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Frontal sinus repair using polymethyl methacrylate after craniectomy for a resection of a fronto-parietal osteoma in a dog.

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Abstract:	A three-year-old spayed female German Shepherd dog was presented for investigation and treatment of a firm slow growing mass over the right surface of the skull. Computed tomography (CT) of the head revealed a proliferative, rounded, and well-defined compact bone mass expanding extracranially. A right rostrotentorial craniectomy was performed with "en bloc" mass resection. To achieve clear margins, the excision of the outer table of the frontal bone, with subsequent opening of the right frontal sinus, was necessary. To provide an appropriate sealing between the cranial cavity and the nasal cavity, thereby preventing future complications, a cemented partial obliteration and reconstruction of the right frontal sinus was performed. The dog recovered uneventfully. Histopathological analysis confirmed complete resection with clear margins and the final diagnosis of an osteoma. The dog was progressing with no clinical signs 6 months after the surgery.

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TITLE OF CASE

Frontal sinus repair using polymethyl methacrylate after craniectomy for a resection of a fronto-parietal osteoma in a dog.

SUMMARY

A three-year-old spayed female German Shepherd dog was presented for investigation and treatment of a firm slow growing mass over the right surface of the skull. Computed tomography (CT) of the head revealed a proliferative, rounded, and well-defined compact bone mass expanding extracranially. A right rostrotentorial craniectomy was performed with "*en bloc*" mass resection. To achieve clear margins, the excision of the outer table of the frontal bone, with subsequent opening of the right frontal sinus, was necessary. To provide an appropriate sealing between the cranial cavity and the nasal cavity, thereby preventing future complications, a cemented partial obliteration and reconstruction of the right frontal sinus was performed. The dog recovered uneventfully. Histopathological analysis confirmed complete resection with clear margins and the final diagnosis of an osteoma. The dog was progressing with no clinical signs 8 months after the surgery.

BACKGROUND

Postoperative complications secondary to the frontal sinus (FS) approach are not uncommon in humans, with a complication rate of 1.8 to 17%[1]. The most common complications are intracranial infections, cerebrospinal fluid leakage, and mucosal cyst formation[1-5]. Postoperative complications after transfrontal craniotomies in dogs and cats have also been reported, such as tension pneumoencephalus[6- 7] and meningoencephalocele[8]. Based on the author's experience, infectious meningoencephalitis is also a possible complication after transfrontal craniotomies.
To prevent future complications, different surgical techniques for frontal bone and frontal sinus repair have been described in human medicine: 1) FS cranialisation, 2) FS obliteration and 3) FS reconstruction[2,5,9]. Frontal sinus cranialisation consists of stripping the sinus of all mucosa, plugging the nasofrontal duct and removing the inner table of the frontal bone; thus integrating the frontal sinus space with the intracranial space[2,5]. Frontal sinus obliteration consists in packing the FS with an inert material which seals it off from the nasal cavity, essentially eliminating the sinus as a functional unit. A variety of different tissues or materials have been used to obliterate the sinus which are classified as autografts (pericranium, adipose tissue, temporalis fascia, bone chips[4], lyophilized cartilage) and alloplastic grafts[2,5] (oxidized cellulose, gelfoam[9], bone cement[1,10], bioglass, and calcium sulphate). Finally, FS reconstruction is comprised of restoring the FS wall (inner and/or outer tables) by means of fixation when the bone surface is still available or using autologous bone graft, alloplastic materials, or titanium mesh[2,5,9].
To the author's knowledge, this is the first report describing a FS obliteration and reconstruction performed after a craniectomy in a dog. The aim of this technique is to avoid the postoperative complication risks which arise from craniectomy with nasal cavity involvement.

CASE PRESENTATION

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A 3-year-old 30kg spayed female entire German Shepherd dog was referred to the Small Animal Hospital of the University of Glasgow for further investigation and treatment of a slow growing firm mass on the skull producing an asymmetric cranial deformity. The dog had no relevant previous clinical history. Physical examination was unremarkable, apart for the bulging of head at the level of the right temporalis muscle. A hard, rounded, adhered and non-painful mass could be palpated under the temporalis muscle. No deficits were noted on the neurological examination. No other clinical signs such as restricted movements of the jaw, pain or seizure activity were described by the owner.

INVESTIGATIONS

A complete haematology and biochemistry were within normal limits. Computed tomography of the head revealed a large, rounded, well defined but with irregular surface and moderately heterogenous bone attenuating mass emerging from the right frontal bone. The mass was markedly mineralised (hyperattenuating) on the periphery but hypoattenuating at the centre. Focal and smooth sclerosis of the cancellous bone adjacent to the mass also was evident. No bone destruction (osteolysis), intracranial invasion or anomalies of the encephalic structures were noticed. The cranial edge of the mass was growing over the right external table of the frontal bone, which comprises the right frontal sinus. Secondarily, the mass displaced the right temporalis muscle dorsally (Figure 1). Thoracic CT and abdominal ultrasound revealed no evidence of metastatic disease.

A core needle biopsy was taken from four sites of the mass which revealed strands of fibro-collagenous tissue associated to well differentiated trabecular bone remodelling suggestive of reactive periosteal bone proliferation. A definitive diagnosis could not be obtained from these biopsies, though a well differentiated bone tumour was suspected.

DIFFERENTIAL DIAGNOSIS

Based on the initial histological results, the main differential diagnosis was a neoplastic process arising from the skull surface, such as an osteoma, osteochondroma, osteosarcoma or, less likely, multilobular osteochondrosarcoma. The CT findings, consistent with a well demarked bone mass with lack of bone destruction and intracranial invasion, also supported the suspicion of a benign well differentiated bone tumour. Given the rounded polyp-like mass; instead of a focal thickening and proliferation of the skull bone, a benign calvarial hyperostosis was considered unlikely.

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TREATMENT

Resection with curative-intent margins was the main goal for the planning of the surgical approach. To obtain a surgical defect with 1cm of clear margins from the defined tumour boundaries, partial resection of the external table of the right frontal bone was required, thereby exposing the right FS. Further, the planning for the tumour excision placed the medial margin at the level of the sagittal crest (over the dorsal sagittal venous sinus); and the ventral margin was located at the right parietal and right temporal bones union (at the level of the zygomatic arch). A 3D-printed model of the skull with the mass and another with the "ideal" surgical-defect were printed and used as a guide during the surgery (Figure 2 A, B).

The dog was premedicated with dexmedetomidine (5mcg/kg) and methadone (0.2mg/kg) administered intramuscularly. Anaesthesia was induced with propofol (4 mg/kg intravenously titrated to effect) and maintained with sevoflurane and oxygen mixture. Perioperative pain management was managed with additional intravenous fentanyl (5-15mcg/kg/hour) and ketamine continuous rate infusion (10mcg/kg/min). Cefuroxime (20mg/kg) was administered intravenously preoperatively and then repeated every 90 minutes throughout the procedure. The dog was placed in sternal recumbency with moderate deviation of the head to the left side and was prepared aseptically. A half-moon shape incision was made from the bregma to the occipital crest and subcutaneous tissue was bluntly dissected exposing the temporalis muscle. The right temporalis muscle was detached from the skull, revealing the right frontal-parietal surface of the skull with the rounded mass (Figure 2C). The right temporalis muscle was displaced ventrally. Given the thickness of the temporal muscle, the prominent mass growing outwards and the anatomical limitation due the zygomatic arch, the ventral margin of the surgical approach offered insufficient space to drill. To obtain adequate space, the temporalis muscle was sectioned transversely (Figure 2C). An oval shape craniectomy line was performed with approximately 1cm margins from the macroscopic tumour CT-boundaries using the 3D-model as guide. Following completion of the craniectomy line, periosteal elevators were used to achieve an "*en bloc*" resection of the mass. No macroscopic changes were observed on the surface of the dura. The opening defect was formed by bones of different thicknesses which did not allow the placement of soft tissue grafts sutured to the bone edges. Frontal sinus obliteration and repair using polymethylmethacrylate (PMMA) (DePuy CMW3 with gentamicin, 325 Paramount Drive, MA, USA) was performed to avoid permanent communication between the FS and the cranial cavity. With the aim to provide adequate support and fixation for the PMMA, three monocortical screws were placed (as scaffolding) from the edge of the outer table of the frontal bone towards the inner table of the frontal bone, crossing perpendicularly the FS (Figure 2D). After that, the PMMA was introduced into the FS, enclosing the screws, and filling the edges of the FS aperture (adhering the PMMA to the inner and outer tables of the frontal bone, to ensure the correct sealing of the nasal cavity).

The bony defect after the craniectomy was covered with absorbable collagen packing and the temporalis muscle was overlaid covering the craniectomy defect. The skin closure was routine. Immediate postoperative CT showed an obliteration of the FS (of the lateral part of the FS) and successful separation between the FS and the brain surface (Figure 3). The dog recovered uneventfully and remained in an intensive care setting for 3 days post operatively; after which she was discharged without showing neurological deficits, excessive pain, or nasal discharge.

OUTCOME AND FOLLOW-UP

The dog was re-examined three weeks after the craniectomy. General physical and neurological examination were normal. No cranial asymmetries were noted, and the surgical site was fully healed. However, moderate pain whilst yawning was suspected

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during the first week post-surgery by the owner which was attributed to the right temporal muscle dissection. The owner was contacted by phone consultation 8 months after surgery and no concerns were reported.
Histological analysis of the resected bone revealed a nodular, well demarcated, thinly encapsulated and poorly cellular mass composed of bone interspersed by mature adipose tissue (at the centre of the lesion) and aggregates of heterogenous round cell population (bone marrow). The bony component throughout was well-differentiated and comprised of a peripheral region of densely arranged trabeculae of bone. Towards the central area those trabeculae of bone merged with more loosely arranged trabeculae of bone lined by a single layer of cuboidal to round cells (osteoblasts), and to a lesser degree, with hyaline cartilage. The superficial regions were covered by collagen with numerous stellate-shaped to cuboidal cells and were commonly associated with islands of osteoid. All sections of the mass appeared to have narrowly been excised completely with a smallest complete margin of 3mm. Based on the benign histological features, the final diagnosis was an osteoma.

DISCUSSION

Intracranial surgery is increasing in frequency in veterinary medicine. The approach to lesions affecting the frontal lobes usually requires passage through the FS. This approach may result in postoperative complications in both human and veterinary medicine, such as intracranial infection[11,12], cerebrospinal fluid leakage[13], mucocele formation[1-4], pneumoencephalus[6,7] or meningoencephalocele[8]. One case report describes a concomitant pneumoencephalus, herniation of the olfactory bulb and septic meningoencephalitis in a dog secondary to dorsal rhinotomy[14]. The FS is an air space containing microbial flora, that communicates with the nasal cavity, for this reason the frontal approaches may be associated to complications such as infections which can be potentially life-threatening[5]. The presence of a diverse nasal flora, potentially with pathogenic agents in healthy dogs has also been described[15].

Multiple publications in human medicine support the use of different methods for prevention of these complications[1-5]. These methods usually are focussed on several goals: 1) completely blocking the connection between the frontal sinus and the intracranial space, 2) filling the dead space[1,2,9] ,3) performing an airtight suturing of the dura mater[1,5], and 4) restoring facial contour[5]. However, specific guidelines in veterinary medicine have not been reported. Moreover, anatomical differences exist between the FS and the nasal cavity of dogs and humans, which requires a careful evaluation of each case.

Because cranialisation involves exposure of the entire sinus and a fastidious removal of all sinus mucosa[5], and in our case only the caudal aspect of the right frontal sinus was exposed, this technique was not considered as an option.

Regarding the obliteration technique, different materials (and their combinations) have been broadly used in human medicine[1,4,5,9]. Soft materials mixture such as surgical glue with haemostatic sponges, bone dust or abdominal fat may form an effective barrier[4,9]. However, the glue material may deteriorate overtime, making the seal construct unstable[1]. Moreover, sneezing can lead to disruption of the surgical seal, increasing the risk for postoperative complications[1]. A case report in a dog describes the failed attempts of sealing the cranial cavity with a fat graft and fascial graft from the temporal muscle. The dog underwent a second surgery to place a bone graft from the wing of the ilium over the cribriform plate defect; however, subsequently rotation of the bone graft was diagnosed by CT which caused neurological deterioration of the patient[14]. Other materials, such as bone wax was also routinely used in human neurosurgery[1,5]. However, bone wax is not recommended any longer, as infection and foreign body reaction have been reported[1,16] Surgical cements, specifically PMMA, have

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been frequently used for obliteration and reconstruction of the FS in human medicine as it is widely available, simple, cheap, extremely durable, safe and is associated with shorter operative times[1]. However, granuloma reactions or infections related to bone cement have also described[17,18]. In our case, only the caudal area of the FS was approached and filled with PMMA with gentamicin. Due to the larger size of the FS in dogs, compared with humans, the authors considered necessary, in this case, to provide support to the PMMA mass by means of the three screws crossing the large space of the FS. No signs of infection or foreign body reaction were observed over the 8 months of follow-up.

In recent times, the use of PMMA solely or combined with titanium mesh has been reported in veterinary medicine when cranioplasty is required to repair a skull bone defect[11]. However, the aim of the PMMA-cranioplasties in those cases is the reconstruction of the cranial vault to cover and protect the brain surface instead of separating the nasal and cranial cavities. One of the three dogs reported by Holmes *et al.* was diagnosed with a recurrent sinus infection as well as implant infection which required a second surgery to replace the implant[19]. In our case, the placement of the PMMA bulge worked as a reconstruction of the inner table of the frontal bone, leading to sealing of the cranial cavity from the sinonasal cavity. Although the dog is not showing any complications at the time of the publication, the risk of material infection is possible at any time after the surgery. To the authors knowledge, this is the first report describing the sealing and reconstruction of the frontal sinus with PMMA and monocortical screws after a craniectomy in a dog. No complications were noted 8 months after surgery. However, moderate pain during yawning was suspected by the owner during the first postoperative week, which was attributed to the right temporal muscle dissection.

Osteomas are rare and benign bone tumours[19-21] typically composed of bone that appear morphologically normal which have a prevalence recorded of up to 6% of all primary canine bone neoplasms[20]. Usually, osteomas tend to develop on the surface of the bones of the skull[20]. As in this case, radiographically benign bone tumours are usually highly mineralised, smooth margined[20] and showing no evidence of active bone destruction[22]. However, definitive diagnosis of an osteoma depends both on imaging results and histopathologic features[19]. In this case, the histological analysis was not conclusive, and a definitive diagnosis could not be established, so other malignancies were still considered before the surgery. Treatment of choice for an osteoma is surgical excision, which is usually curative[19]. However, for skull bone tumours, the incomplete surgical margins and high histologic grade of tumour have been associated with decreased time to local recurrence[23]. Even with benign neoplasia such as osteomas, recurrence at the surgical site has been reported[24]. For that reason, histologically clear bone margins should be attempted with an excisional craniectomy. A publication recommended that bone margins of 1-2 cm should be the goal of excision[25]. In our case the macroscopic margins planned were of 1cm. Although, the histological analysis revealed the smallest clear margin of 0.3cm.

In conclusion, to avoid life-threatening complications, the sealing of the cranial cavity from the nasal cavity should be considered in craniotomies or craniectomies which involves the frontal sinus. Further investigations to conclude the prevalence of complications, such as meningitis, tension pneumoencephalus or meningoencephalocele, in veterinary patients after craniectomies invading the frontal sinus should be performed. Because of the lack of guidelines in veterinary medicine, the selection of the sealing technique must be planned in each case, considering the individual anatomy of the patient, the surgical approach, and the materials available.

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LEARNING POINTS/TAKE HOME MESSAGES

The role of the FS invasion during cranial surgery and its relationship with previously described complications (intracranial infection, pneumoencephalus, cerebrospinal leakage, and meningoencephalocele) should be investigated in veterinary medicine. The prevalence of these complications in dogs and cats is unknown. Human literature suggests an increased risk of complications when the FS is invaded during cranial surgery and proper sealing of the cranial cavity by means of a FS reconstruction is recommended.

There is no consensus about the sealing of the cranial cavity from the nasal cavity in veterinary medicine. Polymethyl methacrylate is a cheap, widely available, easy to use and is malleable to different surfaces. Further, it is extremely durable and does not deteriorate easily; for that reason, PMMA could be a good option to consider in veterinary medicine. However, potential infection of the PMMA is also possible.

Osteomas should be considered as a differential diagnosis when benign findings (non-osteolytic changes) are observed on CT or MRI in a skull growing mass. However, it is an uncommon neoplasia in dogs and future studies are needed.

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FIGURE/VIDEO CAPTIONS

Figure 1: Bone window CT of the head. Transverse (a), dorsal (b), and 3D reconstruction (c) images showing the skull mass growing from the frontal bone

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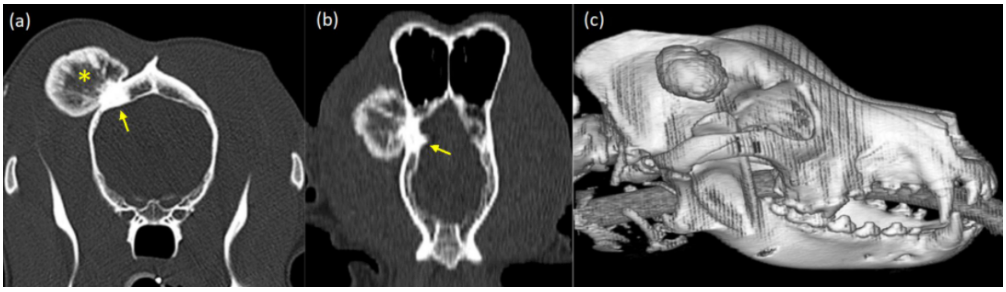
resulting in a deviation of the right temporalis muscle. Note the hyperattenuating mineralisation on the periphery of the mass with the hypoattenuating centre (asterisk). Focal sclerosis of the cancellous bone is obvious on images (a) and (b) (yellow arrows).

Figure 2: 3D-printed models (1:1 scale) of the skull (a, b) and intraoperative view (c, d), rostral is to the right in all images. (a) 3D-printed model with the bone-mass growing from the right frontal bone. (b) A second 3-D printed model with the planned surgical-defect with 1cm of margins was used as a guide during the surgical approach (FB: frontal bone). Note the vertical, irregular and curved shape of the opening formed by frontal, parietal and temporal bones with different thicknesses. (c) Note the temporalis muscle sectioned in half to increase the ventral space (arrow). (d) Imaging showing the screws placed crossing perpendicularly the frontal sinus (b: brain surface, IT: internal table of the frontal bone).

Figure 3: Immediate postoperative bone window CT of the brain. Transverse (a), dorsal (b), sagittal (c) and 3D reconstruction (d) images revealed the PMMA and screws placement at the level of the caudal aspect of the right frontal sinus. (d) Note the craniectomy edges (red arrows) and the cement wall as the inner table of the frontal bone reconstructed (green arrows).



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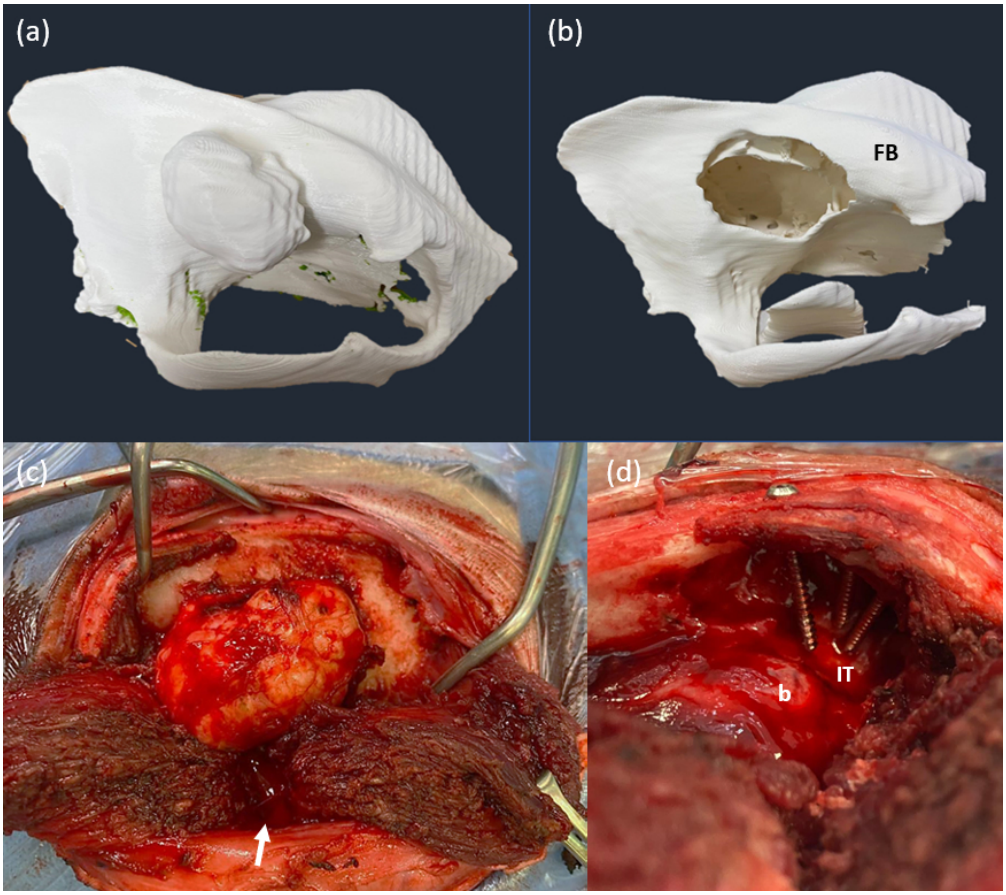
287x81mm (96 x 96 DPI)



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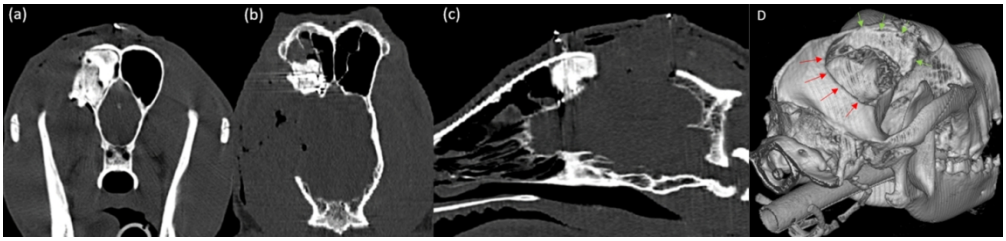

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383x89mm (96 x 96 DPI)