Catheterization Series

Swine as Models in Dental and Oral Surgical Research

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Introduction

The use of swine in dental and oral surgical research was relatively uncommon in the past, probably due to the anatomy of the head, neck, and oral cavity. However, there has been increased activity in porcine models involving dental research and there are >300 literature citations since 2000. The skull in Figures 1-2 is from an immature domestic pig and the one in Figures 3-4 is from a sexually mature wild boar. Much of the older literature is related to descriptions of the anatomy and pathophysiology and the newer literature is more related to development of actual models.[1-23]

Dental Anatomy[1, 2, 6, 8, 11-13, 15, 17, 20, 22, 23]

Calcification of the deciduous teeth starts in utero at day 55 of gestation. The pig is born with eight teeth which are the upper and lower third incisors and the canines. The canines are sharp and project laterally. They are generally clipped soon after birth to prevent damage to the sow's nipples. The usual dental formula for deciduous teeth in miniature swine is 2(I 3/3, C 1/1, M 3/3) = 28. Some of the literature refers to the deciduous molars as deciduous premolars[1, 11-13] and the nomenclature of these teeth remains controversial. You will also note that in the examples to follow the authors identified 4 sets of molars (or premolars) in the deciduous teeth making the formula 2(I 3/3, C 1/1, M 4/4) = 32.[22, 23] This is due to the late eruption of M1 which sometimes is absent. The maxillary and mandibular teeth erupt at slightly different times. There are some slight differences between miniature and domestic pigs and between different breeds. There are also some slight differences of days to weeks in the timeline between individuals within a breed. In general, all of the deciduous teeth erupt by 4-5 months of age. The sequence of eruption is more consistent than

Figure 1: Immature domestic pig skull lateral view.

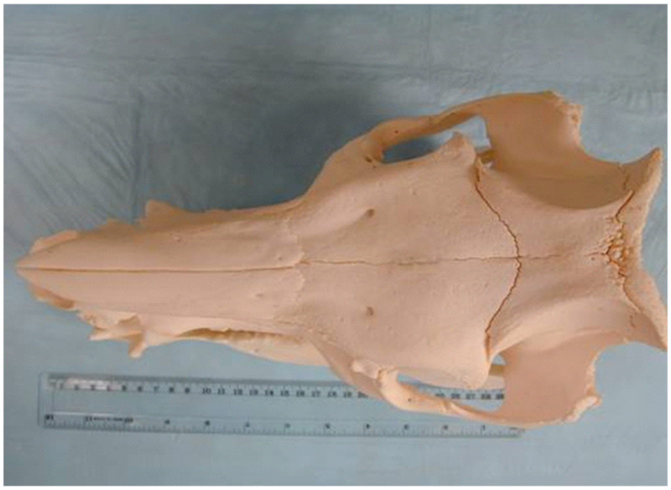

Figure 2: Immature domestic pig skull dorsal view.

the time of the eruption. Examples of the differences between two breeds of miniature pigs are described in the following paragraphs.

The eruption patterns of the deciduous teeth of the Pitman-Moore miniature pig were studied.[23] The maxillary eruption pattern is: I_1 1-4 weeks, I_2 8-17 weeks, I_3 present at birth, C present at birth, M_1 17-26 weeks, M_2 5-9 weeks, M_3 1-3 weeks, M_4 3-4 weeks. The mandibular eruption pattern is: I_1 1-4 weeks, I_2 7-11 weeks, I_3 present at birth, C present at birth, M_1 7 weeks (may be absent), M_2 6-12 weeks, M_3 3-5 weeks, M_4 1-3 weeks.

The deciduous eruption pattern of the Sinclair miniature pig has a slightly different timeline.[22] The maxillary eruption pattern is: I_1 4-10 weeks, I_2 11-19 weeks, I_3 present at birth, C present at birth, M_1 17-23 weeks, M_2 7-11 weeks, M_3 3-11 weeks, M_4 7-11 weeks. The mandibular eruption pattern is: I_1 1-4 weeks, I_2 7-11 weeks, I_3 present at birth, C present at birth, M_1 7 weeks (may be absent), M_2 6-12 weeks, M_3 3-5 weeks, M_4 1-3 weeks.

Permanent teeth have a dental formula of 2(I 3/3, C 1/1, P 4/4, M 3/3) = 44. Eruption of the permanent teeth occurs in a range from 3-20 months in domestic breeds. The pig has the full number of teeth possessed by placental mammals. In domestic farm pigs, the molars are the first permanent teeth to erupt and appear between 4 months and 20 months of age. The incisors change between 8 and 20 months, the canines between 9 and 10 months, and the premolars between 12 and 15 months. The same statements about variation between breeds and individuals made above about deciduous teeth also apply to the

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permanent teeth. The tooth eruption sequence of adult permanent teeth is $P_1/M_1/I_3/C/M_2/I_1/P_3/P_4/P_2/I_2/M_3$. [1, 2, 6, 8, 11-13, 15, 17, 20, 22, 23]

The eruption patterns of the permanent teeth of the Sinclair miniature pig have been studied.[22] The maxillary eruption pattern is: I_1 50-60 weeks, I_2 74-94 weeks, I_3 33-63 weeks, C 35-49 weeks, P_1 53-69 weeks, P_2 55-66 weeks, P_3 57-65 weeks, P_4 57-66 weeks, M_1 17-28 weeks, M_2 42-54 weeks, M_3 92-110 weeks. The mandibular eruption pattern is: I1 51-62 weeks, I2 65-93 weeks, I_3 31-39, C 35-47 weeks, P_1 37-54 weeks, P_2 56-67 weeks, P_3 57-65 weeks, P_4 57-66 weeks, M_1 17-25, M2 40-52 weeks, M_3 86-105 weeks.

The teeth in the adult pig are slightly larger than the corresponding teeth in an adult human. The incisors have extensive enamel on the labial surface of the crown but the lingual surface has enamel only on the margins. The roots of these teeth are long, round and deeply implanted. The canine teeth become the tusks in the boar. Growth of the tusks is delayed in females and castrated males. The tusks are open- rooted and are replenished as they grow at the alveolus. The tusks are conical and curved caudally. The convex cranial surface is coated with enamel but the concave surface is coated with cementum. The premolars and molars are covered with enamel and the roots with cementum. The premolars perform a combination of cutting and crushing functions. The molars have complex crushing mounds. The premolars and molars have 2-6 roots.[6, 8, 13, 15, 23]

The periodontal ligament is wider than man with profuse collagenous fiber bundles. It also has numerous large periodontal glomeruli. The cementum tends to be thicker than man. Epithelial rests, cementicles and excementoses are similar to those of man. Osteoclastic activity occurs on both the tooth surface and alveolar bone.[23]

Figure 3: Wild boar skull with upper canines (tusks) removed lateral view.

Figure 3: Wild boar skull with upper canines (tusks) removed dorsal view.

Cranial Anatomy

There is a substantial difference in the conformation of the head and neck among different breeds. The snout of the Yucatan, Sinclair, and most other miniature pigs is considerably shorter than that of domestic farm breeds and the Hanford miniature pig. The heads of miniature breeds tend to be more rounded than that of the farm breeds and the Hanford, which has a head and snout shape similar to wild pigs. Selection of a breed for oral and maxillofacial surgery should include a consideration of the differences in head and neck conformation.[1]

The bones of the cranium and the mandible are massive. The temporomandibular joint has been compared to other species and man in a detailed anatomic study.2 The authors concluded that the pig was an appropriate animal model to study temporomandibular joint abnormalities because it was most similar to humans. The pig has a reciprocally fitting meniscotemporal joint and a condylomeniscal joint of the condylar type. The size of the articular structures, the shape of the meniscus, and the omnivorous chewing characteristics of swine provided additional justification for the use of this model over that of rodents, rabbits, carnivores, and herbivores that were examined.

Principles of Oral Surgery[1, 3- 5, 7, 9, 10, 14, 16- 19, 21]

Oral surgical techniques used on humans may be applied to swine. If the oral cavity requires prepping for prevention of infection, as in the implantation of biomaterials, then a combination of therapies has proved to be effective. Antibiotics may be administered starting the day before surgery in order to have a blood level at the

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time of surgery and for several days postoperatively. Amoxicillin has proved to be effective for this type of prevention but other antibiotics may prove to be equally effective depending upon the procedure. Endotracheal intubation should be performed and the endotracheal cuff inflated during induction of anesthesia. In the prep room the oral cavity can be rinsed with a dilute betadyne solution. The solution is allowed to remain in the mouth for 3-5 minutes and then it is flushed with sterile saline prior to transporting the animal to the operating room.[1]

Dental and oral surgical procedures can be expected to cause pain. Consequently, administration of an NSAID such as carprofen 2 mg/kg or buprenorphine 0.05 mg/kg sc or iv should be administered preemptively in the prep room. Depending upon the procedure analgesics may have to be administered postoperatively for several days.[1]

It may be necessary to provide soft food or a liquid diet postoperatively as well. We have found that a combination of canned dog food and a liquid protein diet can sustain swine during this recovery period. Oral glucose/electrolyte solutions are also well tolerated by swine. Decisions on the perioperative care need to be made in consultation with the attending veterinarian. The behavior and activity of the animal will determine the necessity of the treatments in the postoperative period.[1]

The tusks of the pig need to be trimmed periodically in adult animals, especially in boars, for personnel safety.[1, 5] In order to perform this procedure, pigs should have general anesthesia or chemical restraint. They may be trimmed in restraint slings with sedation. The roots of the canine teeth are deep and difficult to extract, consequently, the tusks are usually trimmed at the gum line using either Gigli wire or saws. In the adult male, this procedure needs to be performed every 3-6 months. Tusks are slower growing in castrated males and females and may not need to be trimmed. Veterinary advice should be sought to make this determination.

Dental extractions can be performed on the other teeth using standard methods of root elevation followed by extraction. Mucoperiosteal flaps may be reflected from the gingiva in the cranial aspects of the oral cavity using standard techniques of incision and retraction of the gingiva. Use of local anesthetics containing epinephrine as an adjunct to general anesthesia should aid hemostasis by the induction of local vasoconstriction. Oral incisions should be closed with absorbable sutures.[1]

Models

The sequence of eruption, especially of the permanent teeth, is predictable and follows a similar pattern to human. In addition the pig has the highest number of permanent teeth of any of the larger animals. Because the pig is an omnivore the chewing pattern and wear on the surface of the teeth is another indication for their use in dental surgery.[1, 2, 8, 15, 17, 20]

Much of the research conducted in swine in this arena deals with the implant of biomaterials and the study of wound healing patterns. Attempts have been made to determine the critical-size defect for mandibular healing to occur.[16] Defects of 1.9cm^3 to 10.1 cm^3 have been created in the mandible of minipigs with the alveolar crest defects being covered with periosteum. Healing after six weeks varied from 57.4% to 75.5% not necessarily related to the size of the defect. It is likely that there is a variation between breeds and ages of pigs to determine this figure. An average of 5cm^3 has been suggested.

Standardization of the radiographs and CT scans in minipigs has been performed by several investigators. These have included both intra- and extra-oral techniques as well as the optimal angles, focal distances and time of the exposures.[18]

Conclusions

It is likely that the minipig will continue to be utilized in dental and oral surgical procedures. Although primates may be an attractive model because of their taxonomic relationship to humans, their use for these types of procedures will continue to be minimal due to ethical and species conservation issues. The pig as an omnivore with the anatomic and physiologic similarities described above and in the references is an attractive model for future studies, especially those involving implantion and wound healing techniques.

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