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Do Oral or Minimally Invasive Cheek Tooth Extraction Techniques Reduce the Incidence of Post-operative Complications in the Horse When Compared to Repulsion Methods?

A Knowledge Summary by

Victoria. A. Colgate MA VetMB MRCVS[1*]
Claire. E. Wylie BVM&SMSc (Equine Science) MSc (Vet Epi and Public Health) PhD MRCVS [2]
Timothy P. Barnett BSc(Hons) BVM&S MSc CertAVP DipECVS MRCVS[1]

[1] Rossdales Equine Hospital, Cotton End Road, Exning, Newmarket, Suffolk, CB8 7NN
[2] University of Sydney, Sydney, New South Wales, Australia
[*] Corresponding Author (vicky.colgate@rossdales.com)

ISSN: 2396-9776
Published: 18 Jul 2018
in: Vol 3, Issue 3
DOI: http://dx.doi.org/10.18849/ve.v3i3.158
Reviewed by: Russell Parker (BVSc, MSc, MRCVS, ECVS) and James Carmalt (MA, VetMB, MVetSc, PhD, FRCVS, DABVP(Eq), DAVDC(Eq), DACVSMR(Eq), DACVS Professor - Equine Surgery)
Next Review Date: 18 Jul 2020

KNOWLEDGE SUMMARY

PICO question

Do oral or minimally invasive cheek tooth extraction techniques reduce the incidence of post-operative complications in the horse when compared to repulsion methods?

Clinical bottom line

There is evidence that both oral and minimally invasive cheek tooth extraction techniques may reduce the incidence of post-operative complications in the horse when compared to repulsion methods. However, the published literature covering equine cheek tooth extraction techniques is sparse and of low evidential quality, so a definitive answer on the optimal methods available is not easily determined. Bearing this in mind, the results of this PICO suggest the use of oral extraction, after periodontal stretching, as the first line treatment due to its apparently more favourable success rate. Where an alternative approach is required, such as with fractured teeth or loss of clinical crown, which can prevent the use of routine oral extraction methods, results indicate that minimally invasive extraction techniques may result in a better outcome, with fewer complications, than repulsion methods. Further research that accurately categorises the various minimally invasive techniques available and compares them to repulsion and conventional oral extraction methods is needed.

Clinical Scenario

A 7-year old Thoroughbred (TB) mare presents with a recent history of right facial swelling, which is painful and warm on palpation. After examination with an oral speculum, oral endoscopy and radiography you make a diagnosis of periapical infection of cheek tooth Triadan 107 (2nd premolar, upper right arcade). You discuss treatment options with the owner: one of which is to extract the affected tooth. However, the owner is concerned by reports online that cheek tooth removal is associated with a large number of potential complications. What evidence is there to inform the owner that the oral or minimally invasive cheek tooth extraction techniques you have at your disposal are associated with less post-operative complications compared to repulsion techniques carried out under general anaesthesia (GA)?

The evidence

Cheek tooth exodontia is a common procedure in equine practice, yet it is often a complex surgery that has the potential to cause serious short and long-term complications for the horse (Casey and Tremaine, 2010; Ramzan, 2009). Cheek teeth have previously been removed with a punch and hammer by repulsion through an osteotomy or by lateral buccotomy, both of which often require a GA. The traumatic nature of repulsion means that damage to the alveolus, surrounding teeth, as well as the maxillary and mandibular bones is common (Dixon, Hawkes and Townsend, 2008). This can lead to serious post-operative sequelae including: alveolar bone sequestrae, localised osteomyelitis and orosinus fistula with subsequent sinusitis. The clean-contaminated nature of both the repulsion and buccotomy techniques additionally increase the risk of incisional dehiscence and infection to the extent that Lillich (1998) described complications of dental surgery to be 'inevitable'.

With the advent of effective sedatives and regional anaesthetic techniques, more advanced surgeries have become possible in the standing horse (Dixon *et al.*, 2005) and oral extraction is now the treatment of choice for cheek tooth exodontia. Uncomplicated oral extraction should leave the supporting bones intact and the less traumatic nature of the technique means that post-operative complications are comparatively uncommon and, when they do occur, are much easier to treat (Dixon, Hawkes and Townsend, 2008). An 89% success rate

for oral extraction was recorded by Dixon *et al* (2005) in younger horses with a long reserve crown. Additionally Ramzan, Dallas and Palmer (2011) reported an 87% success rate for complete removal of fractured cheek teeth using a dental pick elevation and oral forceps extraction technique under endoscopic guidance. Suggested difficulties of the oral extraction technique include low patient compliance, the presence of teeth with advanced disease that cannot withstand forces of extraction or teeth that have too small a crown to be grasped by instruments (Langeneckert *et al.*, 2015). Even in cases where reversion to a surgical approach is required it has been documented that an initial attempt at oral extraction significantly loosens the periodontal ligament to allow repulsion techniques to be carried out with less force, potentially resulting in fewer complications (Dixon *et al.*, 2012).

Where a surgical approach is required initial evidence suggests that methods, such as minimally invasive transbuccal screw extraction (MITSE) and minimally invasive repulsion may provide a superior alternative to traditional repulsion (Langeneckert *et al.*, 2015). At the very least, these techniques can be performed under standing sedation thus negating the costs and potential morbidity and mortality associated with a GA. Although there is currently little literature on the minimally invasive techniques it seems that these are also not without complication. The transbuccal surgical approach still risks causing damage to the parotid salivary duct, facial vessels and nerves (Langeneckert *et al.*, 2015). Reichert *et al*, (2014) suggested that pre-operative antibiotics were required in all cases as repeated introduction of instruments through the cannula in the cheek led to contamination of the incision, predisposing to infection and dehiscence.

Removal of cheek teeth causes disruption of the mastication unit that, in turn, can lead to wear abnormalities and tooth drift with subsequent adverse long-term effects on the chewing process (Vlaminck *et al.*, 2008). These long-term effects of tooth loss and the complications associated with GA will not be discussed here. Rather, this Patient/Population-Intervention-Comparison-Outcome (PICO) question focuses on the benefits and complications directly associated with the technique chosen for cheek tooth exodontia. A total of 10 papers were found to fit the PICO criteria and the evidence gained from these is reported below.

Summary of the evidence

Langeneckert (2015)	
Population:	Equids (38 Warmbloods (WB), 6 Draft horses, 3 TBs, 3 Quarter horses, 2 ponies, 1 miniature horse and 1 mule) presented to 4 referral centres (3 in Switzerland and 1 in the UK) between 2010 and 2014 for attempted cheek tooth removal by the MITSE technique. Animals ranged in age from 3 to 23 years (mean 11 years) at the time of treatment. Reasons for cheek tooth exodontia included 50 teeth with apical infection, 48 fractures, 4 neoplasia, 2 displacements and 1 supernumerary cheek tooth.
Sample size:	54 equids on which 58 separate MITSE procedures were carried out.
Intervention details:	Medical records between 2010 and 2014 were searched for equids that had undergone a MITSE procedure. In each case identified, the following information was recorded from the medical history: • Signalment • Affected tooth • Preoperative clinical findings and imaging modalities used • History of prior oral extraction attempts and reasons for their failure. • Complications encountered during MITSE and hospitalisation • Additional surgical procedures after MITSE • Duration of hospitalisation

	MITSE was carried out on 49 maxillary and 9 mandibular cheek teeth. A small stab incision was used to create a transbuccal approach and a commercial, purpose built instrument set with a trocar-cannula unit, used to perform the procedure. Follow up information obtained 6-46 months after hospital discharge by telephone interview with the owner or referring vet. Specific information regarding nasal discharge, facial asymmetry and signs consistent with surgical site infection was requested.
Study design:	Multi-centre case series with follow-up.
Outcome studied:	Outcome of MITSE (success or failure), where extraction was defined as successful if the entire dental structure was removed with no need for further intervention. Frequency and type of intraoperative, short and long-term complications were recorded.
Main findings: (relevant to PICO question):	The paper reports that: • 55/58 (95%) cases had previously experienced failed oral extraction. • Subsequent MITSE successfully removed the entire dental structure in 47/58 cases (proportion = 0.81, 95% CI of proportion = 0.70-0.90). Success was seen in 41/49 (84%) maxillary and 6/9(67%) of mandibular cases. • MITSE failed to remove the entire dental structure in 11 cases: 9/11 of these teeth were then successfully removed by a minimally invasive repulsion technique and 1/11 by traditional repulsion. • In 1/11 MITSE failed to completely remove a supernumerary molar but no further efforts were made to extract the residual dental material. • 54/58 MITSE procedures were carried out under standing sedation. Four equids received a GA due to dangerous behaviour. 83 intraoperative difficulties were recorded during 44/58 procedures: • Extraction screw pullout occurred in 32 procedures due to friable tooth material (n=19) or mechanical lockage of the target tooth in the extraction pathway (n=13). • 4/58 cases (7%) developed significant haemorrhage from the trocar incision leading to post-operative swelling of the cheek and transient facial nerve paralysis in 2 cases. • 1/58 cases developed an oroantral communication. • 3/58 cases developed temporary (24 hour) loss of facial nerve motor function due to diffusion of local anaesthetic. Long-term follow-up was available in 41/44 cases where MITSE was successful: • All transbuccal approaches healed without scarring or facial asymmetry.

	• 98% of owners satisfied with cosmetic and functional outcome. • No long-term complications reported after mandibular MITSE. • In 6/17 maxillary cases with pre-operative nasal discharge MITSE failed to resolve this with 5/6 cases requiring further surgical treatment and 1/6 left with intermittent nasal discharge.
Limitations:	• Retrospective study with follow-up being obtained up to 46 months post-surgery, introducing potential for recall bias and loss of cases prior to follow-up. • No control or comparison group. • Limited statistical analysis. • Some horses had multiple teeth removed - each extraction counted as a separate procedure even though it was the same horse. • Most but not all cases had previously undergone oral extraction, which had failed, causing conversion to MITSE.

Reichert (2014)	
Population:	Horses (12 WBs, 3 ponies, 2 Haflingers, 1 Arabian, 1 Morgan, 1 TB and 1 Standardbred) with fractured clinical crown of a cheek tooth admitted to a single German clinic between July 2012 and January 2014 for removal of the tooth by a method other than oral extraction. Mean age of study horses was 11.7 years (range 4-26 years).
Sample size:	21 horses from which 23 cheek teeth were independently removed.
Intervention details:	Medical records of all horses admitted to the clinic between July 2012 and January 2014 were reviewed. Inclusion criteria: Horses that underwent cheek tooth removal by a method other than oral extraction due to presence of an existing clinical crown fracture or that developed idiopathic fracture during attempted oral extraction. Cheek teeth were removed by a variety of techniques: - minimally invasive buccotomy with and without screw extraction (n=20) - traditional repulsion (n=1) - combination of repulsion and traditional lateral buccotomy (n=1) - combination of repulsion and minimally invasive buccotomy (n=1) Short term complications (<14 days post-surgery) were recorded from the clinical records. Long term complications (>14 days post-surgery) and outcome

	obtained by telephone questionnaire with the owner.
Study design:	Single centre case series with follow-up.
Outcome studied:	Outcome of alternative techniques for cheek tooth removal when oral extraction has failed. Type and frequency of complications encountered. Complications were divided into intraoperative, short and long term as well as being further categorised as related to surgery or not.

Main findings: (relevant to PICO question):	• All 23 teeth were successfully removed(100% success rate):
	  ○ 5/23 intact
	  ○ 18/23 in multiple fragments
	
	• Intra- and post-operative complications occurred in 15/23 procedures (65.2%) with 7 of these suffering multiple complications.
	• 12 intraoperative complications were related to surgical technique:
	  ○ development of oro-maxillary fistula after minimally invasive buccotomy (n=6)
	  ○ fragments left in the alveolus after minimally invasive buccotomy(n=3)
	  ○ haemorrhage from the buccotomy site with haematoma formation (n=2)
	  ○ laceration of the palatine artery with resultant haemorrhage during minimally invasive buccotomy (n=1).
	
	The only short-term surgery related complication recorded was incisional infection at the buccotomy site (n=2).
	
	Long-term surgery related complications included:
	• Development of an alveolar sequestrum following piecemeal tooth extraction by minimally invasive buccotomy (n=2).
	• Development of necrotic tissue at the buccotomy site (n=1).
	
	Facial nerve paralysis was not observed after any surgical procedure.

Limitations**:**	• Retrospective study at a single clinic with a small sample size. • The technique for cheek tooth removal was not the same in all cases but results presented together. • Largely descriptive with minimal statistical analysis. • The paper defines fragments left in the alveolus to be an intraoperative complication related to the surgical procedure. • Long term complications and outcome obtained by telephone questionnaire with the owner, giving potential for reporting bias.

O'Neill (2011)	
Population:	Horses (42 WBs, 26 TB crosses, 13 TBs, 11 ponies, 4 miniature ponies and 18 miscellaneous breeds) admitted to 2 referral centres (1 in Belgium and 1 in the UK) between 1999 and 2009 for removal of a cheek tooth by lateral buccotomy. Included horses had an average age of 8.09 years at admission (range 2-25 years) and consisted of 54 geldings, 51 mares and 9 intact males. 52% of buccotomies were carried out due to fractured cheek teeth and just 34% due to periapical infection.
Sample size:	114 horses from which 134 cheek teeth were removed.
Intervention details:	Case records from 114 horses undergoing lateral buccotomy for cheek tooth removal obtained and the following information recorded: • history • presenting signs • diagnostic tests performed • intraoperative complications • post-operative outcomes Short (<2 months) and (> 2 months) outcome obtained by re-examination or telephone interview with the owner/trainer. In all cases where a clinical crown was present oral extraction was initially attempted under standing sedation. If unsuccessful, lateral buccotomy was carried out under GA 24 hours later.
Study design:	Multi-centre case series with follow-up.
Outcome studied:	Success rate (not clearly defined) of lateral buccotomy for cheek tooth removal and frequency of procedure-related, short and long-term complications. Chi-squared test used to compare the incidence of wound dehiscence for maxillary and mandibular extractions. Significance set at $P<0.05$
Main findings: (relevant to PICO question):	The paper reports that lateral buccotomy had a success rate of 70% in the short term and 92% in the long term. 34/114 (30%) horses suffered a procedure-related complication: • 16 horses (14% of total horses) suffered partial wound dehiscence at the lateral buccotomy site, which healed by secondary intention within 6 weeks post-surgery. 13 of these incisions were maxillary and 3 mandibular. • 3 horses (3%) developed permanent facial paralysis with drooping of the lower lip. This was not reported to impair prehension of food or ridden exercise in the long term. • 6 horses (5%) showed signs of temporary paresis of the buccal branch of the facial nerve that resolved within 1

	week. • 4 horses (4%) developed an oroantral fistula. • 4 horses developed myositis post GA. In 3 horses this resolved within 48hrs but a 19yr old horse was euthanased due to severe myositis. (Average GA time was 124 minutes, range 29-200 minutes). • 5 horses developed persistent sinusitis after surgery. 8/114 horses (7%) required further surgical procedures, mostly to treat ongoing sinusitis. In 16% of horses the complications of lateral buccotomy led to long-term sequelae or further surgical intervention in the short term. 92% of the 112 horses available for follow-up (1horse euthanased and another lost to follow-up) returned to their previous level of work >2 months after surgery. There was no significant difference in incidence of wound dehiscence between maxillary and mandibular extractions. (P = 0.55)
Limitations:	• Retrospective study. • Success rates are reported but the definition of a 'success' is not given. • Authors conclude that 'no long-term complications were noted' yet 3 horses suffered permanent facial nerve paralysis. • No control or comparison group. • Most horses had undergone attempted oral extraction, which had failed. • In the methodology the paper claims to compare the incidence of wound dehiscence for maxillary and mandibular extractions but a proportion, rather than an incidence rate, is what is actually calculated. • The lack of a statistically significant difference between these proportions, as calculated by the chi-squared test, is not evidence of lack of a real difference due to the small sample size and lack of a power calculation giving the statistical test low validity.

Ramzan (2011)	
Population:	Horses (15 TB or TB crosses, 7 WB or WB crosses and 8 pony or mixed breed horses) that underwent standing oral extraction of fractured cheek teeth under endoscopic guidance at a single UK hospital between April 2007 and April 2010. 16 mares and 14 geldings were included with an average age of 11.5 years (range 5-23 years). All horses had clinical signs or fracture configurations that were considered to warrant exodontia.
Sample size:	30 horses from which a total of 31 fractured cheek teeth were removed.
Intervention details:	Medical records of horses admitted to the hospital for cheek tooth removal between April 2007 and April 2010 were reviewed.

	Inclusion criteria: horses that underwent oral extraction of a fractured cheek tooth under endoscopic guidance. Exclusion criteria: horses where extraction of the entire tooth was not the aim. In each included case the endoscopic video was reviewed and the following details recorded from the medical history: • Signalment • tooth location • fracture configuration • outcome • variables Under standing sedation and endoscopic guidance, dental picks were used to progressively disrupt the periodontal attachments before elevators and forceps were used to complete the oral extraction. Use of cheek tooth 'separators' was avoided to prevent further breakdown of the clinical crown.
Study design:	Single centre case series
Outcome studied:	The outcome was recorded as a binary categorical variable of 'successful or unsuccessful', where a success was defined as the complete removal of the fractured tooth from the alveolus. Median age of horses in the success and failure group was compared using a Mann-Whitney U-test.
Main findings: (relevant to PICO question):	27/31 fractured teeth (87%) were successfully removed by standing oral extraction with endoscopic guidance. For 4/31 fractured teeth, oral extraction was unsuccessful due to: • Fragmentation of the clinical crown prior to sufficient periodontal loosening (n=2) • Poor access to tooth (n=1) • Poor patient compliance (n=1) Median age of horses in the extraction failure group was 7 years, which was significantly younger than the median age in the extraction success group (median 12 years, P= 0.01, Mann-Whitney U-test)
Limitations:	• Retrospective study with a small sample size. • Study performed at a single hospital, thus limiting generalisability of the results obtained to the wider equine population. • No control or comparison group. • Solely reports success or failure of extraction technique with no details of any complications and no follow-up. • All teeth removed were fractured - so representing a very specific clinical situation.

Coomer (2011)	
Population:	Horses (n=12) and ponies (n=6) undergoing standing cheek tooth repulsion following failed oral extraction in a single UK hospital between 2006 and 2009. Breeds and sexes are not reported but median age of included horses was 7 years (range 1-30 years). All horses had maxillary (n=15) or mandibular (n=5) cheek tooth disease that necessitated exodontia.
Sample size:	12 horses and 6 ponies from which a total of 20 cheek teeth were successfully removed.
Intervention details:	Medical records of 82 horses that underwent attempted oral extraction of a cheek tooth were reviewed. Inclusion criteria: horses where oral extraction failed and the tooth was subsequently removed by standing repulsion (n=18). For included horses the following information was recorded from the medical notes: • signalment • results of clinical, oral, radiographic and endoscopic examinations • surgical technique • post-operative complications Long-term (>6month, range 6-41 month) follow-up was obtained by: • repeat clinical examination (n=9) • telephone interview with owner (n=8). • telephone interview with referring vet (n=1). Repulsion in this study is an adaption of the traditional approach: • For intact teeth a 16mm Galt trephine and dental punch were used to create an osteotomy. • For root fragments a carbide metal drill bit was used to remove bone in preparation for a 5mm dental punch. Intraoperative radiographs were obtained periodically to check punch position and hammering was continued until the tooth was loose enough to be manually removed from the mouth. All surgeries were carried out under standing sedation with maxillary and/or infraorbital nerve blocks to provide regional anaesthesia.
Study design:	Single centre case series with follow-up.
Outcome studied:	Proportion of cases where standing repulsion was successful and type and frequency of post-operative complications.
Main findings: (relevant to PICO question):	The paper reports that: • All 20 cheek teeth (100%) successfully removed by standing repulsion. • In 8 horses the infraorbital nerve block failed to provide

	sufficient desensitisation, requiring a maxillary nerve block to be additionally performed.
	• 10/17 horses (59%)(1 horse euthanased for an unrelated reason and lost to follow-up) showed resolution of the presenting clinical signs following repulsion. 41% required additional medical or surgical treatment to resolve the clinical signs.
	• Only complication after repulsion of mandibular cheek teeth was ongoing discharge in one horse that resolved after antibiotic treatment.
	• The authors report that after maxillary cheek tooth removal sinusitis was the only complication encountered (6/13 horses, 46%). Sinusitis was due to:
	  ○ displacement of the alveolar plug (n=2)
	  ○ cause not reported (n=1)
	  ○ on-going sinusitis (n=3).
	• This should not really be regarded as a surgical complication but more an observation that the procedure failed to resolve one of the presenting clinical signs.
	• Minimal haemorrhage reported during repulsion - most likely due to the elevated head position afforded by standing surgery.

Limitations:	• Small retrospective study performed on data from a single hospital. • No control or comparison group. • All horses had initially undergone oral extraction, which failed. • Some whole teeth and some dental fragments removed but results not separated. • Largely descriptive results. • Some follow-up gained by questionnaire up to 41 months after the procedure introducing the potential for recall bias and loss of cases to follow-up. • No definition of success or calculation of proportion of successful procedures - just implied by the statement that 20 cheek teeth were successfully extracted. • As presented above, numerical proportions and percentages used interchangeably throughout the text, often without qualification of the denominator.

Tremaine (2010)	
Population:	Horses (2 TBs, 1 Arab, 2 Friesians, 1 Appaloosa, 1 Irish Draft cross, 1 Connemara cross, 1 Welsh and 1 Welsh Cob) presenting to a single UK clinic between 2002 and 2008 for removal of impacted cheek teeth. Study horses included 4 geldings, 5 mares and 1 intact male with a median age of 5 years (range 2-11 years). All horses had clinical signs of dental disease, including maxillary or mandibular swelling.

Sample size:	10 horses from which 11 incompletely erupted, impacted cheek teeth were removed.
Intervention details:	Medical records of horses requiring removal of incompletely erupted, impacted cheek teeth were reviewed and the following information collected: • signalment • results of clinical and ancillary diagnostic examinations i.e. radiography and oral endoscopy • treatment • response to treatment Long term (> 6 months, range 6-48 months, median 9 months) follow-up information was obtained by: • re-examination (n=4) • telephone questionnaire with owner (n=5) Cheek tooth removal was carried out by: • transcortical osteotomy and buccotomy (n=9) • repulsion assisted by ventral osteotomy (n=1) Both procedures were performed under GA with additional regional nerve blocks. Fluoroscopy was used to confirm position of the osteotomy which was made using a sharp osteotome or air-powered drill. Periodontal attachments were disrupted and the tooth sectioned before dental fragments elevated and removed through the osteotomy or repulsed into the oral cavity.
Study design:	Single centre case series with follow-up.
Outcome studied:	Descriptive report of the procedures carried out, complications encountered and long term outcome.
Main findings: (relevant to PICO question):	• 2 horses (18% of procedures) developed incisional dehiscence after the alveolar packing was removed. • 2 horses (18% of procedures) had a prolonged discharging tract post-surgery due to a fissure in the alveolus. Both eventually resolved after curettage of the alveolus. • No facial nerve deficits were seen post-operatively. • All 10 horses were reported to have developed a marked, non-painful mandibular swelling after surgery that gradually remodeled, but was still present 6 months later in 3 horses (3/11 (27%) of procedures). (It seems unlikely that a mandibular swelling would have occurred in the single horse having a maxillary tooth removed, so it is likely this proportion should only be out of 10 but a percentage out of 11 is what the paper reports.) • At median 9 month follow-up all horses had returned to work and no longer showed any clinical signs of dental disease.

Limitations:	• Retrospective study carried out at a single hospital with a small sample size. • Some follow-up information obtained by questionnaire up to 48 months after surgery introducing potential for recall bias and loss of cases to follow-up. • Largely descriptive with no definition of a successful procedure or proportion calculated. • Not all cases received the same treatment yet data interpreted together. • All cases of incompletely erupted, impacted cheek teeth yet in reality exodontia may be performed for many reasons. • Presentation of results is confusing as the paper presents numbers of horses combined with percentages of the total teeth removed/procedures carried out.

Dixon (2005)	
Population:	Younger horses (median age 8 years, range 2-18 years) presenting to a single UK clinic between 1998 and 2003 for oral extraction of rigidly attached cheek teeth. Study horses included 34 TBs, 20 TB crosses, 26 ponies, 5 Draught horses, 5 WBs and 10 miscellaneous breeds. Horses presented with a variety of disorders: 54 primary apical abscesses, 21 fractured cheek teeth, 13 displacements, 8 diastema, 2 supernumerary cheek teeth and 2 wear abnormalities.
Sample size:	100 horses from which 111 cheek teeth were extracted.
Intervention details:	Data collected from 100, mainly younger horses, consecutively undergoing standing oral extraction of rigidly attached cheek teeth by the first author. To be included, long-term post-operative evaluation had to be available. Cases of oral cheek tooth extraction in older horses with short reserve crowns or advanced periodontal disease were excluded. Oral extraction was carried out using the following technique: • Dental pick used to separate the gingiva from the cheek tooth. • Cheek tooth separator (molar spreader) then pushed into each interdental space and left in place for 3-5 minutes. • Cheek tooth extraction forceps (molar extractors) placed on the clinical crown and moved gently in a horizontal plane until foamy blood seen at the gingival margin. • Once the tooth was digitally loose a fulcrum was used to lever it vertically into the oral cavity. Follow up was obtained by postal questionnaire sent to owners/trainers at a median of 16 months post-surgery.
Study design:	Single centre case series with follow-up.

Outcome studied:	Outcome of oral extraction reported as a binomial categorical variable of 'success or failure'. Type and frequency of post-operative problems encountered. Largely descriptive report of long-term outcome.
Main findings: (relevant to PICO question):	• Oral extraction of cheek teeth was successful in 89% of younger horses. • In 11/100 horses oral extraction failed to remove the affected tooth intact. • Intraoperative fracture of the clinical crown was the most common cause of oral extraction failure (9/11 horses). 5/9 (56%) horses had existing pathological changes to the clinical crown that predisposed to fracture. • In 18/21 horses with pre-existing cheek tooth fracture (86%) oral extraction was successful, indicating value as the initial line of treatment in these cases. • 3/21 horses with existing fracture developed idiopathic clinical crown fracture during extraction, necessitating later removal by repulsion. • 8 cases suffered post extraction complications; mainly alveolar sequestration (n=4) and localised osteitis. • 7/49 cases with primary apical infection where the tooth was successfully extracted (14%), developed post-operative complications compared to 2.5% of cases without apical infection. • Local trauma to the hard palate was common after maxillary extraction. • 1 horse developed haemorrhage as a result of damage to the greater palatine artery during extraction. This was controlled and led to no further complications. • The paper reports that when extraction failure and post-operative complications are combined, 12/54 cases with apical infection (22%) developed extraction related problems compared to 7/46 (15%) of other cases.In the statistical analysis section, comparison of present results of oral extraction of 54 horses with apical cheek tooth infections (22% failures or post-operative problems) is made with the results of repulsion in 71 cases of apical cheek tooth infection also at this clinic, but reported in a previous study (49 % of post-operative problems) (Dixon et al 2000b). When Pearson's chi-squared test for proportions was used this showed a significantly lower level of surgical failures and post-operative problems with oral extractions compared to repulsion (x^2 =8.46, p=0.003). • Comparing just post-operative problems the level of significance increases (x^2=14.12, p<001).
Limitations:	• No contemporaneous or randomised control group with comparisons made to a previously published historical control group of repulsion in 71 cases of apical cheek tooth infection at the same clinic. • Comparisons of success are drawn between techniques of

	oral extraction (this study) and repulsion (previous study at same clinic) for removal of cheek teeth. • Largely descriptive data, with application of a chi-squared test as a test of association for the proportion of surgical failures and post-operative problems combined in the oral extraction and the historical control group. No further analysis of outcome data performed. • Study based at a single hospital. • Long-term follow-up data displayed in the results table but not sufficiently discussed.

Duncanson (2004)	
Population:	Horses (6 TBs, 27 TB crosses, 6 Arabs, 5 Arab crosses, 1 Shire, 1 Irish Draught cross, 3 Hunters, 5 Cobs, 4 Welsh ponies, 1 Highland pony, 23 Shetland ponies, 1 Connemara pony and 42 cross bred ponies) requiring cheek tooth removal consecutively treated by the author in UK general practice, between September 1997 and February 2001. Reasons for cheek tooth exodontia included: • Loose tooth/teeth (n=91) • Iatrogenic fractured tooth (n=8) • Displaced tooth (n=6) (1 supernumerary) • Maxillary tooth apical infection with secondary sinusitis causing malodorous nasal discharge (n=8) • Rostral maxillary tooth apical infection with external discharging sinus tract (n=2) • Mandibular tooth apical infection with external discharging sinus tract (n=7) • Diastema (n=3) The study horse population consisted of 68 mares, 55 geldings and 2 intact males.
Sample size:	125 horses (71 ponies and 54 horses) from which 155 cheek teeth were removed.
Intervention details:	125 horses consecutively undergoing cheek tooth removal by the author were included in the study: 68 primary cases and 57 referrals from other vets or equine dental technicians. For each horse the following details were recorded: • sex, size, estimate of breed • history • Body condition Score as determined by visual assessment where 1=cachectic and 10= obese. • clinical signs attributable to dental pathology. Horses age was recorded as one of the following groups:

	1) Birth- 6 months (age of erupting deciduous teeth) (n=0) 2) 6 months- 2.5 years (age of deciduous teeth in wear) (n=0) 3) 2.5-5 years (age of shedding of deciduous teeth) (n=2) 4) 6-11 years (age of disappearing cups) (n=12) 5) 12-18 years (age of disappearing stars) (n=28) 6) 19 years and older (age of V-shaped mandible, no stars) (n=83) Cheek teeth were removed by: • Standing oral extraction with instruments (n=117). • Digital manipulation (n=8). No regional anaesthesia used to aid extraction in any case.
Study design:	Single centre case series
Outcome studied:	Time taken for completion of extraction. Nature and frequency of any complications encountered.
Main findings: (relevant to PICO question):	• Oral extraction of cheek teeth under standing sedation was successful in all 125 horses. • In 91/125 horses (73%) extraction was completed in <20 minutes (all these teeth were digitally loose on initial palpation) • Average time for extraction in old horses (Group 6 n=83 and group 5 n=28) was just over 20 minutes, range 3-49 minutes. • Average time for extraction in young horses (Group 4 n=12 and Group 3 n=2) was 74 minutes, range 60-122 minutes. Author suggests that difference in average length of the procedure is a good indicator in the difference in difficulty level of extracting a cheek tooth from an old, compared to a young horse. 3/125 horses suffered fracture of the tooth root during extraction but all fragments were eventually removed. Alveolus was not packed post-extraction and no horses required additional surgery as a result.
Limitations:	• Results collected from a single ambulatory practice. • Results mainly descriptive with little statistical analysis. • No comparison or control group. • Study in general practice of mainly older horses, which limits its comparability with alternative extraction techniques investigated in different studies carried out on young horses in the referral setting. • No follow-up carried out. • Body condition score recorded but data not interpreted.

Dixon (2000b)	
Population:	Horses suffering from primary apical infection of their cheek teeth referred to a single UK equine clinic. In 92 horses (median age 7 years) a maxillary cheek tooth was affected and in 70 horses

	(median age 5 years) a mandibular tooth was affected. Specific breed and sex details are not reported but ponies made up 35% of the entire group of study equids and 54% of mandibular cases.
Sample size:	162 horses suffering from primary apical cheek tooth infection, of which 96 had the infected tooth removed by repulsion under GA and 26 by oral extraction under standing sedation.
Intervention details:	Records of 400 horses suffering from dental disease and admitted to Edinburgh Vet School for treatment by the first author were analysed. This included: • 353 consecutive cases seen between 1984 and 1998. • 47 documented cases with follow up information seen prior to this period(Dixon et al 2000a). Of the 400 horses referred, 162 suffered primary apical infection of the cheek teeth and were included in this Part 4 paper (the same study has produced results that have been published in 4 separate papers - this paper being the 4th of the series) Of relevance to the PICO are those that had the infected tooth removed: • Mandibular tooth repulsed under GA via a ventral mandibular osteotomy beneath the apex of the affected tooth (33 cases). • Standing oral extraction of a mandibular tooth without regional or local anaesthesia (14 teeth from 12 cases). • Oral extraction of a mandibular tooth under GA (3 cases). • Maxillary tooth repulsed under GA via a 2-3cm trephine hole for rostral maxillary teeth or via a 5-6cm maxillary flap for caudal maxillary cheek teeth (69 teeth from 63 cases). • Standing oral extraction of maxillary teeth (10 cases). • Oral extraction of maxillary tooth under GA (4 cases). For each case, records, dental specimens and radiographs were re-examined. (Due to advances in knowledge during the study period this sometimes led to alteration of the initial diagnosis.) Follow up information was usually obtained by repeat examination. If this was not possible information was obtained by telephone or written questionnaire with the owner/trainer/referring vet.
Study design:	Single centre case series with follow-up.
Outcome studied:	Outcomes studied that are relevant to the PICO: • Frequency of successful extraction with different techniques. • Frequency and nature of short- and long-term complications encountered. All outcomes are discussed separately for extraction of mandibular and maxillary cheek teeth.

Main findings: (relevant to PICO question):	For mandibular cheek teeth extracted by repulsion (n=33): • Affected apex and distal reserve crown usually disintegrated due to concussive forces before the tooth was palpably loose *per os*. • In some cases displacement of the dental punch led to mandibular fracture. Fracture replaced by digital compression without long-term consequence. 28/33 cases were available for follow-up, of which: • 5/28 cases showed food at the surgical site due to displacement of the wax plug, however, this did not lead to any long-term problems. • 1/28 developed quidding of feed months after surgery when food became trapped beneath a loose acrylic plug. • 6/28 cases (21%) had chronic post-operative sinus tracts. For mandibular cheek teeth removed by oral extraction (n=12): • All 14 teeth successfully removed intact. • 9/12 cases available for follow up (median 1.5years) and all showed complete resolution of clinical signs. The study concluded that oral extraction was the method of choice for removal of most mandibular cheek teeth. Oral extraction resulted in fewer post-operative complications with 9/12 cases (75%) responding to initial treatment, compared to 18/28 (64%) with repulsion. For maxillary cheek teeth removed by repulsion (n=63): • 4 cases with dental sinusitis at presentation developed an oromaxillary fistula due to premature loss of the alveolar plug after surgery. 43/63 cases were available for follow-up: • 19/43 cases were cured from dental infection after initial treatment, but 4/19 developed non-dental related post-operative complications such as pyrexia and severe sinus haemorrhage. • 24/43 cases showed continuation or recurrence of clinical signs following repulsion. • 3 cases showed chronic sinusitis with low-grade nasal discharge for > 6 weeks post-operatively. For maxillary cheek teeth removed by oral extraction (n=14): • All 10 cases with rostral cheek teeth extracted healed quickly with no further complications. The paper concludes that when oral extraction and repulsion results are combined; initial surgery had a cure rate of 84% for rostral maxillary and 68% for mandibular cheek teeth. Horses presenting with secondary dental sinusitis had a poorer prognosis with just 33% cured with initial treatment.
Limitations:	• Retrospective study carried out at a single clinic over >14

	year period, during which time (as the paper admits) diagnostic and surgical techniques were altered/updated. This means individuals in each group did not all receive exactly the same treatment, limiting their direct comparability. Yet conclusions were made about differences between groups without statistical validity. • Comparison drawn between 96 horses undergoing repulsion and 26 undergoing oral extraction of cheek teeth but no randomised control group included in the study. • Largely descriptive analysis of results and comparison of proportions between treatment groups. • Cheek tooth removal is not the entire focus of the paper. • Data on success of technique difficult to interpret as results from maxillary and mandibular teeth are sometimes separated and sometimes grouped.

Prichard (1992)	
Population:	Horses undergoing repulsion of diseased cheek teeth in a single American hospital. The 36 horses (12 TBs, 6 Quarter horses, 5 Standardbreds, 4 Belgians, 3 Arabians, 3 grade horses and 3 of other breeds) undergoing maxillary repulsion had a median age of 5 years (range 2-27 years) and consisted of 21 mares, 8 geldings and 7 intact males. The 25 horses (7 TBs, 4 Standardbreds, 3 Quarter horses, 3 grade horses, 2 Arabians, 2 Morgans and 4 of other breeds) undergoing mandibular repulsion had a median age of 4 years (range 1-14 years) and consisted of 12 mares, 9 geldings and 4 intact males.
Sample size:	61 horses from which 50 maxillary and 27 mandibular cheek teeth were removed.
Intervention details:	Hospital records searched to identify horses that had undergone cheek tooth repulsion for treatment of alveolar periostitis. 61 cases were reviewed and the following information recorded: • signalment • clinical presentation • methods of therapy • complications encountered during surgery and hospitalisation All teeth were removed by repulsion under GA with varying surgical approaches. For maxillary teeth: • 19 flap sinusotomies • 11 trephinations • 3 windows created by motorised burrs • 2 windows created by enlarging the draining tract with

	rongeur forceps • 1 approach unrecorded For mandibular teeth: • 13 ventral windows created with a motorised burr • 7 trephinations • 4 using an osteotome and mallet • 1 approach unrecorded Long-term follow up (> 5 months post-op) obtained by re-examination or telephone interview with the owner/trainer.
Study design:	Single centre case series with follow-up.
Outcome studied:	Type and frequency of intra- and post-operative complications following surgical repulsion of a diseased cheek tooth under GA.

Main findings: (relevant to PICO question):	36/61 horses underwent maxillary tooth repulsion (50 teeth):
	
	• 4/36 horses suffered intraoperative complications:
	  • repulsion of the incorrect tooth (n=1)
	  • fracture of lateral alveolar wall (n=1)
	  • fracture of medial alveolar wall and palatine bone (n=1)
	  • extensive osteomyelitis causing the bone flap to be discarded (n=1)
	
	• 17/36 horses (47%) suffered serious post-operative complications with 8 horses requiring further intervention. (usually due to development or recurrence of nasal discharge).
	• 30 horses were available for long-term follow up. (2 died and 4 were lost to follow-up)
	• 6/30 (20%) horses suffered chronic nasal discharge +/- oro-maxillary fistula.
	• 24/30 (80%) healed with no further complications.
	
	25/61 horses underwent mandibular tooth repulsion (27 teeth):
	• 3/25 horses suffered intraoperative complications:
	  ○ fracture of medial alveolar wall (n=2)
	  ○ fracture of lateral alveolar wall and incorrect tooth repelled (n=1)
	
	• 8/25 horses (32%) suffered serious post-operative complications with 4 requiring additional surgery. Eventually:
	  ○ 3/8 recovered fully
	  ○ 3/8 developed chronic discharging tracts
	  ○ 2/8 died before long-term follow up
	
	• 2/3 horses with chronic draining tracts additionally developed mandibular swelling.

	• 1 case of mandibular swelling developed an odontogenic carcinoma at the surgical site. • 14/17 horses available for long term follow up (82%) healed with no further or mild problems such as swelling or mild scarring. The paper concludes that although serious post-operative complications were common following repulsion. However, long-term outcome was good with approximately 80% of horses with available follow-up resolving the complication and having no further problems 5 months or more after surgery.
Limitations:	• Retrospective study carried out at a single centre. • Different surgical approaches are used for repulsion but all outcome results interpreted together. • Horses only treated by repulsion so no direct comparison to other methods of cheek teeth removal can be made. • Nature of serious post-operative complications are mentioned in the abstract but not explained or discussed in the paper. • With some follow-up information obtained by telephone questionnaire up to 5 months post-surgery there is potential for introduction of recall bias and loss of cases to follow-up.

Appraisal, application and reflection

Ten case-series studies were identified to be relevant to the PICO, largely reporting descriptive data on a single surgical technique, with minimal statistical analyses. Due to the lack of control groups in the published studies comparisons of techniques have to be drawn between different studies, as demonstrated in Dixon et al (2005). There are inherent differences between all these studies in terms of the signalment of the equine population included, the reason for cheek tooth exodontia and the definition and type of complications recorded. Whilst the heterogeneous nature of the study designs, population of horses and recorded data preclude direct comparisons of their results with each other, this PICO has presented clear evidence in the differing populations for the benefit of oral extraction, in terms of reduced complication rates, over repulsion for extraction of equine cheek teeth.

In line with our scenario, and often the case clinically, most of the studies include referral cases of cheek tooth exodontia in fairly young horses. However, Duncanson (2004) carried out a case series of 125, mainly older horses, undergoing standing oral extraction in general practice. 66% (83/125) of horses included in the study were >19 years old, often with the teeth requiring extraction being digitally loose on palpation. This represents a very different horse population to the young horses with firm periodontal attachments referred to a hospital for exodontia. As such this study is of limited relevance to the PICO and findings should be compared to those of the other studies with caution.

Cheek tooth removal could be indicated for a number of reasons, as demonstrated by the variation and scope of inclusion criteria between studies. The initial clinical presentation is likely to affect the extraction method used and, in turn, the outcome of the surgical procedure and any potential complications encountered. For example, Tremaine and McCluskie (2010) carried out a study on a very small population of horses all requiring exodontia due to incompletely erupted, impacted cheek teeth. However, it has been reported that idiopathic apical infection is the most common indication for cheek tooth removal in the young horse (Dixon *et al*, 2005). Therefore, the results of these two population may not be directly comparable, and any conclusive comparisons need to be made with caution.

While making up part of the population in other studies, Ramzan, Dallas and Palmer, (2011) and Reichert *et al* (2014) report on methods for extraction of cheek teeth solely with fractured clinical crowns. A fractured

clinical crown has previously been reported as a reason to preclude oral extraction (Boutros and Koenig, 2001) and the fragility and likelihood of fragmentation of these dental tissues complicates exodontia (Ramzan, Dallas and Palmer, 2011). As such, studies including fractured teeth could be reporting a falsely high frequency for complication that actually is not associated with the procedure but the presenting complaint.

Although potentially lacking definitive evidence, there is almost universal agreement amongst the published authors that oral extraction under standing sedation should be the treatment of choice for equine cheek tooth exodontia, but when this fails a viable alternative is required. Coomer, Fowke and McKane (2011), O'Neill *et al* (2011) and Langeneckert *et al* (2015) report on methods of extraction used when initial oral extraction has failed. This accurately represents the clinical situation but the disruption of the periodontal ligaments that occurs during oral extraction may have aided subsequent surgical removal (Dixon *et al*., 2012) to improve the success and reduce the complication rates reported.

How the outcome of the surgical procedure and complications encountered is reported also shows great variation amongst the papers studied.

The outcome of surgery is reported as a binomial categorical variable but only Ramzan, Dallas and Palmer (2011) and Langeneckert et al (2015) clearly define what is regarded as a 'success' or 'failure': for the other studies we must just assume that a 'success' was removal of the affected tooth. All of the studies report a calculated proportion for outcome and occurrence of complications when an incidence rate is what is needed to answer our PICO.

Complications encountered are largely reported in a descriptive nature with little categorisation or standardisation between studies. Indeed, Tremaine and McCluskie (2010) reported a long-term complication of non-painful, mandibular swellings that developed post-surgery in all cases and were still present 6 months later in 27% (3/11) of cases. Prichard and Hackett (1992) also noted post-operative swelling but discounted it as a minor long-term problem. This lack of uniformity indicates an overarching need for standardisation of recording, and definition of surgical procedures, to allow more accurate comparisons to be drawn between studies.

Despite these limitations, the low quality of evidence and absence of any randomised controlled clinical trials that means a definitive answer to the PICO cannot be provided; the evidence available indicates certain trends that should be investigated further in future studies.

Evidence on repulsion techniques suggests that long-term outcome is generally good albeit with some cosmetic imperfections and significant short-term morbidity. Intra- and short-term post-operative complications are common and often serious, to the extent that further surgery may be required. This would be unacceptable to many owners and indicates the need for a more reliable and successful first line of treatment.

With lower incidence of complications compared to repulsion techniques, oral extraction should be used as the initial technique of choice for equine exodontia. However the success rate is not 100% so in cases where it fails an alternative cheek tooth removal technique may still be required. The evidence suggests that minimally invasive techniques may have a higher initial success than repulsion but they have, so far, failed to prevent some serious post-operative sequelae.

In conclusion, analysis of the available evidence indicates a need for further research to conclusively answer the PICO. Such approaches could include a large, multi-centre, prospective cohort study, utilising a strict inclusion criteria to minimise the presence of confounding variables, or a gold-standard randomised, controlled clinical trial. These epidemiological approaches would elucidate whether oral or minimally invasive cheek tooth extraction techniques do significantly reduce the incidence of post-operative complications in the horse when compared to repulsion methods.

Methodology Section

Search Strategy	
Databases searched and dates covered:	CAB Abstracts on the OVID platform (1973 to 2017 Week 23) PubMed accessed via the NCBI website (1910-2017, filtered for Veterinary Science)
Search terms:	**PubMed search:** #1 (horse or equine or equidae or equus or colt or pony or mare or filly or gelding or stallion or yearling or thoroughbred or warmblood) Filters: Veterinary Science #2 (tooth or dental or dentistry or mouth or oral or buccal or bucco) Filters: Veterinary Science #3 (extract or extracts or extraction or extractions or extracted or extracting or remove or removes or removal or removed or removing or removement or surgical or surgical or surgically or surgery or surgeries or exodontia or exodontics or exodontic or endodontic or endodontics or peridontics or periodontics or peridontal or periodontal or repulse or repulses or repulsed or repulsing or repulsion or trephination or trephined or trephine or trephines or trephining or MTE or MITR or transbuccal) Filters: Veterinary Science #4 (#1 and #2 and #3) Filters: Veterinary Science **CAB Abstracts search:** 1) (equine or equines or horse or horses or equus or colt or colts or pony or ponies or mare or mares or donkey or donkeys or filly or fillies or gelding or geldings or stallion or stallions or yearling or yearlings or thoroughbred or standardbred or warmblood).mp. or equidae/ or equus/ or horses/ or foals/ or colts/ or mares/ or stallions/ or thoroughbred/ or donkeys/ 2) (tooth or teeth or dental or dentistry or mouth or oral or buccal or bucco).mp. or teeth/ or tooth diseases/ 3) (extract or extracts or extraction or extractions or extracted or extracting or remove or removes or removal or removed or removing or removement or surgical or surgical or surgically or surgery or surgeries or exodontia or exodontics or exodontic or endodontic or endodontics or peridontics or periodontics or peridontal or periodontal or repulse or repulses or repulsed or repulsing or repulsion or trephination or trephined or trephine or trephines or trephining or MTE or MITR or transbuccal).mp. or surgical techniques/ or surgical operations/ or periodontal diseases/ 4) 1 and 2 and 3 ********** mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes
Dates searches performed:	22nd June 2017

Exclusion / Inclusion Criteria	
Exclusion:	Pre-defined exclusion criteria included: not in the English language, book chapters, review articles, single case reports and articles from non-peer reviewed journals. Additionally studies where cheek tooth removal was not the main focus and that reported on complications of loss of teeth from the arcade (i.e. tooth drift), rather than complications arising as a result of the extraction procedure were excluded.
Inclusion:	Any primary evidence study in which cheek teeth removal from equidae was the main focus and that reported on the surgical techniques used and the complications encountered.

	Search Outcome						
Database	**Number of results**	**Excluded – not in English language**	**Excluded – did not address the PICO question**	**Excluded – book chapter, review article, single case report or non-peer reviewed publication**	**Excluded - could not be sourced**	**Excluded – duplication**	**Total relevant papers**
NCBI PubMed	753	20	700	24	1	0	8
CAB Abstracts	911	164	642	51	2	50	2
Total relevant papers when duplicates removed							10

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

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