

Tooth extraction techniques in horses, pet animals and man

Extractietechnieken bij het paard, gezelschapsdieren en de mens

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ABSTRACT

Several techniques have been developed to extract teeth in different animal species regularly seen in veterinary practice. Many of these techniques have a lot of similarities with human extraction techniques, whereas others are species specific. Overall, they can be divided into simple or closed extractions, and surgical extraction techniques. Simple extractions involve the removal of teeth or root fragments using an intra-oral approach and without exposing or removing alveolar bone. More complex intra- or extra-oral approaches and surgical techniques are used during surgical extractions. This paper reviews the current concepts of the different methods for removing teeth in horses, dogs, cats, lagomorphs and rodents, and compares them with human exodontic procedures.

SAMENVATTING

Om tanden te verwijderen bij die diersoorten die regelmatig de dierenartsenpraktijk betreden, beschikken we over verschillende extractietechnieken. Veel van deze technieken zijn ontleend aan de humane tandheelkunde terwijl andere methoden specifiek ontwikkeld werden voor een bepaalde diersoort. Algemeen gezien kunnen we een onderscheid maken tussen eenvoudige of gesloten extracties en chirurgische extracties. Het eerste type wordt uitgevoerd via de mond terwijl bij het tweede type de zieke tand zowel via de mond als van buiten de mond kan verwijderd worden. In dit artikel worden de huidige trends overlopen op het vlak van tandextracties bij het paard, de hond en de kat, alsook bij konijnen en knaagdieren en plaatst deze tegenover de gangbare technieken die gebruikt worden in de humane tandheelkunde.

INTRODUCTION

Although the primary goal of dentistry should be the preservation of the dentition, for varying reasons, tooth extraction may be in the best interest of the individual presented with a clinical problem. In addition, tooth extraction is by far the most commonly performed oral surgical procedure in man (Batenburg *et al.*, 2000) and domesticated animals such as the horse, the dog, the cat, lagomorphs (rabbit) and rodents (Gaughan, 1998; Bellows, 2004a). Common indications for tooth removal are quite similar in all species and include pulpitis or periapical infection induced by dental decay or traumatic pulp exposure, severe periodontal disease, retained deciduous teeth and malocclusion problems (Scheels and Howard, 1993; Legendre, 1994; Dixon, 1997a; Wiggs and Lobprise, 1997a; Sullivan, 1999; Alsheneifi and Hughes, 2001; Richards *et al.*, 2005). The solution of malocclusion problems may involve extraction of a healthy tooth contributing

to misalignment (Wiggs and Lobprise, 1997b; Richards *et al.*, 2005). In man, teeth may also be extracted for pre-prosthetic reasons (Richards *et al.*, 2005). Less commonly reported indications for tooth extraction in both man and animals include the presence of impacted teeth (Edwards, 1993; Saunders *et al.*, 2003; Esposito, 2006; Taney and Smith, 2006), supernumerary teeth (Dole and Spurgeon, 1998; Solares and Romero, 2004; Dixon and Dacre, 2005), teeth involved in pathologic lesions such as tumors, and teeth in the line of a jaw fracture compromising bone healing.

General extraction techniques and equipment are similar in most species, although species-specific instruments and surgical approaches to teeth have been developed to accommodate to the differences in tooth characteristics, skull anatomy, the embedded dentition and its surrounding soft tissues. Each dental case requires a thorough evaluation to choose the best suitable technique so the best result can be obtained. Decision making must be based on tooth identity,

Table 1. Explanation of dental terminology

Dental terminology	explanation
Apical	direction toward the root tip
Buccal	the surface of the tooth facing the cheek
Coronal	direction toward the tooth crown
Distal	the surface of the tooth facing away from the central point of the tooth arch
Gingival papilla	cone-shaped pad of gingiva filling the space between teeth up to the contact area (syn.: interdental papilla)
Interproximal space	space between adjacent teeth
Labial	the surface of the tooth facing the lips
Lingual	the surface of the tooth facing the tongue
Mesial	the surface of the tooth facing the central point of the tooth arch
Occlusal	at the level of the occlusal surface of the tooth
Palatal	the surface of the tooth facing the hard palate

the pathology encountered, surgical experience, knowledge of the anatomy of the oral structures and of the different extraction techniques, and the availability of surgical equipment. This first review in a series of two papers focuses specifically on the different available extraction techniques in man and commonly seen animals in veterinary dental practice. The purpose of this paper is to review the similarities and differences in extraction techniques between man and animals. This should introduce the veterinary practitioner to the variety of extraction procedures, and guide him/her in the choice of the correct technique in accordance with the situation and the patient they are confronted with. A thorough knowledge of extraction procedures is imperative for understanding their specific pitfalls and subsequent potential for complications. A second review will focus on these matters.

Dogs and cats will be referred to as 'small animals'. Dogs, cats, lagomorphs and rodents will be referred to as 'pet animals'. The commonly used dental nomenclature is summarized in Table 1.

GENERAL CONSIDERATIONS REGARDING TOOTH EXTRACTION

The teeth of all species discussed in this review are firmly set in tooth sockets, residing within the margins of the maxillary and mandibular bones (thecodont teeth). They are attached to the bony walls by the periodontal ligament. This ligament serves as a fixator for the teeth in the jaw but also has shock absorbent and pain-perceptive functions (Grove, 1985). All extraction techniques focus on the disruption of this ligament, thus enabling the removal of the tooth. Species-dependent intra- and extra-oral approaches have been described to accomplish this task. For intra-oral extraction procedures, a simple approach involves the removal of teeth or dental root fragments without exposing or removing alveolar bone, whereas during a surgical approach, gingival tissues are incised and the alveolar cortex may be removed to expose the diseased tooth and its roots.

Man and small animals have a lot of similarities regarding their dentition and the accessibility of their teeth for dental procedures (Wiggs and Lobprise, 1997c; Burns and Herbranson, 1998). Their teeth are characterized by limited growth in time (anelodont dentition) and have distinct roots that are longer than the crown (brachyodont teeth). They clearly differ from horses, lagomorphs and some rodents in the variation in size and shape of their teeth (Harvey and Dubielzig, 1985). Accessibility of the mouth and of all its related structures is excellent due to the wide range of motion of the temporomandibular joint (TMJ) and the flexibility of the labial commissures. The use of a mouth gag facilitates accessibility and exposure of the dentition in dogs and cats, although this device should be used with caution to prevent iatrogenic damage to the muscles and TMJ (Bellows, 2004a).

Horses and rabbits have long-crowned teeth with no (lagomorphs) or limited (horse) anatomical root formation, which are called hypsodont teeth (Baker, 1991; Crossley, 1995a; 1995b). These teeth erupt continuously to compensate for tooth wear caused by the abrasive nature of their diet (Crossley, 1995a; Easley, 1996). The presence of a toothless zone between incisors and cheek teeth (diastema), and the rostral positioning of their labial commissures hinder the accessibility to the cheek teeth.

Some rodents, including the guinea pig and the chinchilla, have a complete hypsodont dentition. Most others (mouse, hamster, prairie dog) have hypsodont incisors but brachyodont cheek teeth. The accessibility of the mouth is very poor in most rodents.

The majority of extraction procedures in man are performed using local and regional anesthesia, occasionally combined with the administration of anxiolytic or sedative drugs (Batenburg *et al.*, 2000). Infiltration anesthesia and regional nerve blocks, including inferior alveolar, lingual, buccal, maxillary, nasopalatine and infraorbital nerves, are routinely performed by the human dentist. Analgesia by inhalation of a mixture of oxygen and nitrous oxide or even general anesthesia can be used

in mentally disabled or very anxious or fractious human patients or for more invasive or extensive procedures such as the extraction of several "wisdom" teeth (Batenburg *et al.*, 2000).

Several regional anesthesia procedures have been described for exodontics in the standing horse in combination with sedatives or tranquilizers (Scrutchfield *et al.*, 1996; Vlamincx and Steenhaut, 2001; Ramzan, 2002). Difficult or complicated equine cases are preferably performed under general anesthesia (Dixon, 1997b; Tremaine, 2004).

General anesthesia is the rule of thumb for dental procedures in pet animals. The growing appreciation of pre-emptive pain management to prevent or minimize intra- and postoperative pain encourages the use of local infiltration anesthesia or intra-oral regional anesthetic nerve blocks (Rochette, 2005), including the rostral and caudal infraorbital, the maxillary, the inferior alveolar, the mental and the buccal nerve blocks (Lantz, 2003; Bellows, 2004b). No local anesthesia procedures have been described in lagomorphs or rodents.

SIMPLE OR CLOSED TOOTH EXTRACTION

A simple or closed tooth extraction involves an intra-oral minimally invasive procedure for tooth removal without incising the gingival mucosae or removing alveolar bone tissue (Knaake and van Foreest, 2005). It is the first choice procedure for removal of most single-rooted teeth or severely diseased teeth with minimal periodontal attachment. In all other cases, surgical extractions are preferred (Hooley and Golden, 1994). This technique has been described for the removal of all teeth in man with the exception of the 3rd molar (Batenburg *et al.*, 2000).

In dogs, it can be used for removal of all incisors, and for the 1st premolar and 3rd molar, whereas in cats it can be used for removal of the upper 2nd premolar and upper 1st molar, depending on the periodontal health of these teeth (Smith, 1998; Gorrel, 2004). However, several authors strongly recommend the use of surgical extraction techniques in cats because of the brittle nature of their teeth and because the increased chance of root ankylosis in the presence of feline odontoclastic resorptive lesions is the primary indication for feline exodontics (Bellows, 2004a; Harvey, 2004; Knaake and van Foreest, 2005). Closed extraction is the standard technique for oral extraction of cheek teeth in horses (Lowder, 1999; Tremaine, 2004; Dixon *et al.*, 2005).

The incisors of rabbits and rodents can be readily extracted using the closed technique. However, limited visibility and difficult access to the oral cavity generally makes the use of this technique more difficult for the removal of the long-crowned cheek teeth, with the exception of the first cheek tooth (Capello and Gracis, 2005a). The brachydont teeth of larger rodents such as the prairie dog can be removed using the intra-oral approach (Capello and Gracis, 2005a).

Releasing gingival attachments

Closed extraction requires the use of several instruments, including dental luxators or syndesmotoms,

elevators and extraction forceps (Figure 1). In the first step of the extraction, the gingival attachment to the tooth is severed up to the level of the cortical alveolar rim. In man, this is normally done using a dental or periosteal elevator of various shapes and forms (Sullivan, 1999; Malden, 2001), or by direct use of the extraction forceps (Boering, 1976a). Myer (2002) advocated the use of a dental luxator in man.

This instrument has a sharp tip and wide, thin slicing edges allowing easy insertion in between the tooth and its surrounding tissues, thus severing not only the gingival attachments but also the periodontal fibers. The same can be done using a syndesmotom, a half moon shaped instrument with a sharp tip. In pet animals, the use of elevators as well as luxators of appropriate size has been described (Bellows, 2004a; DeBowes, 2005), although scalpel blades have also been recommended for the same purpose (Verstraete, 1983; van Foreest, 1992; Scheels and Howard, 1993). In the horse, severing of the gingival attachment to the cheek teeth is performed using a long-handled, flat-bladed dental pick or a customized periodontal elevator (Dixon *et al.*, 2005; Tremaine and Lane, 2005).



Figure 1. Illustration of different instruments used for tooth extractions in man. 1. Syndesmotom; 2. Dental elevator; 3. Upper molar extraction forceps; 4. Lower molar extraction forceps. 5. Dental luxator; 6 and 7. dental root elevators.

Periodontal ligament breakdown

The next step of the closed extraction technique involves severing the fibers of the periodontal ligament. In man and pet animals, the most coronal part of this ligament can be cut using a dental luxator, although a dental elevator can also be used for this purpose. The luxator is gently pushed in between the tooth and the alveolar bone plate and is worked circumferentially around the tooth, releasing the first millimeters of the ligament's attachment to the alveolar wall. The luxator is not suitable, however, for levering actions because the instrument can break easily. Consequently, Bellows (2004a) considered this instrument to be an advanced oral surgical tool for use only by the experienced dental veterinary surgeon.

The actual breakdown of the periodontal ligament is accomplished using dental elevators. It is important to realize that the highly resistant periodontal ligament is broken down more easily with slow, steady pressure instead of quick, brutal force (Lowder, 1999).

The use of the dental elevator is similar in the majority of the different types of teeth in man and small animals. Using constant small rotational movements, a straight dental elevator is pushed as deeply as possible apically into the interproximal space between the tooth and the alveolar wall using a buccal approach. Moderate rotational pressure, maintained for several seconds to minutes, constantly stretches the periodontal ligament, causing hemorrhage and gradual fatiguing (van Foreest, 1992; Batenburg *et al.*, 2000). Initially, progress may be slow and frustrating but as torque time is increased, the tooth will eventually become mobile (Bellows, 2004a). In man, it is sometimes beneficial to use an adjacent tooth as an abutment to exert force on the diseased tooth, provided that this element is firmly supported by surrounding structures and not weakened by dental decay or interproximal tooth restorations (Batenburg *et al.*, 2000; Myer, 2002). This action is discouraged in dogs and cats because the relatively small diameter of the tooth neck in relation to the length of the roots increases the risk of crown fracture (Verstraete, 1983; van Foreest, 1992). Elevator actions are continued until the tooth can be removed or becomes sufficiently loose to allow subsequent forceps extraction.

The shape of the 'Crossley luxator' has been specifically developed to break down the periodontal ligament of incisors and cheek teeth in lagomorphs and rodents, although other dental elevators or properly bent 18 to 20 gauge hypodermic needles can also be used in these species (Wiggs and Lobprise, 1995; Hartcourt-Brown, 2003; Capello and Gracis, 2005a; 2005b; 2005c; 2005d). In contrast to luxators for human and small animal use, the 'Crossley luxator' can be used to exert limited levering force on the teeth.

Equine retained deciduous incisors and the 1st premolar, which is also called the wolf tooth, are amenable for dental elevator procedures (Dixon, 1997b; Gaughan, 1998). To stretch and tear the periodontal ligament of the equine cheek teeth, a molar spreader or separator is used. The wedge-shaped blades of this instrument are gradually forced into the interdental space rostral and caudal to the affected tooth, just above the gingival margin (Figure 2) (Dixon *et al.*, 2005).

Pressure on the instrument is maintained for 1 to 3 minutes to induce tearing of the rostral and caudal periodontal attachments, taking care to avoid undue force. By alternating the instrument's position rostral and caudal to the tooth, and repeating the wedging action of the spreader, the instrument will eventually close completely, facilitating further extraction with the use of forceps (Lowder, 1999; Tremaine, 2004).

Tooth extraction

Once the tooth is markedly loosened, the final extraction can be performed. For readily accessible teeth, this can be achieved by pushing the dental elevator deeper into the alveolar space and lifting the tooth out of the alveolar socket (van Foreest, 1992; Smith, 1998). The curved root of the large canine tooth in small animals is less amenable for this technique (Scheels and Howard, 1993). Alternatively, extraction can be done using appropriately sized forceps. This instrument is firmly fixed on the tooth's crown as apically as possible. Remaining periodontal ligament fibers are torn by gently rotating the tooth on its longitudinal axis until the tooth can be removed from the alveolus (Boering, 1976a). Firm resistance indicates that a significant portion of the periodontal ligament is still intact and further 'elevator' work is needed before reapplying the forceps (Verstraete, 1983).

In man, teeth are commonly extracted 'per forceps' without the prior use of dental elevators (Batenburg *et al.*, 2000). Boering (1976a) stated that extraction with a dental elevator is only indicated when extraction 'per forceps' is impossible. The forceps is first gently placed on the tooth's crown above the level of the gingiva. Next, the instrument is gradually advanced apically using rotational movements to reach the level of the alveolar rim and subsequently firmly fixed on the crown. Extraction forces are exerted in a buccolingual or bucco-palatal direction. To avoid tooth fracture, the use of rotational forces in the beginning of the extraction procedure is contra-indicated except for the mandibular premolars and maxillary central incisors because of the round shape of their roots.



Figure 2. A. Side view of a molar spreader. The jaws of this instrument are wedge-shaped to allow placement between two equine cheek teeth to tear the rostral and caudal periodontal attachments. B. The spreader is used between the 2nd and 3rd lower premolar.

Once the tooth can be partially luxated, rotational movements with the forceps will further weaken the periodontal ligament, thus allowing complete extraction. During this procedure, the alveolar process should be supported with thumb and index finger of the non-extracting hand (Batenburg *et al.*, 2000). Extraction 'per forceps' requires maximum contact between the tooth and the extraction instrument.

Only Scheels and Howard (1993) described the same principle for exodontia in dogs or cats, whereas most authors recommend the elevator technique to first loosen the tooth and then to apply a dental extraction forceps for the actual extraction (Verstraete, 1983; van Foreest, 1992; 1995; Smith, 1998; Bellows, 2004a; DeBowes, 2005). Human extraction forceps have been constructed in accordance with the anatomy of the different elements in man. However, they seldom fit dog and cat's teeth, thus making 'per forceps' extraction in these animals a relatively risky procedure (Bellows, 2004a). Harvey and Emily (1993) expressed their concerns for the increased risk of tooth fracture in dogs and cats when only a forceps is used. However, some human instruments fit well for dental extractions in small animals, and special instruments have been constructed for specific use in these animals (Verstraete, 1993; Zoll, 1991, van Foreest *et al.*, 1992).

The use of a specially adapted extraction forceps has been described for oral extraction of the 1st hypodont cheek tooth in lagomorphs and the brachyodont cheek teeth of large rodents, although extraction can also be performed using simple hemostat clamps (Capello and Gracis, 2005b). The small size of most rodents often precludes intra-oral attempts for hypodont cheek tooth removal. Extra-oral techniques are therefore preferred in most cases. In lagomorphs, the extra-oral approach is used whenever an intra-oral technique fails (Capello and Gracis, 2005e).

In equine patients, the correct use of specially designed extraction forceps is crucial for successful intra-oral extraction of a diseased cheek tooth with an intact periodontal ligament. The sole use of dental elevators will not result in tooth removal (Dixon, 1997b; Lowder, 1999; Dixon *et al.*, 2005). Molar extractors of different sizes should be available to allow the best grip on the diseased tooth (Tremaine, 2004). The forceps is firmly fixed on the clinical crown close to the level of the alveolar rim (Figure 3). Continuous, alternating latero-lateral force is exerted to induce disruption of the buccal and lingual/palatal periodontal attachments. This procedure may take up to 2 hours before a hypodont tooth in a young horse is sufficiently loosened to allow subsequent removal (Tremaine and Lane, 2005). For the actual extraction, a separate instrument, the fulcrum, is needed, which serves as a levering point for the exertion of a vertical extraction force on the tooth. This fulcrum is placed on the occlusal surface of the tooth in front of the diseased element. Gentle but continued vertical pressure on the extraction forceps is necessary to lift the tooth from its alveolus. Space limitations in the back of the horse's mouth sometimes necessitate deviating the tooth medially, in order to be able to extract it entirely. If this is impossible, the tooth can be removed in two pieces after cutting it in half with molar cutters or using

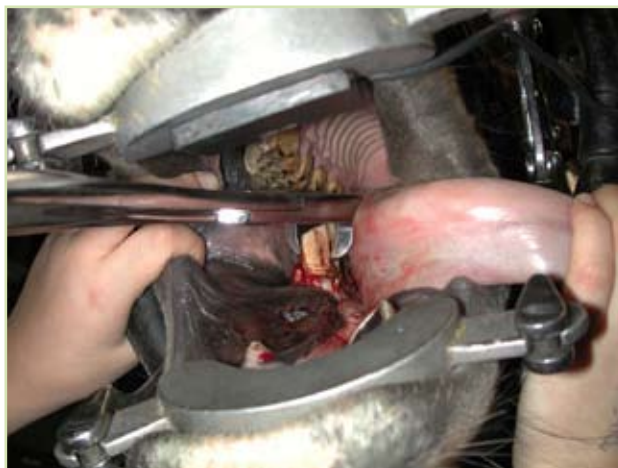


Figure 3. Fixation of the extraction forceps on the mandibular 2nd premolar in a horse.

Gigli wire (Lowder and Mueller, 1998; Dixon *et al.*, 2000). Extraction 'per forceps' without the prior use of dentalelevators is a straightforward procedure for removal of retained deciduous cheek teeth or 'caps' in horses. The thin flat 'caps' are rolled medially during extraction to avoid fragmentation of the short buccal dental roots (Scrutchfield *et al.*, 1996; Tremaine and Lane, 2005).

Sectioning multi-rooted teeth

Sectioning multi-rooted teeth to facilitate extraction is rarely indicated in human dentistry. The roots of human teeth are relatively short and the presence of diverging roots in multi-rooted teeth is quite exceptional, allowing intact extraction using the standard elevator and/or forceps techniques (van Foreest, 1992; Batenburg *et al.*, 2000). Tooth sectioning has been described for removal of two or three-rooted molar teeth and is often started by removal of the entire crown followed by further sectioning into single-rooted segments (Boering, 1976b). Sectioning procedures and the use of more invasive techniques are more frequently indicated for tooth removal in cases of advanced dental decay with higher risks of crown fracture (Sullivan, 1999; Batenburg *et al.*, 2000), and for the surgical management of impacted 3rd molar teeth (Mehra and Baran, 2006). Irrigation is imperative in each sectioning procedure, to avoid heating the tooth and inducing the development of thermal necrosis of the surrounding bone.

In dogs and cats, tooth sectioning is a standard procedure prior to extraction of most multi-rooted elements with an intact periodontal attachment. The multi-rooted brachyodont teeth of these animals are more firmly fixed in the mouth compared to human teeth, due to the frequent divergence of the different roots (Figure 4), the smaller periodontal space, and the larger root-crown ratio, which can render their 'en bloc' extraction extremely difficult and hazardous (Verstraete, 1983; Kapatkin *et al.*, 1990; van Foreest *et al.*, 1992). However, multi-rooted teeth with advanced periodontal disease and secondary mobility may be extracted without prior sectioning (Smith, 1998).



Figure 4. Sectioning of this upper 4th premolar in a dog was indicated not only because of the normal divergence of the roots but also because of dilaceration (severe bending) of the mesio-buccal root.

In horses, lagomorphs and rodents, tooth sectioning techniques for closed extraction procedures of their hypsodont teeth have not been described, most likely because their roots are underdeveloped.

Tooth sectioning is mostly performed with a high-speed, dental handpiece and a bur (Scheels and Howard, 1993). The type and size of the bur are dependent on the size of the tooth. In human teeth, a fissure bur is recommended to make an incomplete cut starting at the level of the crown and directed towards the furcation (Batenburg *et al.*, 2000). Separation of the incompletely cut tooth segments is achieved by introducing a small dental elevator that is torqued. In small animals, the use of round, pear shaped, cylindrical straight or tapered burs has been described for sectioning (Scheels and Howard, 1993; Smith, 1998; DeBowes, 2005). In contrast to the procedure in man, a complete cut is made starting at the level of the furcation and working towards the crown (Smith, 1998; DeBowes, 2005). To improve visualization of the root furcation, Wiggs and Lobprise (1997c) recommended discrete elevation of the cortical alveolar plate using a surgical periosteal elevator. In a lot of cases, however, supplementary surgical exposure is required by reflecting a mucoperiosteal flap and removing a part of the buccal or labial alveolar wall, thus making this procedure a surgical extraction (Figure 5) (Smith, 1998; Maretta, 2002; DeBowes, 2005). Other devices have been used as alternative instruments for tooth sectioning in small animals, including a Gigli wire saw, a tooth splitting forceps, and a diamond disk on a straight handpiece. However, these instruments lead to an increased risk of damaging adjacent bone and soft tissues (Verstraete, 1983; van Foreest, 1992; Harvey and Emily, 1993; Smith, 1998).

After sectioning, the single-rooted fragments can be subsequently removed using dental elevators and/or extraction forceps techniques (Boering, 1976b; Smith, 1998).

SURGICAL EXTRACTION

Surgical exodontic procedures involve the creation of mucoperiosteal flaps and/or the removal of cortical bone to improve tooth/root exposure and to facilitate



Figure 5. Maxillary 4th premolar of a dog which has been sectioned after flap elevation and removal of part of the buccal alveolar wall.

extraction (Smith, 1998; Malden, 2001; Knaake and van Foreest, 2005; Batal and Jacob, 2006). These more invasive techniques are indicated for the removal of more complex multi-rooted brachydont teeth in man and small animals (Batenburg *et al.*, 2000; Carmichael, 2002; Maretta, 2002), and for the extraction of the less accessible hypsodont cheek teeth in lagomorphs, rodents and horses (Turner and McIlwraith, 1989; McIlwraith and Robertson, 1998; Capello and Gracis, 2005e). The extraction of canines in small animals and horses (Smith, 2001; Fitch, 2003; Dixon and Gerard, 2006), as well as of equine incisors, also requires more invasive procedures (Gaughan, 1998; Tremaine and Lane, 2005). Both intra- and extra-oral approaches have been described, depending on the animal species and the diseased tooth.

Intra-oral approach for surgical tooth extraction

Reduction of the height of the alveolar rim

By removing a small portion of the alveolar rim, the surface of exposed crown will increase, allowing a more secure fixation of the tooth with extraction forceps. Thin bony margins can be removed by crushing them with rongeurs or an extraction forceps, as described in man (Boering, 1976b) and horses (Dixon *et al.*, 2005). However, this procedure is currently advised against in human dentistry in favor of atraumatic tooth extraction to maximally preserve the height of the alveolar ridge for immediate or future placement of implants (Quayle, 1990; Levitt, 2001). For the removal of retained root fragments, reduction of the alveolar height with dental burs is more frequently performed in man (Boering, 1976b; Batenburg *et al.*, 2000; Malden, 2001) and small animals (Smith, 1998; DeBowes, 2005) to expose the fragments.

Mucoperiosteal flap elevation and alveolar bone removal

Mucoperiosteal flaps provide better visualization and access to the underlying structures and protect tissues from possible iatrogenic trauma during bone removal and tooth sectioning (DeBowes, 2005). Several



Figure 6. This triangular flap with a mesially located releasing incision provides adequate exposure of the underlying alveolar bone for extraction of a maxillary 4th premolar in a dog.

flap designs have been described: in the envelope flap, a horizontal incision is made across the interproximal gingival papilla without vertical releasing incisions. On the other hand, flaps with mesial and/or distal vertical releasing incisions creating a triangular or rectangular/trapezoid shape provide better exposure of the alveolar bone plate (Figure 6) (Bellows, 2004a; Knaake and van Foreest, 2005; Batal and Jacob, 2006).

Properly designed flaps are imperative for accurate postoperative wound closure without tension (Bellows, 2004a). When creating large flaps, one should avoid sectioning the major nerves and blood vessels (Scheels and Howard, 1993). A sharp periosteal elevator is the instrument of choice for elevating the flap tissues from the underlying bone. If this results in exposure of the furcation area of multi-rooted teeth, tooth sectioning and subsequent removal of the single-rooted parts is done using the above described elevator and extraction techniques (Kapatkin *et al.*, 1990).

If the furcation of the tooth is not visible after flap elevation, the height of the alveolar rim can be moderately reduced (alveolotomy) to allow further extraction procedures (van Foreest, 1992; Batenburg *et al.*, 2000; Knaake and van Foreest, 2005). Alveolotomy is rarely indicated in human exodontia and, if possible, avoided in order to preserve the height of the alveolar rim for future implant placement (Batal and Jacob, 2006). Exceptions include the removal of tooth roots or impacted teeth, and last molar extraction complicated by improper positioning or impaction (Boering, 1976b; Batenburg *et al.*, 2000; Mehra and Baran, 2006). Flap elevation combined with an alveolotomy is the preferred technique for removal of the upper 4th premolar, upper and lower 1st molars, and retained roots in dogs and cats (Carmichael, 2002; Mareta, 2002; Bellows, 2004a). It is also indicated when performing single or multiple (full mouth) extractions in cats (DeBowes, 2005; Knaake and van Foreest, 2005).

Removal of larger amounts of alveolar bone or complete removal of the alveolar wall on one side of a tooth (*alveolectomy*) has been recommended for exposure of ankylosed roots, for canine teeth removal in small animals (Smith, 2001; Fitch, 2003), and for canine or incisor extraction in horses (Tremaine and Lane, 2005; Dixon and Gerard, 2006).

For extraction of the canine tooth in small animals, a distally directed triangular, rectangular or trapezoidal mucoperiosteal flap is created on the buccal side to follow the caudal (distal) extension of the root. The buccal alveolar bone is completely (Scheels and Howard, 1993) or partially removed to expose $\frac{1}{3}$ to $\frac{1}{2}$ of the root (Fitch, 2003). Afterwards, longitudinal superficial grooves (Legendre, 1996; Fitch, 2003) or localized slots (Smith, 1998) are made along the mesial and distal borders of the tooth to allow the use of a dental elevator for gradual loosening of the periodontal ligament. Extraction is accomplished with elevator or forceps techniques (van Foreest, 1992; Holstrom *et al.*, 1992; Harvey and Emily, 1993). More recently, a lingual approach has been described for extraction of the mandibular canine tooth in dogs to avoid possible damage to the neurovascular structures of the mental foramen and the roots of the mandibular 1st and 2nd premolar teeth (Legendre, 1997; Smith 1996; 1998; 2001). A mucoperiosteal flap is created near the lingual frenulum and intermandibular symphysis, and this is followed by removal of a large part of the lingual alveolar bone. Canine tooth removal is then performed using previously described elevators and extraction forceps. Currently, both techniques are accepted for canine tooth extraction, and a combined approach (buccal and lingual) has been described (Gorrel, 2004).

In horses, a buccal or labial longitudinal incision is made in the gingival tissues along the long axis of the canine or incisor teeth, respectively. After elevation of the gingival tissues and removal of part of the alveolar wall, the teeth can be extracted as described above (Gaughan, 1998; Tremaine and Lane, 2005; Dixon and Gerard, 2006).

No comparable intra-oral surgical extraction technique has been described in lagomorphs or rodents.

Extra-oral approach for surgical tooth extraction

Extra-oral approaches for tooth removal have not been described for standard exodontia in man and small animals. However, some of these techniques have been used for cheek tooth extraction for more than 100 years in horses (Merillat, 1906). Currently, most equine surgeons advise a forceps extraction attempt before surgical extraction is performed (Gaughan, 1998; Tremaine and Lane, 2005). Extra-oral extraction is also the preferred technique for removal of difficult to access hypsodont cheek teeth in lagomorphs and rodents (Capello and Gracis, 2005e). In these species, the technique is specifically useful for extraction of all mandibular cheek teeth, whereas the last maxillary cheek tooth cannot be approached extra-orally because of its location immediately below the eye. Other indications in the rabbit include dental ankylosis, retained root tips, severe root deformity, periapical abscessation and osteomyelitis (Capello and Gracis, 2005e).

Several extra-oral techniques have been described. Overall, they can be categorized in two groups: one involving an approach to the root(s) through the external cortical bone, and another involving a lateral approach to the tooth through the buccal soft tissues.

Approach to the roots through the external cortical bone

In horses this technique is known as extraction by repulsion. It requires an osteotomy or trephination to expose the roots of the diseased tooth. Extraction is achieved by driving/repelling the tooth into the mouth with a dental punch (Turner and McIlwraith, 1989). Although all cheek teeth can be removed by repulsion, Tremaine and Lane (2005) suggested the technique to be the best surgical choice for the removal of the three maxillary molars and the last mandibular molar because these teeth are less accessible for the buccotomy technique. The location of the trephine hole should be directed precisely over the apices of the tooth, which is facilitated by the use of intra-operative radioscopic guidance.

For mandibular cheek tooth repulsion, the osteotomy site is located ventral or ventro-lateral to the mandible; for the maxillary premolars it is located on the dorso-rostral aspect of the maxillary bone (Turner and McIlwraith, 1989; Dixon and Gerard, 2006). A rounded, U-shaped or linear skin incision is made and the underlying soft tissues are dissected to expose the cortical bone. A more lateral approach through the masseter muscle (McIlwraith and Robertson, 1998a), or after elevation of the masseter muscle from the caudal portion of the mandible (Gayle *et al.*, 1999) provides better access for repulsion of the 3rd mandibular molar. After incising and reflecting the periosteum, a round or rectangular bone window is created using an osteotome, oscillating saw or trephine. During the actual repulsion, the crown of the diseased tooth is palpated orally to detect vibrations and confirm correct positioning of the dental punch. In most cases, the tooth will be removed in several pieces (Dixon, 1997b).

For removal of the maxillary cheek teeth (P4 – M3) with roots seated in the rostral and caudal compartments of the maxillary sinus, a sinusotomy can be performed creating a large maxillary bone flap which allows a better visual and digital inspection of the tooth roots (McIlwraith and Robertson, 1998b; Dixon and Gerard, 2006). Several authors (Lane, 1994; Tremaine and Lane, 2005) have questioned the advantages of such a bone flap and advocate the use of traditional trephination. A combined frontal and maxillary sinus approach has been described for repulsion of the caudodorsally inclined 2nd and 3rd maxillary molars (Boutros and Koenig, 2001; Tremaine and Lane, 2005).

In lagomorphs and rodents, the first steps of incising the skin and dissecting the soft tissues are similar as in horses. The cortical bone can be perforated with a hypodermic needle or a water-cooled high-speed dental bur (Wiggs and Lobprise, 1997a), creating a surgical window for root exposure (Capello and Gracis, 2005e). The diseased tooth is then elevated through the surgical incision and removed (Hartcourt-Brown, 2003), although an endodontic plugger or another suitable instrument can also be used to repulse the tooth into the mouth (Crossley, 1995a; Wiggs and Lobprise, 1995). Wiggs and Lobprise (1995) mentioned the possibility of removing alveolar bone on the ventral side of the mandibular incisors to allow tooth elevation and subsequent extraction.

Lateral approach through the buccal soft tissues – buccotomy

A hypsodont cheek tooth can also be removed using a lateral approach that involves entering the oral cavity through an incision in the buccal soft tissues and removing the lateral alveolar bone plate (Evans *et al.*, 1981; Dixon and Gerard, 2006). This technique is called buccotomy and, similar to dental repulsion, has been practiced for over 100 years in horses (Dixon and Gerard, 2006). Several authors recommended this technique as a last resort for cheek tooth removal in rabbits and rodents, when no other extraction options are available (Crossley, 1995a; Wiggs and Lobprise, 1995). However, to our knowledge the procedure has not been described in detail. This procedure requires a prolonged postoperative analgesia and is accompanied by a high incidence of complications in these species (Crossley, 1995a).

Buccotomy is only considered suitable for extraction of premolars in horses (Dixon, 1997b), though it has also been used to remove upper and lower molars (Evans *et al.*, 1981). According to Dixon and Gerard (2006), it is the most suitable technique for chronically infected cheek teeth with substantial cement deposits around the roots, which make it impossible for the tooth to be orally extracted or repulsed. Most authors recommend the use of a horizontal incision parallel to the occlusal surface of the cheek teeth to approach the diseased tooth (Evans *et al.*, 1981; Hawkins and Dallap, 1997; Dixon and Gerard, 2006). Tremaine and Lane (2005) described a vertical incision, parallel to the tooth axis. Special attention is given to avoid damage of the parotid duct, the branches of the facial and buccal nerves, and blood vessels. After dissection of the soft tissues, the lateral alveolar bone is exposed and removed using appropriate instruments such as an osteotome, an oscillating saw or a surgical fissure bur. The tooth is subsequently removed in one piece using dental elevators (Edwards, 1993), or after longitudinal sectioning with a dental bur or osteotome (Hawkins and Dallap, 1997; Gaughan, 1998).

ALVEOLAR DEBRIDEMENT AND WOUND CLOSURE**Root fragment/tip and dental fragment removal**

Radiographic and visual examination of the vacant alveolus and inspection of the tooth after extraction are required to confirm complete removal of all dental structures (Scheels and Howard, 1993). The necessity for root tip removal has been questioned in all species (van Forest, 1995). The current concept in human dentistry is to allow the root tip to be left in place if the risks for retrieval of the root are greater than the benefit of removing it. The absolute requirements in such cases, however, are that the root fragment must be smaller than 4 to 5 mm, deeply embedded in bone and not infected (Batal and Jacob, 2006). The same rules can be applied in small animal dentistry. Non-infected roots are believed to remain vital and will either become encapsulated or be resorbed (Harvey, 2004), but this requires an intact vascular supply to the tooth

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fragment (Smith, 1998). Similarly, Dixon and Gerard (2006) stated that up to one-third of the root of the equine canine can be left in the alveolus in the absence of apical infection, without causing postoperative problems. Retained root fragments of extracted wolf teeth also rarely cause clinical signs (Tremaine and Lane, 2005).

Tooth fragments or fractured root tips can be removed using appropriate intra- or extra-oral extraction techniques according to each species' feasibilities. If the tooth was well-luxated and mobile before fracture of the root occurs, it may be possible to remove small root tips by irrigation and suction (Batal and Jacob, 2006). When the root is still firmly attached to the alveolar bone, it may be further elevated and removed using specialized root elevators and root extraction forceps (Kapatkin *et al.*, 1990; van Foreest *et al.*, 1992; Bellows, 2004a; Batal and Jacob, 2006). In man (Boering, 1976b; Batenburg *et al.*, 2000) and dogs or cats (Smith, 1998; Bellows, 2004a), intra-oral surgical extraction techniques have been used involving mucoperiosteal flap elevation and/or alveolar cortical bone plate removal (Figure 7). Several authors have described the technique of pulverizing retained root fragments in dogs and cats, using a large round bur on a water-cooled dental unit (Kapatkin *et al.*, 1990; Harvey and Emily, 1993; van Foreest, 1995). Scheels and Howard (1993) even considered this procedure as the easiest technique for root tip removal in cats. However, this technique is currently not recommended because it either removes too much of the thin surrounding bone or not enough of the dental tissue, thereby inducing secondary inflammatory reactions and prolonging postoperative pain sensation (Bellows, 2004a; Harvey, 2004).

The presence of dental fragments after tooth repulsion is very common in horses. These fragments can be removed by gentle curettage and flushing of the alveolus. Fractured roots can also be removed with the help of dental picks or root fragment forceps. MacDonald *et al.* (2006) recently described a technique to remove cheek tooth fragments in the standing horse, using the Steinmann pin repulsion method.

Flushing and debridement of the alveolus

After complete tooth extraction, flushing and gentle debridement of the alveolus will remove loose fragments, debris and infected apical tissues (DeBowes, 2005; Knaake and van Foreest, 2005). This can be done using an intra- or extra-oral approach, depending on the surgical technique. Debridement is carefully performed using a dental excavator or appropriately sized bone curette, avoiding damage to the surrounding healthy structures. It is contra-indicated to remove the entire periodontal ligament (excochleation), as this will impede proper healing of the tooth socket (Boering, 1976b). Thorough curettage of the apical region of the rabbit's incisors is of major importance for the purpose of removing any remaining pulp tissue and destroying the dental germinal tissues in order to prevent incisor tooth regrowth (Steenkamp and Crossley, 1999).



Figure 7. A broken root tip of a maxillary 4th premolar in a dog is exposed by mucoperiosteal flap elevation and alveolar bone removal.

Alveoloplasty

Sharp alveolar rims or exostoses caused by intra-oral extraction techniques must be smoothed (alveoloplasty) to avoid possible post-surgical irritation. Squeezing the alveolar bone plates with thumb and index finger immediately after extraction can considerably reduce protruding sharp edges in man and small animals (Batenburg *et al.*, 2000). If necessary, further correction can be achieved with rongeurs or a round dental bur (Scheels and Howard, 1993; Legendre, 1996). This enhances osseous healing and the healing of soft tissues over the extraction site (DeBowes, 2005). It also minimizes possible perforation of a sutured flap by sharp bony edges (Smith, 1998). However, a conservative approach is recommended in man in order to preserve a maximum alveolar ridge height for prosthetic treatment or implant placement (Boering, 1976b). Alveoloplasty has not been reported in horses, lagomorphs or rodents.

Alveolar supplementation

The post-extraction application of bone substitutes in the alveolus has become a common procedure in human dentistry to preserve alveolar ridge height and to provide a firm basis for future implant placement (Calan, 2001). Numerous substances have been commercialized and multiple studies describe new or improved bone regeneration products (Misch and Dietsch, 1993; Huys, 2002). The use of osseointegrative synthetic bone grafts to preserve the alveolar ridge contours has been advocated in dogs and cats following surgical extraction procedures (Maretta, 2002; Bellows, 2004a). It has also been strongly recommended after mandibular canine tooth extraction in small animals, in order to support the strength of the mandible (Legendre, 1997). In maxillary canine extraction, bone grafting has been reported to provide a better cosmetic result by preventing the upper lip from rolling inwards after post-extraction bone resorption (Legendre, 1996). Alveolar supplementation has not been described in the horse, lagomorphs or rodents.

The application of medication in the vacant alveolus is contra-indicated in man and pet animals as it may interfere with wound healing (Boering, 1976b; Scheels and Howard, 1993). However, tetracycline impregnated gelfoam has been mentioned as a preventive drug for post-extraction alveolar osteitis complicating 3rd molar extractions in man (Sorensen and Preisch, 1987). Nevertheless, this method is not universally accepted as a standard treatment in man or small animals (Scheels and Howard, 1993). The application of a doxycycline periosteal gel or a tetracycline ophthalmic ointment after cheek tooth extraction has been described in rabbits (Wiggs and Lobprise, 1997; Capello and Gracis, 2005a).

Dixon *et al.* (2000) mentioned the use of metronidazole soaked gauze bandages after cheek tooth extraction in horses. Following a buccotomy procedure in the horse, the entire alveolus can be packed with a gauze bandage that is gradually removed over a period of 10 to 14 days via an external stab incision (Lane, 1994; Dixon, 1997b). Complete packing of the equine alveolus with gauze bandages, dental wax or acrylics (Evans *et al.*, 1981; Mueller, 1991) has currently been replaced by the use of plugs that only fill the oral third portion of the alveolus (see below).

Closure of the extraction wound

In all species, it is generally accepted to close the extraction wound as this enhances wound healing, prevents contamination from food particles, effectively stops hemorrhage and reduces postoperative pain (Boering, 1976a; DeBowes, 2005; Knaake and van Foreest, 2005; Dixon and Gerard, 2006). This procedure is contra-indicated, however, in cases of active infection in man and small animals in order to allow drainage of infected debris or liquids (Verstraete, 1983). Providing possibilities for extra-oral drainage of infected areas is feasible after extra-oral tooth extraction procedures (approach through cortical bone) in lagomorphs and horses, allowing primary closure of the alveolus (Capello and Gracis, 2005e).

In man and pet animals, closure of the alveolus is done by interrupted resorbable sutures (Figure 8) (Batenburg *et al.*, 2000; Bellows, 2004a). The needle is preferably introduced from the buccal to the lingual gingiva, as the buccal gingiva is the most mobile (Boering, 1976a). Tension on mucoperiosteal flaps is prevented by incising the apically located periosteal layer of the flap, thus improving the mobility of the flap (Smith, 1998; Marretta, 2002; Knaake and van Foreest, 2005).

In horses, extraction wounds of incisors, canines and wolf teeth are not sutured but left to heal by second intention (Pence, 2002). The mouth is regularly flushed to remove food particles. Food contamination of the vacant cheek tooth alveolus is prevented by the insertion of a plug in its coronal third. Several substances have been described, including bone wax, methylmethacrylate, dental impression compound, plaster of Paris, gutta percha or gauze bandages (McIlwraith and Robertson, 1998a; Tremaine and Lane, 2005; Dixon *et al.*, 2000; Trostle *et al.*, 2000; Dixon and Gerard, 2006). These plugs are either spontaneously lost



Figure 8. Closure of the alveolus after extraction of a maxillary 4th premolar in a dog is done with simple interrupted sutures.

by granulation tissue formation or removed manually during subsequent dental checkups.

POSTOPERATIVE TREATMENT

Pain control

Pre-emptive analgesia is advantageous in man (Batenburg *et al.*, 2000), but even more important in animals that are less able to express pain sensation. Pre-emptive analgesia decreases the intensity and duration of postoperative pain (DeBowes, 2005). No specific pain relief is required for single closed extractions in man or small animals, but it is certainly justified when multiple or surgical extractions have been performed (Smith, 1998; DeBowes, 2005). NSAID's or opioids are the drugs of choice for pre-emptive and postoperative pain control in all species (DeBowes, 2005). In lagomorphs and rodents, the administration of gastrointestinal motility stimulants is additionally indicated because general anesthesia increases the incidence of intestinal hypomotility (Hartcourt-Brown, 2003).

The benefit of using pre-operative regional nerve blocks in small animals is currently well accepted because it avoids the generation of pain impulses (Rochette, 2005).

Administration of antibiotics or oral antiseptics

Postoperative antibiotic administration for routine exodontics is more an exception than the rule and is only indicated in the presence of an active infection, severe periodontal disease or osteomyelitis (Verstraete, 1983; van Foreest, 1995; Wiggs and Lobprise, 1997c; Smith, 1998; Fitch, 2003; Knaake and van Foreest, 2005). Empirical use of broad-spectrum antibiotics given for 7 days is justified in most cases. Antibiotic choice should be based on culture if the infection is not responding to the initial treatment, in the event of recurrent infection, postoperative wound infection or osteomyelitis (Gorrel, 2004). Oral rinses with 0.12%

chlorhexidine for 1 week have been recommended for small animals (Verstraete, 1983; Bellows, 2004a).

Diet

In man it is preferred not to rinse the mouth the first day after surgery and to avoid pressure on the extraction wound (Batenburg *et al.*, 2000). No food intake until the day after surgery (Verstraete, 1983) or a soft diet for 3 to 7 days can prevent wound dehiscence and contamination in small animals (Smith, 1998; Fitch, 2003; Bellows, 2004a; DeBowes, 2005). Soft or soaked diets are likewise advised in horses (Tremaine and Lane, 2005). Dogs and cats should also be prevented from chewing on tough objects (Knaake and van Foreest, 2005).

CONCLUSION

The differences in anatomy and dentition in commonly seen animals in veterinary practice demand species-specific procedures for the successful extraction of a diseased tooth. Overall, the principles of human tooth extraction techniques can be extrapolated to small animal exodontia due to the brachydont dentition and the possibility to approach teeth from the oral cavity in these species. The teeth of animals with hypsodont dentition may require extra-oral approaches for the removal of their cheek teeth because of the difficult accessibility of the oral cavity. Advances in exodontic techniques and the development of specialized instruments for veterinary use provide optimal conditions to perform tooth extractions in a correct and safe way.

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