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Dimensions of Diastemata and Associated Periodontal Food Pockets in Donkey Cheek Teeth

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1 **A study of the dimensions of diastemata and associated periodontal food**
2 **pockets in donkey cheek teeth**
3

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28   **Summary**

29   Equine cheek teeth (CT) diastemata often cause deep periodontal food pocketing and are
30   regarded as a painful dental disorders of equidae. This post mortem study examined 16
31   donkey skulls (mean age 32 years) containing 45 CT diastemata to define the type and
32   dimensions of diastemata, and of the associated periodontal food pockets that occur with this
33   disorder. These diastemata were found to more commonly involve mandibular (56%) than
34   maxillary CT (44%), and 71% of these diastemata had adjacent intercurrent dental disorders
35   that may be associated with the diastemata. Diastemata were defined as open (60%) or valve
36   (40%) based on their gross appearance. This classification was confirmed to be accurate by
37   measurements of diastemata dimensions that showed valve diastemata to have an occlusal to
38   gingival width ratio of 0.4, in contrast to open diastemata where this ratio was 1.07. Food was
39   impacted in 89% of diastemata and periodontal food pocketing was present adjacent to 76%
40   of diastemata, more commonly on their lateral aspect (73% prevalence – mean periodontal
41   pocket depth 4.04mm) than the medial aspect (47% prevalence – mean depth 2.38mm). The
42   depth of periodontal pockets of diastemata was not associated with the height of the erupted
43   crown.

44   **Introduction**
45   Diastema (pleural diastemata) is defined as the presence of a space between adjacent incisor
46   or cheek teeth (CT) that should normally be in contact at the occlusal surface. Food often
47   becomes entrapped in diastemata causing painful periodontal food pocketing [1]. Consequently,
48   CT diastema is a major cause of dental pain and quidding in horses [1-3]. Such pathological
49   diastemata should not to be confused with the normal physiological diastema present in
50   equids between CT and incisors ('bars of the mouth'). Diastemata can be defined as open
51   (same width throughout the depth of the diastema) or valve (narrower at the occlusal aspect)
52   diastemata, with the latter causing most food entrapment and thus clinical problems [2].
53
54   Cheek teeth diastemata have recently been recognised in donkeys on routine dental
55   examinations [4] but little information is available on their etiopathogenesis or clinical
56   significance. More information is available concerning equine diastemata, but no studies
57   appear to have investigated the morphological appearance of equine CT diastemata in detail.
58   The aim of this study was to define the dimensions of donkey diastemata and adjacent
59   periodontal pockets, and to determine the accuracy of defining diastemata as valve or open,
60   utilising gross post mortem examinations of donkey skulls from the aged population at The
61   Donkey Sanctuary, Sidmouth, UK.
62

63   **Materials and Methods**

64   Donkey skulls from 349 donkeys from The Donkey Sanctuary, Sidmouth, UK that died or
65   were euthanised for reasons unrelated to the head were examined and dental disorders
66   recorded on a dental chart. Age at death was determined from computerised records that
67   estimate the age of donkeys on admission to the sanctuary based on owner information and
68   incisor examination by experienced staff. Only a small percentage of donkeys had precise
69   dates of birth. In these 349 donkeys examined the prevalence of dental disease was 93.4% [5]
70   and the median estimated age was 31 years (range 6 – 52). Random skulls (16) were selected
71   from donkeys which had diastemata (prevalence of 85% [5]) for this study and the median age
72   of these 16 donkeys was 32 years (range 12 – 56 years) which was very similar to all donkeys

73 (349) examined for dental disorders. Diastemata were classed as open or valve diastemata
74 based on macroscopic appearance as previously described [2,3,6].

75 The width of each diastema was measured on its lateral (buccal) and medial (lingual or
76 palatal) aspect at both the occlusal surface (A) and gingival level (B). The depth of
77 periodontal pockets (C) were measured on the lateral and medial aspects when present
78 (Figure 1). The erupted crown height was also measured (D). All measurements were
79 obtained using digital callipers (Knighton[a]).

80 Data was recorded on Excel® and statistics performed using R (R V2.3.1, R Foundation for
81 Statistical Computing). A major difficulty in terms of any statistical analysis was that for 4/16
82 (25%) of the skulls only one diastema was found/observed, but there was up to 6 diastemata
83 in the other skulls (Figure 2). This meant for some skulls there was non-independence
84 between diastemata, suggesting a mixed-effect model approach [7], but the skulls with a
85 solitary diastema precluded such analysis. The concern was any statistically significant
86 results being unduly influenced by multiple teeth from the same skull, but in the skulls with
87 multiple diastemata it was difficult to select one diastema. Therefore, we employed a
88 "bootstrapping" [8] methodology for the statistical testing. One diastema per skull was selected
89 at random, creating a sample of 16 diastemata, on which the various statistical procedures
90 were performed. This sample creation and subsequent statistical testing was carried out
91 10,000 times in order to ensure generation of results that were robust in terms of which
92 diastema had been selected. The results are reported as a percentage of the 10,000 iterations
93 in which statistical differences (at the 5%) level were obtained. The greater the percentage,
94 the greater the robustness of any results that indicate statistically significant differences or
95 correlations.

96 A one-sample t test was used to determine whether the difference between lateral and medial
97 aspects of each diastema at occlusal (A), gingival (B) and periodontal pocket level (C) was
98 statistically different from 0. A Mann-Whitney test was performed to determine the ratio of
99 occlusal to gingival margin width in open and valve diastema on the lateral and medial
100 aspect, as the data was not normally distributed. The depth of periodontal pockets was
101 compared in open and valve diastemata using a Mann-Whitney test. The height of erupted
102 cheek tooth crown was correlated with the depth of the periodontal pocket depth using
103 Spearman's rank correlation test. Statistical significance was assumed at $P < 0.05$.

104 **Results**
105 A total of 45 diastemata were present in these 16 skulls, with between 1 – 6 diastema per
106 skull (Figure 2). Twenty diastemata (44%) were between maxillary CT and 25 (56%) were
107 between mandibular CT. All 45 diastemata were associated with periodontal disease although
108 the severity of periodontal disease was not graded. Periodontal pockets were observed in 34
109 (75.6%) diastemata. Thirty-two (71%) of the diastemata had identifiable intercurrent cheek
110 teeth disorders that may have predisposed to the diastemata, including displaced (n = 20),
111 absent teeth (n = 7), fractured teeth (n = 2) and focal overgrowths on cheek teeth (n = 3).
112 Food was impacted in the interdental spaces in 40 diastemata (89%) (Figure 3), and no food
113 was present in the other 5 diastemata (3 open and 2 valve diastemata) at the time of our
114 examination.

115

116

117 *Difference in lateral and medial parameters*

118 The mean, median and ranges of all the diastema width occlusally (A) and at the gingival
119 margin (B), and periodontal pocket depth (C) at the lateral and medial aspects are tabulated in
120 table 1. The bootstrap analyses revealed that there were no significant differences (P>0.05)
121 between the lateral and medial width of the diastema at either the occlusal surface or the
122 gingival margin, with 99.7% and 99.0% of the 10,000 simulated samples, respectively.

123 Periodontal pocketing (measurement C; Figure 4) was present in 34/45 diastemata (76%)
124 with 33 having pocketing on the lateral aspect and 16 on the medial aspect. From the
125 bootstrap analysis there was a statistically significant difference (P<0.05) in the depth of the
126 periodontal pocketing between lateral and medial aspect with a greater depth of pocketing
127 associated with the lateral aspect of maxillary and mandibular cheek teeth diastemata in
128 92.3% of the simulated samples (Figure 5).

129 *Validating identification of open and valve diastemata*

130 Diastemata were defined as being open or valve based on gross observation. Open diastemata
131 were defined as diastemata that had the occlusal width as wide, or wider than the width at the
132 gingival margin. Valve diastemata were defined as diastemata that were narrower at the
133 occlusal aspect than the gingival margin. Of these 45 diastemata examined in this study 27
134 were defined as open and 18 as valve diastemata.

135 There did not appear to be a particular pattern to the prevalence of open or valve diastemata
136 in the various positions, although overall valve diastemata were more common, comprising
137 55% of maxillary diastemata and 64% of mandibular diastemata.

138 The bootstrap analyses revealed the difference between open and valve diastemata ratios
139 laterally (1.11 and 0.42 respectively) and medially (1.03 and 0.37 respectively) were
140 statistically significantly different (P<0.05) in 99.3% and 86.0% of the simulated samples,
141 respectively.

142 *Periodontal pocket depth*

143 The depth of periodontal pockets in open and valve diastema were compared to ascertain if
144 there was a correlation between type of diastema and depth of periodontal pocketing. There
145 was a tendency towards deeper lateral periodontal pockets beside valve diastemata, but this
146 was not reflected in the bootstrap analyses, where no difference statistically significant at the
147 5% level was observed for 99.2% of simulated samples, with a similar lack of difference
148 present for the medial pockets (99.6%) (Figure 7).

149 *Association of periodontal pocket depth to erupted crown height*

150 There was no association between the crown height to periodontal pocket depth, either
151 medially or laterally, with no statistically significant difference at the 5% level observed for
152 95.2% and 96.0% of simulated samples, respectively.

153

154

Discussion

155
156 Cheek teeth diastemata has been recognised as one of the most painful oral disorders of
157 horses[2] and usually causes quidding but is seldom recognised by practitioners [9]. The
158 prevalence of diastemata in the general equid population is unknown and it is important that
159 veterinarians are trained to clinically recognised cheek teeth diastema as a cause of quidding
160 [3,6,9]. Diastemata have been observed in 4.6% of 349 *referred* horses with cheek teeth dental
161 disorders [9]. A post mortem study of 355 horse skulls found a prevalence of 3.7% [10], while a
162 more recent post mortem study of 50 horses found a prevalence of 20% [11]. The sample of 16
163 skulls that were used in this study were obtained from donkeys in a larger post mortem study
164 examining 349 donkey skulls and had a much higher prevalence of 85.1%[5]. However, the
165 median age of this population was 32 years (range 12 – 56 years) compared to the study by
166 Dixon *et al.* (1999)[9] where the median age was 7 (3-24). The study by Dixon *et al.* (1999)[9]
167 also noted that diastemata occurred with equal frequency in maxillary and mandibular rows
168 and that they were most commonly found between the 09s and 10s, but more recent studies
169 have shown an increased prevalence of diastemata in the mandibular CT[2]. Similarly,
170 diastemata were more prevalent in the mandibular row (63%) compared to the maxillary row
171 (36%) in 349 donkeys examined in a larger study[5] and this was reflected in this sample of 16
172 donkeys skulls with more mandibular (56%) than maxillary (44%) diastemata.

173
174 Diastemata formation between equid cheek teeth is normally prevented by continued
175 eruption of the caudally angulated rostral cheek teeth and rostrally angulated caudal cheek
176 teeth [12]. Primary developmental diastemata can develop if there is inadequate rostro-caudal
177 angulation or if the tooth buds develop too far apart relative to their supporting bones[2].
178 Secondary developmental diastemata can occur for a number of reasons, including beside
179 cheek teeth adjacent to developmental displaced or supernumerary cheek teeth[2]. In equids the
180 natural tapering of reserve crown towards their apices predisposes to the development of
181 senile diastema as the animal ages and the erupted crown becomes narrower. The rostro-
182 caudal angulation of the teeth (which also decreases with age) is then unable to compress the
183 cheek teeth row adequately resulting in the development of senile diastemata [13]. Diastemata
184 can also develop secondary to other acquired cheek teeth disorders such as acquired dental
185 displacements or missing teeth. It can also occur secondary to tall overgrowths causing
186 rostro-caudal cheek teeth drifting [2,3,6]. In the current study, 29% of the diastemata were not
187 associated with intercurrent cheek teeth disorders and due to the high median age of donkeys
188 (32 years) in this population, primary diastemata were most likely attributable to senile
189 diastemata. A large proportion (44%) of these diastemata were associated with displaced
190 teeth, some of which may have been acquired displacements as a consequence of severe
191 periodontal disease associated with diastemata. Age related intercurrent dental disease may
192 result in the development of multiple diastemata per donkey as was seen in 12 of the donkeys
193 in this study.

194
195 The medial and lateral diastema width measurements taken in this study showed that each
196 diastema was the same width on the medial and lateral aspect at both the occlusal and
197 gingival margin. The classification of diastemata as open or closed was based on previous
198 published definitions, with a triangular shaped defect recognised in valve diastema [6,14]. In this
199 study the dimensions of diastemata were measured at the medial and lateral aspects of the
200 occlusal surface and gingival margin after visual classification as being open or valve
201 diastemata. The results from this study clearly illustrate a significant difference in the ratios
202 of occlusal to gingival margin diastema width in open and valve diastemata. However the
203 type of diastema did not appear to affect whether or not food was impacted as only 5
204 diastemata did not have food impacted of which 2 were valve and 3 open diastemata.

205
206 The study by Dixon *et al.* (1999)[9] showed that food pocketing was commonly present with
207 CT diastemata with periodontal pockets of > 50mm deep recorded. Periodontal infection
208 associated with deep periodontal food pocketing may occasionally progress to the mandible
209 and maxillae causing osteomyelitis and oro-maxillary fistulas or sinusitis respectively [9].
210 Recently, direct anastomoses between blood vessels of the periodontal ligament and
211 maxillary sinus have been demonstrated in the horse [15]. This provides a possible route of
212 infection to the sinuses from periodontal disease. Periodontal pockets have also been
213 measured in another equine study where depths up to 35mm was recorded in periodontal
214 disease which was significantly greater than that recorded in non-diseased CT [16]. In this study
215 periodontal disease was observed with all the diastemata and periodontal pocket depths of up
216 to 8.47mm laterally and 7.1mm medially were recorded in 75.6% of the diastemata. It seems
217 likely that the smaller periodontal pockets depths observed in this study could be due to the
218 smaller relative size of the donkeys and the short reserve crowns of the old donkeys
219 examined in this study. Periodontal pockets were more common on the lateral aspect and
220 were predominantly deeper (mean = 4.63 +/- 0.37mm) than medial pockets (mean = 2.38 +/-
221 0.40mm). However, there was no significant difference between the periodontal pocket
222 depths in open or valve diastemata. Periodontal pocket depth did not appear to be related to
223 the height of the erupted crown of the adjacent cheek teeth.
224
225 In conclusion, this study has shown that the gross classification of diastemata into closed and
226 valve types is accurate in older donkeys and in particular, has shown the presence of severe
227 periodontal pocketing adjacent to most diastemata. This study highlights the need for this
228 disorder to be recognised in donkeys, and further clinical studies will be required to
229 determine the clinical significance of periodontal pockets associated with diastemata in
230 donkeys.

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279 **Table 1**

280 *Table 1:* Mean, median and range of lateral and medial measurements A, B and C and
281 measurement D (mm) of all diastemata (n = 45). A = occlusal diastema width; B = gingival
282 margin diastema width; C = periodontal pocket depth; D = erupted crown length.

283

	Mean	Median	Range
A Lateral	1.98	1.86	0 – 5.74
A Medial	1.99	1.96	0 - 5.24
B Lateral	3.02	2.65	0.73 – 7.44
B Medial	3.20	2.98	0 – 7.41
C Lateral	4.04	3.98	0 – 8.47
C Medial	2.38	2.08	0 – 7.1
D Length	13.15	11.75	3.62 – 25.83

284

Figure legends

Figure 1: Illustration of the three measurements taken on the lateral and medial aspect of each diastema. A = diastema width at occlusal level; B = diastema width at gingival margin; C = periodontal pocket depth; D = length of erupted crown; CT = cheek tooth

Figure 2: Column graph illustrating the frequency of donkeys with the specific number of diastema per donkey observed in this study

Figure 3: Long fibres of food are transversely impacted in (A), a valve diastema that has a narrow opening on the occlusal surface and is wider apically, and (B) in an open diastema mandibular that has a wide opening occlusally. Note the presence of early-stage "senile excavation" ("smooth mouth") in the mandibular cheek teeth on the left (A) due to reduction in peripheral infolding at this more apical aspect of the crown.

Figure 4: After removal of impacted food, a large periodontal pocket is now obvious on the lateral aspect of a mandibular cheek tooth diastema. The periodontal pocket has spread rostrally and caudally to involve the lateral aspects of the two adjacent CT.

Figure 5: Boxplot of the bootstrap medians of periodontal pocket depths laterally (C-L) and medially (C-M) in mm

[a]Boxes represent interquartile range and horizontal lines represent medians

Figure 6: Boxplot of bootstrap medians of differences in ratios of occlusal width (A) to gingival margin (B) widths laterally (A-L/B-L) and medially (A-M/B-M) in open (O) and valve (V) diastemata[a]

[a]Boxes represent interquartile range and horizontal lines represent medians

Figure 7: Boxplot of bootstrap medians of differences in periodontal pocket depth in open (O) and valve (V) diastemata on the lateral aspect (C-L) and medial aspect (C-M) of diastemata

[a]Boxes represent interquartile range and horizontal lines represent medians