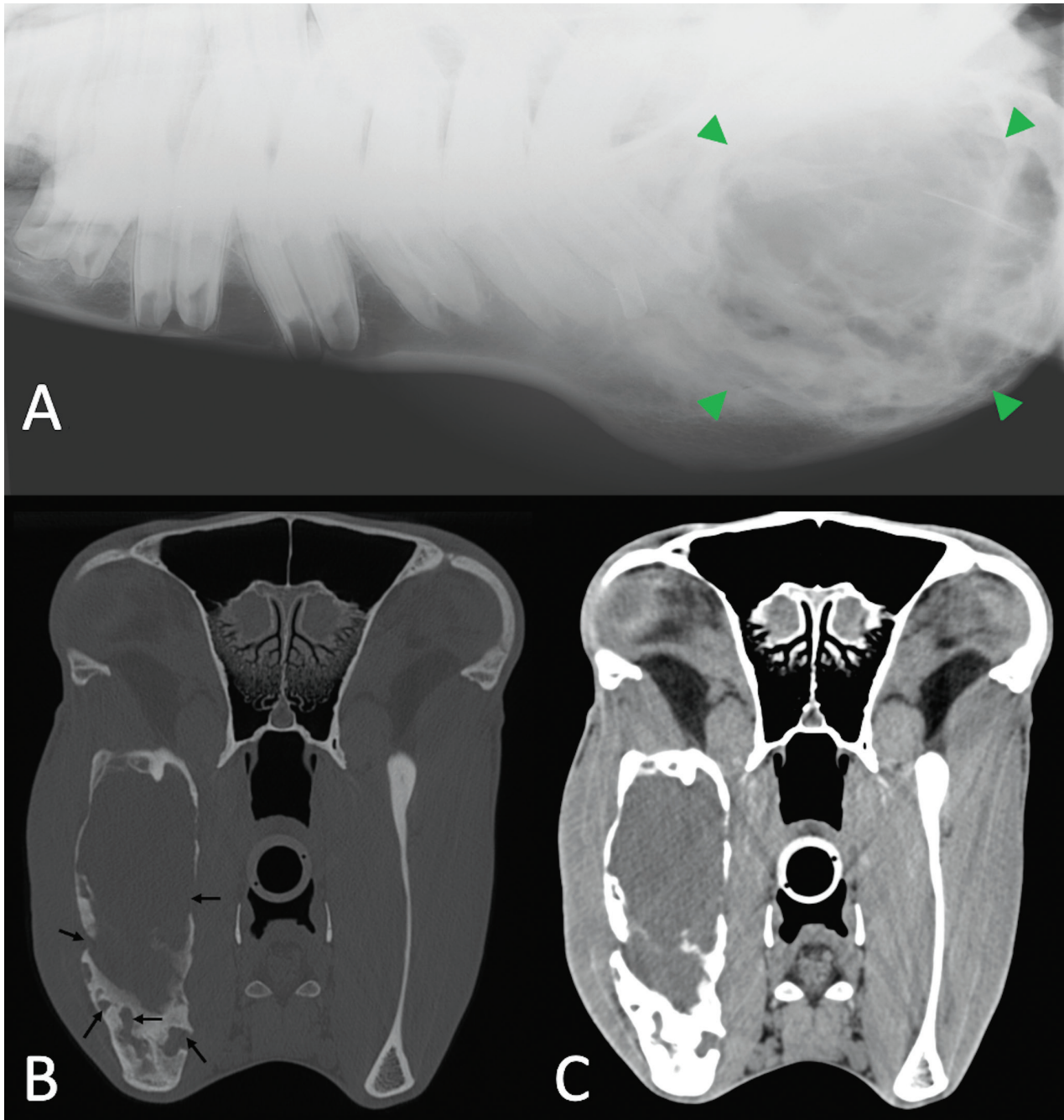
anesthesia confirmed the radiographic findings and showed a well-defined expansile ovoid fluid-attenuating (5 to 10 HU) mass (LWH, 25 X 6 X 9 cm) with slightly undulating margins. There was blunting and shortening of the roots of the adjacent elements 407 and 408 (Figure 1) but the pulp cavities of these elements were unremarkable. Thin osseous septa were visible mostly at the periphery of the mass. The cortical bone was not interrupted, and there was no evidence of new bone formation adjacent to the lesion. The mass involved the region of the mandibular canal and mental foramen. On the basis of these findings, a tentative diagnosis of ABC was made and surgical treatment was planned. Preoperatively, benzylpenicillin sodium (30,000 IU/kg) and flunixin meglumine (1.1 mg/kg) were given IV. Surgery was performed in dorsal recumbency under general anesthesia after aseptic preparation. The ABC was opened rostrally and caudally with a Galt trephine, and samples were taken for histology. The cyst was curetted and flushed with saline. At the same time, 80 mL of bone marrow was harvested from the sternum and tuber coxae. A mixture of the bone marrow with 20 mL of TCP (2.8 to 5.6 mm; chronOS Bone Void Filler; DePuy Synthes) was applied to fill the ABC. Both openings were sutured in 3 layers, and a stent was applied and removed after 3 days. Histology results confirmed an ABC. Postoperatively, phenylbutazone (4.4 mg/kg, PO, q 24 h) and procaine penicillin (20 mg/kg, IM, q 24 h) were given for 6 days followed by sulfadiazine/trimethoprim (30 mg/kg, PO, q 12 h) for 7 days. Recovery and incision healing after surgery were uneventful. Six months after surgery, the swelling clinically decreased and was not painful anymore. Radiographic and CT examinations showed increased opacity/attenuation (550 HU vs 5 to 10 HU before surgery) of the ABC containing heterogeneous mineral opacity/attenuation (Figure 1). Only a small ovoid area of fluid attenuation (2 cm diameter) remained unchanged (Figure 1). This area was at the central to ventral aspect of the initial ABC. There was reduction of the size of the lesion (width of the mandible up to 5.7 cm). There was similar blunting and shortening of the roots of elements 407 and 408. There were also multiple small mineral areas (up to 8 mm) visible in the soft tissues adjacent to the lesion. At 24 months after surgery, the horse had no clinical complaints related to the ABC and a CT showed further mild reduction of the size of the lesion (width of the mandible up to 4.9 cm) with similar mineral attenuation within the ABC except for a similar central ovoid fluid-attenuating area. There were similar changes of the roots of elements 407 and 408. The mineral areas of the adjacent soft tissues resolved. At the last clinical examination, 28 months after surgery, the reduced size of the mandible was stable and the cosmetic appearance was considered good.

### Case 2

A 6-year-old Icelandic horse gelding was referred with hard, nonpainful swelling of 12 X 10 X 8 cm (LWH) at the caudal aspect of the right mandible. The swelling that was first noticed 3 months

earlier slowly increased in size. No previous medical treatment was reported. At referral, the horse was bright and alert and had a BCS of 3/5.<sup>22</sup> Radiography showed an area of heterogeneous osteolysis of the angle and ramus of the right mandible. This area was surrounded by more heterogeneous bone opacity

showing a mix of increased and decreased opacity (**Figure 2**). CT (16-slice Multi Detector Somatom Sensation Open CT scanner; Siemens; scanning parameters were 140 kVp, 250 mA, 1.5-mm slice thickness, 0.8-mm reconstruction interval, matrix size of 512 X 512 pixels, and field of view of 500 mm) under general anesthe-



**Figure 2**—Oblique radiograph and transverse CT images of case 2 at the level of the ABC of the right mandibular angle and body. A—Oblique radiograph of the right mandible. There is a large, round area of heterogeneous osteolysis mixed with areas of increased opacity (green arrowheads) at the angle to the body of the right mandible. B—CT image in bone reconstruction and window. There is marked increased volume and abnormal shape of the right mandible with a mix of irregular thinning and widening of the cortex of the mandible caused by mass effect from the ABC. There are also multiple cortical interruptions and areas of osteolysis of the cortex (black arrows) that are of different size and shape. This appearance is atypical for a benign lesion such as an ABC. C—CT image in soft tissue reconstruction and window at the same level as the image displayed in panel B. Note the thick fluid attenuation of the lesion (mean attenuation value is approx 15 HU), which is lower than the adjacent musculature but higher than the retrobulbar fat.

sia confirmed these findings and showed an expansile ovoid fluid-attenuating (10 to 15 HU) mass (LWH, 13 X 5 X 10 cm) with undulating margins and multiple rather ill-defined and heterogeneous osseous septa. There were multiple rounded areas of cortical lysis and interruption surrounding the lesion (Figure 2). There were also multiple areas of heterogeneous periosteal new bone formation surrounding the lesion and enlargement of the periodontal space of element 411. The mass was involving the region of the mandibular canal and mandibular foramen. An ABC was suspected on the basis of these findings, and surgery was performed under general anesthesia in left lateral recumbency. Surgical areas were aseptically prepared, the ABC was opened with a hammer and chisel via a single opening, and histology samples were taken. The lesion was curetted, flushed with diluted chlorhexidine (0.05%), and filled with a mixture of 20 to 30 mL of bone marrow harvested from the sternum and tuber coxae and 30 mL of TCP (1.4 to 2.8 mm; chronOS Bone Void Filler; DePuy Synthes). The incision was closed in 3 layers. A stent was applied and removed after 3 days. Histology confirmed an ABC. Peri- and postoperative cefquinome (1 mg/kg, IV, q 24 h) and phenylbutazone (2.2 mg/kg, PO, q 24 h) were given for 6 days. The horse made an uneventful recovery with primary closure of the incision. Eight months after surgery, the swelling of the right caudal mandible was reduced and the horse was clinically normal with no problems of mastication reported. Radiography showed a decrease in size with an increased opacity and a more homogeneous aspect of the lesion. No postoperative CT was performed.

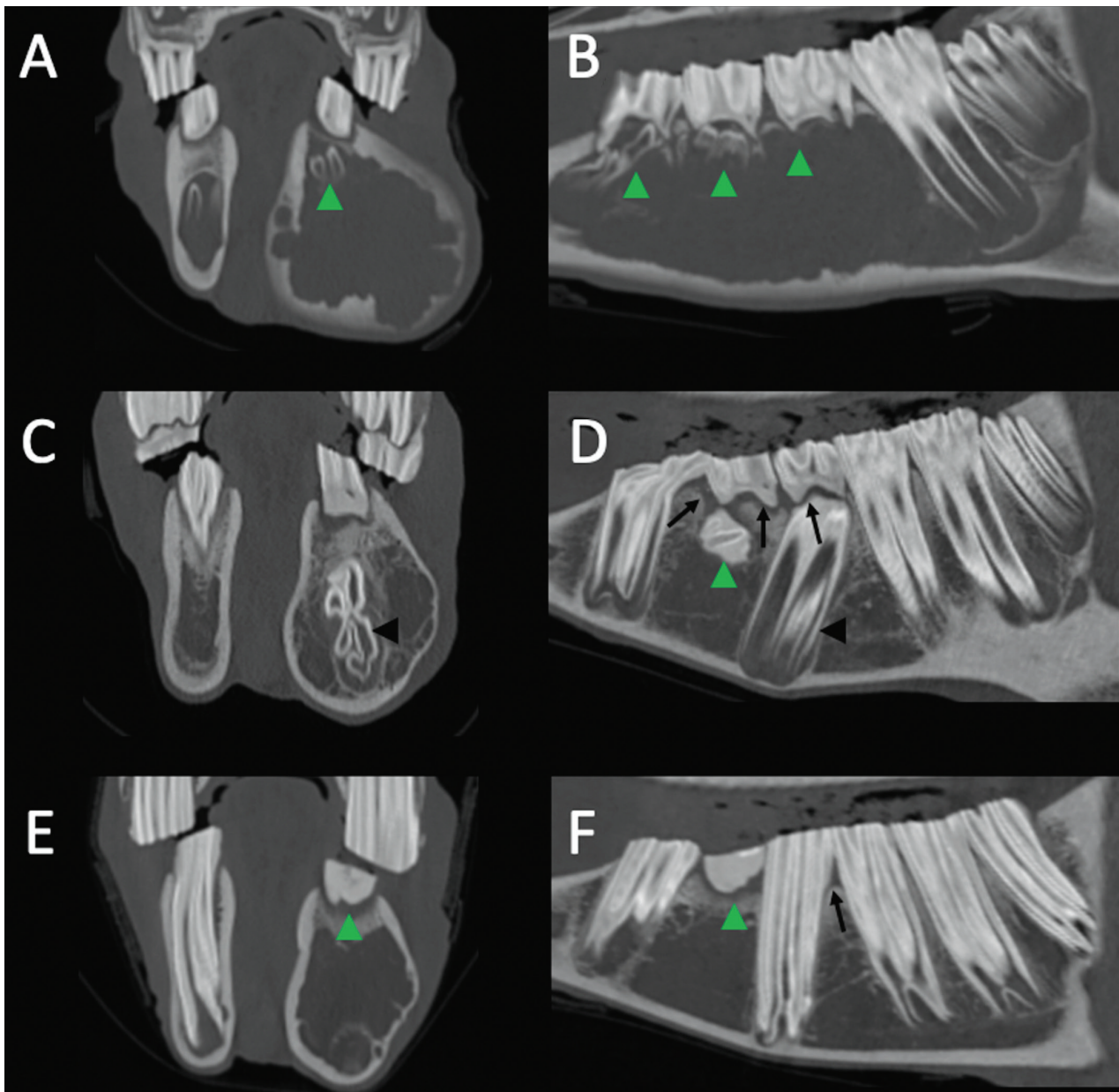
### Case 3

A 22-year-old Standardbred gelding was referred with slightly painful and hard swelling of 15 X 5 X 5 cm (LWH) at the interdental diastema of the right mandible. On this side, the mandibular lymph nodes were enlarged. The swelling was first noted 3 weeks earlier. According to the referring veterinarian, previous treatment with antimicrobials and non-steroidal anti-inflammatory substances (drugs and dosages unknown) mildly and temporarily decreased the swelling. At referral, the horse was bright and alert and had a BCS of 3/5.<sup>22</sup> Radiography showed an ovoid area of geographic lysis (8.1 X 4.3 cm) without osseous septa at the caudal half of the interdental diastema and ventral to elements 406 and 407. There was also thinning and ventral deviation of the adjacent mandibular cortex without signs of cortical destruction or periosteal new bone formation visible. The lesion was in contact with the distal root of element 406, but otherwise there were no signs of lysis of the roots of elements 406 and 407. On the basis of these findings, a tentative diagnosis of ABC was made and standing surgery was performed. The surgical site was aseptically prepared, and a single opening was made using drills of increasing diameter. After opening, tissue samples were taken for histology and the cyst was curetted and flushed with diluted chlorhexidine (0.05%). The ABC was initially filled with 10 mL of TCP (1.4 to 2.8 mm; chronOS

Bone Void Filler; DePuy Synthes). Due to the impression of incomplete filling on radiographic control, the cyst was reopened 1 day after the initial surgery to add 5 mL of TCP. Peri- and postoperatively, benzylpenicillin (30,000 IU/kg, IV, q 6 h), gentamicin (10 mg/kg, IV, q 24 h), and flunixin meglumine (1.1 mg/kg, IV, q 12 h) were given for 2 days. This was followed by doxycycline hyclate (10 mg/kg, PO, q 24 h) and suxibuzone (3.75 mg/kg, PO, q 24 h), given for 14 days. Histology confirmed an ABC. Recovery and incision healing were uneventful. Two months after surgery, the swelling was clinically reduced and was not painful anymore. Radiography showed heterogeneous increased opacity and reduction in size (5.2 X 2.3 cm) of the ABC. The previously described area of geographic lysis was still visible ventral to the 406, and the element itself showed no abnormalities.

### Case 4

A 1-year-old Polo pony stallion was referred with hard, slightly painful swelling of 15 X 8 X 5 cm (LWH) just caudal to the interdental diastema of the left mandible. At referral, the pony was bright and alert and had a BCS of 2/5.<sup>18</sup> The mandibular lymph nodes felt enlarged at palpation. During mastication, the pony showed quidding. Oral examination revealed marked buccal and lingual gingivitis in the third quadrant between elements 706 and 309 with increased interdental spaces causing food impaction. Elements 706, 707, and 708 were loose. There was no radiographic examination performed. A standing CT (first; 64-slice sliding gantry; Definition AS; Siemens; scanning parameters were 140 kVp, 300 mA, 1-mm slice thickness, 0.6-mm reconstruction interval, matrix size of 512 X 512 pixels, and field of view of 500 mm) showed a well-defined ovoid multilobulated expansile fluid-attenuating (20 HU) mass (LWH, 12 X 6 X 7 cm) with undulating margins of the left mandibular body extending from the level of teeth 306 to 308 (Figure 3). This mass had multiple thin osseous septa mostly visible at the periphery. The cortical bone was displaced and thinned by the mass, but there was no interruption. There was mild poorly mineralized periosteal new bone formation surrounding the mass. The mass was involving the region of the mandibular canal and mental foramen. There was also variable degree of displacement and effacement of elements 306, 307, and 308. The left mandibular lymph nodes were enlarged. A tentative diagnosis of ABC was made on the basis of these findings, and surgery was performed under general anesthesia in dorsal recumbency. The surgical areas were aseptically prepared. Preoperatively, ampicillin (15 mg/kg, IV), gentamicin (6.6 mg/kg, IV), and flunixin meglumine (1.1 mg/kg, IV) were given. A Galt trephine was used to create rostral and caudal access, and tissues for histology were sampled. The cyst was flushed with saline, curetted, and filled with 20 mL of TCP (2.8 to 5.6 mm; chronOS Bone Void Filler; DePuy Synthes) mixed with 80 mL of bone marrow harvested from the sternum. Incisions were closed in 3 layers. A stent was applied and removed after 3 days. Postoperatively, meloxicam (0.6 mg/kg, PO, q 24 h) was given for 1 day. Histology confirmed an ABC. The recovery from surgery was uneventful, but wound dehiscence occurred 11 days postoperatively. Bacteriologic examination revealed a *Streptococcus equisimilis*



**Figure 3**—First (presurgical; A and B), second (1.5 years postoperatively; C and D), and fifth (4 years postoperatively; E and F) CT images of case 4 at the level of the ABC of the left mandible. Panels A, C, and E are comparative transverse images at the level of element 307, and right is to the left of the images. Panels B, D, and F are comparative sagittal images at the level of the left mandibular arcade, and rostral is to the left of the images. All images are in bone settings. In panels A and B, there is severe increased volume and abnormal shape of the left mandible at the level of the ABC with a mix of irregular thickening and thinning of the mandibular cortex caused by mass effect from the ABC. Also note the mass effect on the precursor of the permanent elements 306, 307, and 308 (green arrowheads), which are decreased in height with their roots being located more dorsal than expected. In panels C and D, the volume of the left mandible is markedly decreased in comparison with panels A and B and the cortical thickness is more homogeneous, but the cortex is rather thin. There is severe shortening, abnormal shape, and rotation of element 307 (green arrowhead). There is also rotation of element 308 (black arrowhead). The deciduous elements 708 and 709 are still present, and there is osteolysis of the bone adjacent to their roots (black arrows), possibly reflecting periodontitis. In panels E and F, the volume of the left mandible has mildly decreased in comparison with panel C, but there is still mild to moderate increased volume. The rotation of element 308 is significantly improved. Element 307 is severely shortened, with blunting of its apex, and there is widening of the periodontal space and increased bone attenuation at the periapical region of element 307 (green arrowheads) consistent with periodontitis. Also note the shortening and blunting of the interdental bone between elements 308 and 309 (black arrow), consistent with periodontitis and diastema formation.

infection. The incisions were cleaned daily, and surgical site infection gradually resolved without medication. Four and a half months after the surgery, the patient was admitted for a control examination. The pony still had a BCS of 2/5.<sup>22</sup> The swelling of the left mandible was clinically reduced in size and not painful anymore. The caudal skin incision was not completely healed. Oral examination revealed small diastemata between elements 706 and 707 and 708 and 709 and a large diastema between elements 707 and 708. Elements 706, 707, and 708 were not loose anymore. Cheek teeth of both maxillary and mandibular arcades had sharp enamel points on buccal and lingual sides. Food-filled diastemata were cleaned, and sharp enamel points were removed. A standing CT (second) showed a decrease in size and increased attenuation of the ABC. There was mass effect on elements 306, 307, and 308. This mass effect was more marked on element 307, which was markedly shorter and increased in attenuation in comparison with the adjacent elements. There were multiple small mineral-attenuating areas visible in the ventral aspect of the lesion. These areas were also extending through a linear cortical defect ventral to element 307. One and a half years after surgery, the pony was admitted for a second control examination. Clinically, the swelling of the left mandible was similar to the previous examination and there was a fistula at the caudal surgical incision. A standing CT (third) was performed and showed similar size and attenuation of the ABC (Figure 3). There was severe shortening of element 307 and a buccal deviation of its root. There was also mesial displacement of the roots of elements 306 and 308. The multiple small ventral mineral attenuations were still visible, as well as the cortical defect. Because of persistent drainage caused by the chronic infection, the TCP remnants were removed standing. The ABC was flushed with saline and partially closed for additional drainage. Two years and 3 months after initial surgery (9 months after TCP removal), the pony was admitted for a third control examination. Clinically, the skin was intact and the swelling of the left mandible was further decreased compared to the second control. Oral inspection showed diastemata between all elements from 308 to 311 and from 407 to 411. Element 308 was abnormally positioned. Diastemata were cleaned, and overgrowths and sharp enamel points were removed together with the remaining part of element 707. A standing CT (fourth) was performed and showed decreased size and attenuation of the ABC. The attenuation was then consistent with spongy bone. There was marked shortening and rotation of element 307, and the deviation of elements 306 and 308 was significantly improved. The multiple small ventral mineral attenuations were not visible anymore and the cortical defect was less

visible. Almost 4 years after the initial surgery, the pony was admitted for a fourth control examination. The BCS of the pony had improved and was 3/5.<sup>22</sup> Clinically, the swelling of the left mandible had decreased but was still clearly noticeable compared to the right mandible. Oral inspection showed an abnormal wear of element 307 and a diastema between elements 407 and 408. A standing CT (fifth) was performed and showed a mild decrease in size and similar attenuation of the ABC (Figure 3). Element 307 was further shortened, and there was resorption and increased attenuation of the surrounding bone compatible with periodontitis/infection. Elements 306 and 308 remained mildly deviated, and the ventral cortical defect was not visible anymore.

## Discussion

ABCs are osteolytic, expansile, and by definition benign,<sup>1,2</sup> but in some cases, they can be locally destructive, with cortical osteolysis and cortical breach being described in humans.<sup>2,23</sup> This feature was visible in case 2 but not in the other cases. This case series of 4 histologically confirmed ABCs showed successful surgical treatment with TCP filling and provided more insight in the clinical signs, imaging features, and long-term follow-up. Similarly to other reports, there appeared to be no age or sex predilection, and various breeds were encountered, while in earlier reports Thoroughbreds were affected more often.<sup>4,13,16,17</sup> In these 4 cases, clinical manifestation and development were similar to earlier described cases: an acutely developing, almost painless swelling or mass on the mandible that significantly enlarges in weeks to months, without a history of trauma. Although trauma is suggested, the true pathogenesis of ABCs is still unclear. It has been proposed that possible disruption of bone marrow's vasculature secondary to trauma, bleeding disorders, fibrous dysplasia, hematomas, or underlying neoplasia may be responsible for their development.<sup>6,16,18</sup> Most clinical complaints reported were an alarming growth and suspicion of tooth-related problems without concurrent illness. Earlier described cases were examined clinically and radiographically.<sup>13-17</sup> More recently, CT was used to evaluate ABCs.<sup>4,18</sup> This technique allows a detailed evaluation, providing more information concerning the bone morphology, exact extension of the cyst, and involvement of juvenile or adult dental elements. This extra information is very helpful for excluding possible differential diagnoses for expansile lesions of the mandible and maxilla in horses to guide biopsies and subsequently plan the best surgical treatment (Table 1).

**Table 1**—Differential diagnoses for expansile lesions involving the equine mandible and maxilla.

Age	Differential diagnoses
Foals/yearlings	Adamantinoma, <sup>14,15,17</sup> ameloblastic odontoma, <sup>14,17,18</sup> osteogenic sarcoma, <sup>15,18</sup> aneurysmal bone cyst, <sup>15</sup> unicameral bone cyst, <sup>15,17,18</sup> nutritional secondary hyperparathyroidism, <sup>14</sup> mucocoele, <sup>14</sup> (non)ossifying fibroma <sup>17,18</sup> Congenital cysts of dental or sinus origin <sup>14,17,18</sup> Osteoma, <sup>15</sup> cystic osteodystrophia fibrosa, <sup>15</sup> fibrous dysplasia, <sup>17,18</sup> hemangioma, <sup>18</sup> hemangiosarcoma, <sup>18</sup> giant cell tumor, <sup>18</sup> telangiectatic osteosarcoma <sup>17,18</sup>
Adults	Adamantinoma, <sup>13</sup> ameloblastoma, <sup>13,16</sup> odontoma, <sup>13,16</sup> osteogenic sarcoma, <sup>13</sup> aneurysmal bone cyst, <sup>13,16</sup> unicameral bone cyst, <sup>16</sup> nutritional secondary hyperparathyroidism, <sup>16</sup> mucocoele, <sup>16</sup> ossifying fibroma <sup>16</sup> Dentigerous cyst <sup>16</sup> Squamous cell carcinoma, <sup>13</sup> tooth root abscess <sup>16</sup>

In the mandible, the lesion can occur at various locations. In previously reported cases, the rostral part of the mandible including the incisive bone and interdental diastema between incisors and cheek teeth was affected most frequently,<sup>15–18</sup> but a more caudal location with involvement of the cheek teeth was also reported.<sup>13</sup> Complete bilateral involvement of the mandibular body with dental abnormalities was also described in a newborn foal, dead at birth.<sup>14</sup> In another report,<sup>4</sup> the ABC extended from the mental foramen to element 410, almost including the entire right mandibular body. In our cases, caudal location of the lesion in the region of the cheek teeth together with dental abnormalities were detected. In 3 of the cases, it was ventral to the premolars. Tooth root abnormalities were detected in all cases, and these abnormalities were more severe in case 4. In this yearling pony, severe dental abnormalities were most likely caused by the mass effect exerted on the deciduous teeth and precursors of permanent teeth. These extensive abnormalities were not present in our other cases, which were older. In our opinion, this could be due to older horses having shorter reserve crowns and no deciduous teeth, leaving more space for expansion of the ABC before interfering with dental structures. Similar but less extensive cheek teeth abnormalities have been reported in a 2-year-old Thoroughbred.<sup>4</sup> In previous reports, dental abnormalities were uncommonly reported, and this may be due to the use of radiography, which may underestimate dental involvement and the more rostral location of the ABC that did not interfere with the cheek teeth.<sup>13–16</sup>

Based on our review of the literature, there are no reported cases of spontaneous regression of mandibular ABCs in horses. The case described by Purdy<sup>13</sup> that was left untreated, doubled in size in less than a year. Due to the growth of the lesion, this patient's condition deteriorated severely because of difficulty with mastication and finally led to euthanasia. This outcome, together with the fact that in several other cases mandibular ABCs did decrease or stabilize in size after curettage, suggests the necessity of surgical treatment. The goal of surgery is to not only improve cosmetic appearance but also stop the progressive nature of the disease. To stop progression, the inner lining should be removed, which has been done most frequently surgically by curettage.<sup>4,15,16</sup> Recently, sclerotherapy with multiple intralesional injections of doxycycline was reported.<sup>18</sup> Surgical treatment can be done under general anesthesia with the horse in dorsal or lateral recumbency.<sup>4,15,16,18</sup> Surgical treatment of a maxillary bone cyst was also reported in a standing sedated horse.<sup>11</sup> During surgery, irrespective of how the patient is positioned, 1 large or 2 smaller skin incisions are made, and the cyst is opened using either a trephine or hammer and chisel. The distinctive part of the surgical procedure in the current study was that, besides standardized removal of cystic contents, sampling, extensive curettage, and flushing, ABCs were filled with TCP solely or mixed with bone marrow. TCP was used for several reasons. One reason was its

superior role as an osteoconductive matrix.<sup>24</sup> TCP is the ideal biomaterial for bone regeneration, providing a space-maintaining scaffold as long as the new bone is being formed. It can be used with or without autogenous bone marrow.<sup>25</sup> Adding osteoprogenitor cells on the graft materials has been reported to improve replacement of the bone substitute by newly formed bone tissue.<sup>25</sup> Another important reason for TCP application was that the resorption rate corresponds to the formation of new bone, leaving nothing but vital bone behind.<sup>26</sup> Recently, a CHA scaffold was used successfully also in a mandibular ABC.<sup>4</sup> Although both CHA and TCP act as a scaffold, there are some differences between TCP and CHA. The most relevant difference concerning ABC treatment is probably that TCP shows a faster osseointegration (6 weeks) than CHA (4 months).<sup>27</sup> This desirable characteristic of TCP allows for fast stabilization of the initial postsurgical blood filling of the cyst and, subsequently, bone regeneration. Another major difference is that CHA is not resorbed and gives ceramic reinforced bone, in contrast to TCP, which will be resorbed completely during remodeling and resembles physiological cancellous bone at the end.<sup>27</sup> End-stage deformable cancellous bone is highly preferred for cases in which dental elements are developing or are involved, compared to the rigid end product of CHA, which is more suitable in places where severe deformation can be expected.<sup>27</sup>

Equine mandibular ABCs are a rare, albeit benign condition. However, treatment is indicated due to progressive increase in size and local destructive effects. CT is helpful to visualize local destruction and extent of damage and to plan potential surgical intervention because it determines the exact cyst size and involvement of dental elements in the mandible. Surgical curettage followed by filling of the ABC with TCP alone or in combination with autogenous bone marrow provided a good outcome in these cases. In all 4 described cases, disease stabilized with a clear reduction in size, the cyst cavity mineralized, and disease did not relapse. For the young equine patient in which deciduous teeth are present and permanent teeth are developing, the expansile nature of mandibular ABC may have a larger impact than in older horses and can cause severe dental displacement and disease that may compromise the function of the cheek teeth. This warrants early surgical intervention to stop this expansion and dental element changes.

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