

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21

This article has been accepted for publication in VetRec following peer review.
The definitive copyedited, typeset version is available online at [10.1136/vetrec-2018-105163](https://doi.org/10.1136/vetrec-2018-105163)

Lop-eared rabbits have more aural and dental problems than erect-eared rabbits: a rescue population study

Jade C. Johnson and Charlotte C. Burn

The Royal Veterinary College, Hawkshead Lane, North Mymms, AL9 7TA, UK

22 Corresponding author: Charlotte Burn, The Royal Veterinary College, Hawkshead Lane,
23 North Mymms, AL9 7TA, UK, Tel: 01707 666333; email: cburn@rvc.ac.uk

24 Abstract

25 This research aimed to assess whether rabbits having lop-ears is a welfare issue by
26 investigating the occurrence of aural and dental pathology in lop-eared compared with erect-
27 eared rabbits.

28 Thirty rabbits (15 lop-eared and 15 erect-eared) from a rabbit-only rescue shelter were
29 examined. An otoscope was used to visualise the ear canals and mouth. Samples were taken
30 from each ear to examine for mites, bacteria and yeast. Medical records were also examined.

31 Lop-eared rabbits showed statistically significantly more frequent ear canal stenosis, higher
32 scores of cerumen and erythema, and more frequent potential pain response during ear
33 examination, compared with erect-eared rabbits. We also found statistically significantly
34 more frequent incisor pathology, molar overgrowth, molar sharpness, molar spurs and
35 history of veterinary dental treatment in lop-eared compared with erect-eared rabbits. The
36 effect sizes were often large. Age was not statistically significant between the lop- and erect-
37 eared rabbit groups.

38 Thus, lop-eared rabbits are at an increased risk of aural and dental pathology. This brings
39 into debate the ethics of breeding and buying lop-eared rabbits, as they are more likely to
40 suffer conditions that negatively impact welfare, such as pain, and potentially deafness and
41 difficulty eating.

42 Key words: Animal welfare, Conformation; Dental pathology; Otitis; Rabbits; Veterinary
43 Research

44 Introduction

45 Breeding animals for extreme traits is coming under scrutiny, and has thus far mostly
46 focused on dogs¹⁻³. However, the ethics of breeding extreme rabbit conformations, such as
47 pendulous ears and brachycephaly, is also starting to be debated^{4,5}. Lops are among the most
48 common pet rabbit breed groups, representing 57% (n=58/102) and 36% (n=449/1254) of
49 pet rabbits in England according to two surveys by Mullan and Main (2006) and Rooney et
50 al. (2014), respectively. Thus, if the lop-eared phenotype is associated with suffering, it
51 could constitute a prevalent rabbit welfare issue. However, clear evidence of whether this is
52 the case is lacking.

53 Domestication of the wild rabbit has created at least nine breeds with a lop-eared phenotype,
54 as it is a heritable trait^{6,7}. The wild type has erect and mobile pinna due to three
55 interdigitating auricular cartilages that provide a scaffold for the vertical ear canal^{8,9}. In
56 contrast, lop-eared breeds have 3-5mm of soft tissue between the proximal acoustic meatus
57 cartilage ring and the tragal cartilage of the distal ear canal, causing the pinna to fold and
58 become pendulous^{9,10}.

59 Charles Darwin first noted how artificial selection for pendulous pinnae in rabbits was
60 associated with altered skull morphology¹¹. Cordero and Berns (2016) found supportive
61 evidence of this in natural woodrat populations that have likely undergone selection for long
62 ears, finding substantial covariance of ear length and shape of the neighbouring auditory
63 meatus¹². This means that the lop-eared phenotype could not just affect aural function
64 directly, but also other aspects of cranial health, such as dental function.

65 Potential consequences for aural health

66 Lop-eared rabbits have increased stenosis (narrowing) of their ear canals^{8, 13, 14}. This, along
67 with ear canal occlusion by the pinna, is believed by some veterinary professionals to reduce
68 airflow and hinder expulsion of cerumen (or ‘earwax’)^{9, 10, 13}. Cerumen accumulation at the
69 base of the ear in lop-eared rabbits has been suggested as a predisposing factor for otitis
70 externa, caused by bacterial or yeast overgrowths^{10, 13, 15, 16}. Mite infestation with *Psoroptes*
71 *cuniculi* can also cause otitis externa, usually with extensive crusting of the pinna⁹.
72 Veterinary professionals have observed that otitis externa can cause head shaking, ear
73 scratching, pain, depression and inappetance in rabbits^{17, 18}, and if it progresses to otitis
74 media and interna then head tilts and neurological deficits can occur¹⁸. Veterinary opinion
75 suggests that deafness can result from excess cerumen accumulation, otitis interna, or
76 chronic otitis externa or media, at least in cats and dogs¹⁹, so it is possible that this could
77 occur in rabbits also. Additionally, if the length of the lop ear is great, such as in English
78 lops, then there could be increased risk of trauma to the pinnae⁵.

79 Despite the above veterinary and animal welfare expertise suggesting impacts of the lop-
80 eared morphology on aural health, there has been limited empirical research into the issue;
81 we found just one empirical study specifically comparing lop-eared and erect-eared rabbits,
82 which solely investigated aural *Malassezia* yeast variation, and found no significant
83 difference²⁰. Thus, there is currently little evidence to argue the ethics of breeding and
84 buying lop-eared rabbits. Veterinary opinion is mostly formed on the basis of experience
85 with populations requiring veterinary attention, so it is unknown whether the same
86 associations exist in otherwise healthy rabbits. However, it is possible that they do, because
87 canine research has found that dogs with pendulous ears have a higher risk of otitis externa

88 and an increased risk of *Malassezia species* infection, compared with dogs with erect-ears²¹⁻
89 ²³. Thus, we hypothesise that these findings may also extend to rabbits with lop-ears.

90 Potential consequences for dental health

91 Veterinary professionals have suggested that the altered skull morphology of lop-eared
92 rabbits can cause congenital malocclusion of the dental arcades, such as maxillary
93 brachygnathism (relative shortening of the lower jaw)²⁴. This is also believed to occur in
94 brachycephalic and dwarf breeds including the Netherland dwarf^{24, 25}. Rabbit teeth grow
95 continuously, so reduced attrition caused by malocclusion (i.e. if the upper and lower teeth
96 are mis-aligned) can cause the teeth to overgrow^{9, 26}. This has animal welfare implications
97 because, if the teeth are not worn down appropriately then incisor overgrowth, elongated
98 molar tooth roots and molar spurs can occur²⁶. Rabbit incisors can grow at 2-2.4mm per
99 week so problems can rapidly occur and reoccur after treatment, especially if the problem is
100 due to malocclusion and thus cannot be rectified by husbandry changes²⁷. Maxillary root
101 overgrowth can penetrate the nasolacrimal duct and present as epiphora (watering of the
102 eye) and secondary dacrocystitis (infection of the lacrimal sac)²⁷⁻²⁹. Root elongation can put
103 pressure on sensory nerves innervating the teeth causing pain²⁷. Further pain can occur if
104 overgrown incisors penetrate the soft tissue of the lips, and mandibular and maxillary molar
105 spurs can lacerate the lingual and buccal mucosa respectively²⁷.

106 Dental disease is a chronic condition and the resulting oral pain and physical restrictions of
107 overgrown teeth can lead to inappetance, poor body condition, and if severe can cause
108 mortality through gut stasis^{28, 30}. Other presentations of dental disease due to oral discomfort
109 are hypersalivation, and a lack of grooming or caecotrophy that can lead to flystrike^{26, 28, 30}.

110 Aims and hypotheses

111 This research evaluated the number and type of aural and dental abnormalities in lop-eared
112 versus erect-eared rabbit groups in a non-veterinary context: a rabbit-only rescue centre. We
113 used two complementary sources of information: standardised direct observations of the
114 rabbits, and medical records for the same rabbits; the latter were more heterogeneous and
115 clinically driven than the observations, but could indicate past issues in the rabbits.

116 We hypothesised that, if the lop-eared phenotype leads to functional impairment, there
117 would be significantly more aural pathology, such as ear canal stenosis, cerumen
118 accumulation and inflammation, and dental pathology, such as incisor overgrowth and molar
119 spurs, in lop-eared rabbits than in erect-eared rabbits.

120 Materials and Methods

121 Animals and husbandry

122

123 A convenience sample of fifteen lop-eared and fifteen erect-eared rabbits were selected for
124 examination at a rabbit rescue centre. The sample size of 30 was chosen on the basis of
125 feasibility, because the observations required completion within a relatively short time
126 period, and without disrupting the husbandry routines of the rabbits at the shelter. The rabbits
127 were selected by the rescue manager, who attempted to include a wide range of breeds and
128 ages (where ages were known), and only included rabbits amenable to handling (for animal
129 welfare, and health and safety reasons). She was not aware of the hypothesis, but she was
130 aware that we would examine the ears and teeth of the rabbits as well as general health, and
131 we did specify an equal number of lop- and erect-eared rabbits.

132 The rescue centre was capable of holding approximately 100 rabbits. All rabbits observed
133 were housed in outdoor enclosures measuring at least 8ft x 6ft, which varied but typically
134 comprised a large aviary with a hutch or shelter. Most rabbits (22/30) were housed in

135 opposite sex neutered pairs, whilst eight were singly housed, and environmental enrichment
136 included tunnels and chew toys. Water was provided *ad libitum* from bottles, and the diet
137 consisted of a twice daily supply of hay, pellets (BurgessTM, Pickering), and fresh leaves and
138 vegetables.

139 Data were collected about each rabbit, including ear type (lop or erect), breed, face shape,
140 sex, age, weight, and body condition score³¹. Face shape was assessed by subjectively
141 observing the approximate length and breadth of the skull, and subsequently categorised into
142 brachycephalic (broad, short skull, particularly seen in breeds such as the Netharland Dwarf
143 and Lionhead), mesocephalic (moderately short and broad skull) and doliocephalic (narrow
144 and long skull, as seen in the wild type) based on the independent opinion of two observers.
145 Data were collected on standardised recording sheets (Supplementary material). The study
146 received ethical approval from the Royal Veterinary College's Clinical Research Ethical
147 Review Board (URN 2015 1372).

148

149 [Aural health examination](#)

150 Firstly, an observer (JCJ) stood quietly, approximately 1m from the enclosure, for 5 min to
151 record presence or absence of head shaking and ear scratching, and the number of bouts of
152 these. Then, the rabbit was gently restrained by an assistant whilst the observer performed a
153 subjective clinical examination as summarised in Table 1 (details can be seen in
154 supplementary information). Unfortunately, it was not possible to test inter-observer
155 reliability during the examinations, as the available assistants were not medically trained so
156 could not assess the ears or teeth. During direct observations, the observer could also not be
157 blind to ear shape, so to minimise bias, this was explicitly discussed before observations
158 started; we examined the possibility that lop-eared rabbits having conformational problems

159 could be erroneous, especially since the only scientific comparison to date had found no
 160 cytological issues²⁰, and that science was important for debunking incorrect perceptions. We
 161 were also aware of methods for interpreting and publishing studies where no statistical
 162 significance was founde.g. ^{32,33}, which minimised any incentive to find differences where
 163 none may exist.

164 The bases of the ears were palpated for swelling and the skin checked for evidence of
 165 scratching. The external pinnae were observed for crusting and inflammation (erythema,
 166 heat and swelling). An otoscope was used to visualise the ear canal to look for erythema,
 167 stenosis, increased cerumen, abnormal masses and potential pain responses such as flinching
 168 or struggling during only this part of the exam: the examination was shortened and not
 169 forced if this occurred, for animal welfare reasons (if the rabbit showed this response
 170 generally upon initiation of the exam then it was deemed to be due to fear, rather than pain,
 171 and the rabbit was excluded from the study due to it being unable to be examined). The
 172 otoscope heads were sterilised in a chlorhexidine solution between subjects.

173 Table 1. The descriptive criteria for each variable investigated statistically. The criteria are arranged
 174 such that aural pathology is first described, followed by dental pathology. Full details of the data
 175 collected are provided in the Supplementary information.

Examination area	Variable for analysis	Criteria required for each variable to be identified as ‘present’
Aural	Stenotic ear canals	On examination the internal ear canal was deemed to be narrow, the otoscope specula was unable to be passed down the canal, or being unable to visualise down the canal due to limited space between the ear canal walls

Potential aural pain response	<p>On examination the rabbit appeared painful when palpating the base of the ear, inserting the otoscope specula into the ear canal, or swabbing the ear canal</p> <p>‘Appeared painful’ was defined as: flinching or struggling during only this part of the exam</p>
Cerumen of the ear canal	<p>On aural examination there was subjectively deemed to be increased cerumen in the ear canal.</p> <p>Categories were defined as:</p> <p>0= normal low level of cerumen</p> <p>1= mild amount of cerumen</p> <p>2= moderate amount of cerumen</p> <p>3= large amount of cerumen</p> <p>Each ear was categorised separately, then a combined total of both ears was used for the analysis</p>
Erythema of the ear canal	<p>On aural examination there was subjectively deemed to be increased reddening of the ear canal</p> <p>Categories were defined as:</p> <p>0= pale pink, normal</p> <p>1= pink</p> <p>2= dark pink</p> <p>3= red</p> <p>Each ear was categorised separately, then a combined total of both ears was used for the analysis</p>
Scratching the ears	<p>A bout of head shaking or ear scratching was seen during the 5 min pre-examination observation;</p> <p>Or there was fur loss, skin scaling or scabs around the ears on examination</p>
Malassezia-like yeast species	<p>This was categorised in multiple formats:</p> <p>Categorisation 1:</p>

		5 yeasts or more identified on average per 10 high power fields
		Categorisation 2 (presence of yeast species):
		1 yeast or more identified on average per 10 high power fields
		Categorisation 3 (average number of yeasts per high power field):
		Total number of yeasts for combined left and right ears analysed
	Aural veterinary treatment	The veterinary medical history reported a treatment for aural disease whilst the rabbit was in the rescue's care, including ear flush, ear canal surgery, and ear drop prescription
Dental	Incisor pathology	Incisor malocclusion (underbite or overbite), overgrown incisors or fractured incisors were identified on oral examination; Or veterinary treatment for incisor pathology was recorded in the veterinary record
	Molar overgrowth	Abnormally long molars or molars of different height to the other molars were identified on oral examination
	Sharp molars	On oral examination there was subjectively deemed to be an increased sharpness of the molars at the buccal and lingual points, but that were not severe enough to be classified as spurs
	Molar spurs	Buccal or lingual spurs were identified on oral examination; Or veterinary history of treatment for molar spurs (burring)
	Oral mucosal sores	Current or scarred sores were visible on the oral mucosa on oral examination
	Potential oral pain response	The rabbit appeared painful when palpating the jaw region The rabbit appeared painful when using the otoscope to examine the oral cavity 'Appeared painful' was defined as: flinching or struggling during only this part of the exam
	Epiphora	Excess discharge from the eye, a crusting or damp area below the

	eye, seen on gross visual examination;
	Or excess discharge from the eye reported in the rescue's or veterinary history;
	Or a treatment for epiphora reported, such as a tear duct flush
Dental veterinary treatment	The veterinary medical history reported a treatment for dental disease whilst the rabbit was in the rescues care, such as incisor trimming or removal, or molar spur burring
Poor coat condition	The coat looked unkempt on examination, such as matting of the fur
Hypersalivation	There was deemed to be a large amount of saliva at oral examination;
	Or if there was wet or crusty fur around the mouth, dewlap or front paws on examination
Lack of caecotrophy	Caecotrophs were present in the perineal region on examination

176

177 Two samples were taken from each ear by gently inserting a sterile cotton swab into the
178 external part of the ear canal and rotating fully three times. The samples were labelled with
179 codes so that the observer could examine them blind to whether they originated from a
180 rabbit with lop or erect ears. One sample from each ear was put onto a glass microscope
181 slide with liquid paraffin and then covered with a cover slip. These slides were evaluated
182 microscopically the same day using low magnification (10X) and high contrast to assess for
183 mites. The other sample was rolled onto a microscope slide, allowed to dry for 10 min and
184 then stained using Diff-quick (Rapi-Diff II stain, Atom Scientific, Cheshire) as per the
185 manufacturer guidelines. Cytological assessment began with 40X magnification to find a
186 representative area of interest, which was then evaluated using oil immersion and 100X

187 magnification, to count the average number of bacteria (cocci and rods), and yeasts across
188 10 microscopic high-power fields. Cocci were identified as well-defined, circular and blue
189 stained, and rods were identified as well-defined, rod shaped and blue stained.

190 [Dental health examination](#)

191 After conducting the aural examination, the rabbit's face was palpated externally for facial
192 swellings, bony protrusions along the mandible and maxilla, ability to close the mouth and
193 symmetry of the face. The examiner gently separated the lips manually using fingers and the
194 eight incisors were evaluated for pathology including malocclusion, overgrowth, fractures or
195 abnormal appearance such as horizontal ridging of the tooth surface. Then an otoscope was
196 used in the mouth to assess the molars for overgrowth, sharpness, spurs, fractures and
197 variation in tooth height. The lingual and buccal soft tissues were examined using the
198 otoscope for sores and scars indicating healed sores. Evidence of potential pain was
199 monitored for, such as flinching or struggling during only this part of the exam, and the
200 examination was again shortened if this occurred. Secondary signs of dental disease were
201 looked for including epiphora, poor coat condition, hypersalivation (also seen as wet or
202 crusty fur around the mouth and throat), and caecotrophs around the perineum.

203 [Medical history records](#)

204 The medical history of the rabbits whilst at the shelter was checked using hard copies of
205 veterinary records and the rescue centre's weekly health check record, especially focusing
206 on dental and aural disease and any treatments for these. This was carried out after all rabbit
207 examinations were completed, so that the examinations were not biased by knowledge of
208 existing medical conditions.

209 Statistical analysis

210 Where necessary, rare categories of data were collapsed together with similar categories to
211 enable statistical analysis, with the final categories as described in Table 1. IBM SPSS
212 statistics version 24 was used to carry out binary logistic regression on binary dependent
213 variables. The predictors used in the model were ear type, sex, weight and face shape. Five
214 rabbits had unknown ages (three with erect ears and two with lop ears), so, because age was
215 not a statistically significant predictor in any of the initial models, and because mean age
216 showed no significant difference between both groups (as analysed using binary logistic
217 regression: $P=0.492$), it was removed from the final models, allowing data from all 30
218 rabbits to be included. The following outcomes were compared in lop- and erect-eared rabbit
219 groups using binary logistic regression: incisor pathology, molar overgrowth, sharp molars,
220 epiphora, lack of caecotrophy, stenosis of the ear canal, potential aural pain, and the
221 presence of yeast.

222 However, no rabbits from the erect-eared group at all were affected for the following
223 variables: molar spurs, potential oral pain response, oral mucosal sores, poor coat condition,
224 hypersalivation, veterinary dental treatment, aural veterinary treatment, and scratching the
225 ears. This meant there were fewer than five values in one group, so a Fisher's exact
226 statistical test was carried out using GraphPad Prism Version 7.

227 For outcomes that were recorded as continuous scores, Mann-Whitney U statistical tests
228 were carried out using GraphPad Prism Version 7. This was the case for the average number
229 of yeasts per high power field, cerumen in the ear canal and erythema in the ear canal.

230 Results

231

232 Demographics

233

234 Rabbit signalment is shown in Table 2. The known ages of the erect-eared rabbit group
 235 ranged from 5 months to 9 years, whilst those of the lop-eared rabbit group ranged from 8
 236 months to 7 years 9 months. The mean age was not statistically different between the lop-
 237 and erect-eared groups (P=0.492). The rabbits' body weights ranged from 1.4kg to 3.5kg in
 238 both groups. The erect-eared breeds mainly consisted of cross breeds (n=10), followed by
 239 Lionheads (n=3), whilst Dwarf lops (n=3) and Mini Lops (n=3) were the most common lop-
 240 eared rabbits.

241

Signalment	Lop-eared	Erect-eared
Mean known age +/- standard deviation (years)	4.1 +/- 2.2	3.6 +/- 2.7
Sex (Females; Males)	5; 10	7; 8
Mean body weight +/- standard deviation (kg)	2.2 +/- 0.5	2.3 +/- 0.6
Mean body condition score +/- standard deviation	3.00 +/- 0.27 Range = 2.5-3.5	3.03 +/- 0.35 Range = 2.5-3.5
Face shape	3 brachycephalic 6 mesaticephalic 6 doliocephalic	2 brachycephalic 2 mesaticephalic 11 doliocephalic
Breeds	Dwarf lops (x3); Mini lops (x3); Crossbreeds	Crossbreeds (x10);

(x3); Cashmere lops (x2); English lop (x1); Lionheads (x3); Astrex
 Butterfly lop (x1); Harlequin lop (x1); Frost Rex (x1); Angora (x1)
 point lop (x1)

242 Table 2. Demographic details of the lop-eared and erect-eared rabbit groups.

243

244 **Aural health results**

245

246 Statistical results are summarised in Table 3. Lop-eared rabbits had approximately forty-
 247 three times higher odds of having stenotic ear canals (OR=42.7; 95% CI: 4.2-434; P=0.002)
 248 and a statistically significantly higher erythema score of the ear canal (U=50.5; N=15;
 249 P=0.004; Figure 1), compared with erect-eared rabbits. They also had a statistically
 250 significantly higher cerumen score in the ear canal compared with erect-eared rabbits
 251 (U=24; N=30; P<0.001; Figure 2). Lop-eared rabbits had approximately fifteen times higher
 252 odds of demonstrating a potential pain response during ear examination than erect-eared
 253 rabbits (OR=14.8; 95% CI: 1.1-200.9; P=0.043).

254

255 <Figures 1 and 2 about here>

256

257 The health records revealed that 14/15 of the lop-eared rabbits had at least one recording of
 258 excess wax during health checks by the rescue staff, compared with 3/15 of the erect-eared
 259 rabbits (Fisher's Exact $X^2= 13.575$; DF = 1; P < 0.001). The rescue carried out repeated ear
 260 cleaning in 9/15 of the lop-eared rabbits, compared with none of the erect-eared rabbits
 261 (Fisher's Exact $X^2= 10.159$; DF = 1; P = 0.001).

262

Examination	Pathology	Cases in	Cases in	Significance
-------------	-----------	----------	----------	--------------

area	investigated	lop-eared rabbits (n=15)	erect-eared rabbits (n=15)	between lop- and erect-eared groups (P=)	
Aural	Ear canal stenosis	13	2	0.002	
	Potential aural pain response	6	1	0.043	
	Scratching the ears	2	0	0.483	
	Mallasezia-like yeast species	12	8	0.174	
	Record of aural veterinary treatment	4	0	0.100	
	Record of excess cerumen	14	3	<0.001	
	Record of repeated ear cleaning	9	0	0.001	
	Dental	Incisor pathology	7	1	0.015
		Molar overgrowth	13	6	0.015
Sharp molars		13	6	0.015	
Molar spurs		11	0	0.006	
Oral mucosal sores/scars		2	0	0.483	

Potential oral pain response	2	0	0.483
Epiphora	4	1	0.095
Poor coat condition	3	0	0.224
Hypersalivation	2	0	0.483
Lack of caecotrophy	5	2	0.274
Record of dental veterinary treatment	6	0	0.017

263 Table 3. Prevalence of binary variables investigated in both lop and erect-eared rabbit groups and the
264 significance of the difference between both groups.

265

266 No statistically significant difference was found between lop-eared and erect-eared rabbits
267 for evidence of scratching (fur loss or scaling) around the ears (2/15 versus 0/15,
268 respectively), or ear pathology requiring treatment whilst at the rescue centre (4/15 versus
269 0/15, respectively). None of the rabbits had crusting of the external pinna, masses in the ear,
270 head shaking or scratching in pre-examination observation or a head tilt. No statistical
271 significance was found for any of the other predictors used in the binary logistic regression
272 (face shape, sex or weight) for any of the aural pathology outcomes.

273

274 Microscopy revealed the presence of yeast species in some rabbits (12/15 lop-eared rabbits
275 versus 8/15 erect-eared rabbits), which were identified as *Malassezia cuniculi* based on
276 morphology described in other research^{20, 23, 34}. The presence/absence, and also number of,

277 malassezia-like yeasts found on microscopy were not statistically significantly different
278 between lop- and erect-eared rabbits.
279 Only one mite was found, identified as Psoroptes cuniculi, in the ear of an erect-eared rabbit.
280 This rabbit had no associated clinical signs or previous history of aural problems. No rod
281 bacteria were identified, but cocci were found in three lop-eared rabbits and two erect-eared
282 rabbits.

283

284 Dental health results

285

286 Lop-eared rabbits had approximately twenty-three times higher odds of incisor pathology
287 compared with erect-eared rabbits (OR=23.3; 95% CI: 1.9–293.2; P=0.015). They also had
288 approximately twelve times higher odds of having molar overgrowth (OR=12; 95% CI: 1.6-
289 88.9; P=0.015), thirteen times higher odds of molar sharpness (OR=13.4; 95% CI: 1.7-
290 107.2; P=0.015) and were statistically significantly more likely to have molar spurs
291 (attributable risk=0.4667; P=0.006), compared with erect-eared rabbits (Table 3).

292 Veterinary records showed that 8/15 of the lop-eared rabbits had tooth abnormalities,
293 compared with none of the erect-eared rabbits (attributable risk= 0.53, 95% CI: 0.17-0.78;
294 P=0.002). Additionally, 6/15 of the lop ears had been for a dental whilst at the rescue,
295 whereas none of the erect-eared rabbits had, which was again statistically significant
296 (attributable risk=0.4; 95% CI: 0.06-0.67; P=0.017).

297 On the other hand, statistically significant differences between lop and erect-eared rabbits
298 were not found for oral mucosal sores, potential oral pain response, epiphora, poor coat
299 condition, hypersalivation, or lack of caecotrophy, although the trends were for all of these
300 to be slightly more likely in lop-eared rabbits (Table 3). No rabbits had an inability to close
301 the mouth or fractured teeth.

302

303 No statistical significance was found for any of the other predictors used in the binary
304 logistic regression (face shape, sex or weight) for any of the dental pathology outcomes.

305 Discussion

306 The results confirmed that lop-eared rabbits did indeed have a statistically significantly
307 higher level of aural pathology, including stenotic ear canals, potential pain response during
308 aural examination, increased levels of cerumen and erythema of the ear canal. Similarly,
309 there was also a statistically significantly higher level of dental pathology, including incisor
310 pathology, molar overgrowth, molar sharpness, molar spurs and veterinary dental treatment,
311 in lop-eared compared with erect-eared rabbits. Both the direct observations and the medical
312 records showed that the lop-eared rabbits had statistically significantly more aural and dental
313 pathologies than did erect-eared rabbits.

314 The use of a rescue population may of course not represent the general population of pet
315 rabbits. It is difficult to know if rescue rabbits would be affected more than pet rabbits by the
316 issues investigated here, or less. On one hand, rabbits in the rescue centre may be more
317 prone to health problems if they were given to the rescue because their owners could not
318 afford veterinary bills, or due to neglect and being fed an inappropriate diet. On the other
319 hand, the rescue staff were highly knowledgeable about rabbit health and carried out weekly
320 health checks, so current severe dental or aural disease was not found during the clinical
321 examination of this study. In either case, lop- and erect-eared rabbits would have been
322 affected by these factors to a similar extent. Thus, the finding that lop-eared rabbits were
323 prone to the aural and dental pathology investigated here constitutes a welfare concern

324 associated with breeding and buying lop-eared rabbits, for reasons described below in more
325 detail.

326 Aural pathology

327 The increased erythema, ceruminous discharge and stenosis of the ear canal found in the
328 lop-eared rabbits here, could indicate a higher frequency of otitis externa. This would concur
329 with two canine studies that found higher prevalences of otitis externa in dogs with
330 pendulous ears^{21, 22}. In many of the rabbits, this appeared to be a chronic condition as the
331 medical records showed that 9/15 of the lop-eared rabbits required repeated ear cleaning
332 whilst at the rescue.

333 Thus, the welfare consequences of a rabbit having lop-ears include pain, as indicated by
334 statistically significantly increased pain responses during examination of lop-ears.
335 Additionally the higher frequency of signs consistent with otitis externa found in the lop-
336 eared compared with the erect-eared rabbits, suggest potential for pain, auditory deficit or
337 even deafness^{17, 18}, which in turn increases the vulnerability of the animal to threats and
338 could cause anxiety¹⁹. Deafness itself could not be tested in the current study, but this could
339 be assessed in future studies using Transient Evoked Otoacoustic Emissions testing, which
340 has been successfully used as a less invasive and relatively inexpensive alternative to
341 brainstem auditory evoked responses in puppies³⁵. The rescue centre staff anecdotally
342 believed that more of the lop-eared rabbits had auditory impairment than the erect-eared
343 ones had, and unpublished research from our laboratory suggested that lop-eared rabbits
344 showed more signs of anxiety in a novel object test than erect-eared rabbits³⁶.

345 The results here suggest that the aetiology of any potentially associated auditory deficits
346 would be multifactorial as it is in dogs and cats^{19, 37}, with the over-hanging immobile pinnae,

347 the stenotic ear canals, and the accumulation of cerumen all comprising physical barriers to
348 sound perception. The middle and inner structures themselves may also be more prone to
349 issues, such as tympanic membrane rupture and sensorineural damage, if repeated infection
350 occurs.

351 The lack of a statistically significant difference in the presence of *Malassezia cuniculi*
352 between lop and erect-eared rabbits could of course be due to the fairly small sample size
353 here, but it agrees with the findings of Quinton et al. (2014), who reported no statistically
354 significant difference due to ear type in 146 clinically healthy domestic pet rabbits. This
355 could be explained by *Malassezia* being a normal coloniser of the rabbit ear canal, as in
356 other species such as dogs and cats^{16, 20}. In future, culture could offer a more sensitive
357 method for quantifying *Malassezia* colonisation than cytology³⁸. Campbell et al. {, 2010
358 #4640} found a positive correlation between the amount of ceruminous discharge and the
359 culture of *Malassezia*. However, although the present study found higher levels of cerumen
360 in lop-eared rabbits, the lack of difference in *Malassezia* colonisation suggests that this
361 increased cerumen was due to difficulties in expulsion, potentially due to the anatomy of the
362 lop-ear, rather than a *Malassezia* overgrowth⁹.

363 Dental pathology

364 The increased presence of dental pathology found in lop-eared rabbits in this study partially
365 supports results from Mullan and Main³⁹, who found that dwarf lops were reported by their
366 owners to have statistically significantly more dental abnormalities compared with other
367 breeds (including some other lops), but only when diet and age were excluded from the
368 model. However, the present results disagree with a Finnish study⁴⁰ of 167 pet rabbits,
369 which found no associations between lop-eared breeds and dental disease, although they did

370 find statistically significantly more dental pathology in Lionhead rabbits, which are erect-
371 eared, but brachycephalic. A possible explanation for the disagreement is that the study by
372 Mäkitaipale et al.⁴⁰ was carried out on healthy pet rabbits whose owners voluntarily signed
373 up for the study, so those with known current dental problems may have been excluded from
374 that study.

375 The rabbits in our study represent a convenience sample of a rescue population, but if our
376 results can be replicated more widely, the increased risk of dental pathology for lop-eared
377 rabbit welfare is concerning for several reasons. Rabbit dental pathology can lead to lesions
378 of the mouth, pain, difficulty chewing food e.g. avoidance of, or prolonged chewing of, hard
379 foods as seen in bears with dental pathology⁴¹, and possibly gastrointestinal problems
380 following inadequately chewed food as found in humans^{42,43}, among other issues described
381 earlier. The rescue staff caring for rabbits in the current study were more knowledgeable of
382 and attentive to rabbit health issues than many owners, and health records indicated that they
383 had already identified more dental issues requiring veterinary attention in lop-eared than
384 erect-eared rabbits, before our study started. Indeed, the rabbits at the rescue centre
385 underwent weekly health checks by experienced rescue staff with the use of an otoscope.
386 Despite this enhanced care and monitoring of dental pathology, we observed statistically
387 significantly more abnormalities in both incisors and molars in the lop-eared rabbits. The
388 potentially associated secondary issues, such as trauma to the mouth and lips,
389 hypersalivation, and pain responses, were too rare to reach statistical significance, but all
390 showed trends towards being slightly more common in lop-eared rabbits.

391 The dental abnormalities here are unlikely to be due to diet, because there is currently no a
392 priori reason to believe that lop-eared rabbits would have been fed poorer diets than erect-
393 eared rabbits. Thus, they are likely to be caused at least partly by the skull and jaw

394 conformations associated with the lop-eared phenotype. Future studies could help confirm
395 this by observing random sample populations, and by utilising radiology to look at oral
396 conformations, alongside oral examination if possible^{28, 30, 40}.

397 Conclusions 398

399 The results from this research support the hypothesis that lop-eared rabbits have more dental
400 and aural pathology than erect-eared rabbits. This brings into debate the ethics of breeding
401 and buying lop-eared rabbits, as they may be more likely to suffer from these conditions,
402 which can be painful and often chronic or recurrent.

403

404 Acknowledgements

405 The authors wish to thank the staff at The Rabbit Residence Rescue, Royston for allowing
406 the inclusion of their rabbits in the project, Dr Anette Loeffler for her guidance on making
407 and interpreting ear smears, Dr Anke Hendricks for her help with equipment and advice,
408 Katie Lovell for supplying laboratory equipment, Katie Franklin for her assistance at the
409 rescue and providing the list of rabbits, and Natalie Chancellor and Tomaso Carucci for their
410 help handling the rabbits for examination. This research was carried out in part fulfilment of
411 JCJ's Bachelor of Veterinary Medicine with Intercalated BSc Bioveterinary Sciences
412 degree, in year 5 of this course at the Royal Veterinary College. The Royal Veterinary
413 College assigned the following ID number to this study: PPS_01851.

414 References

415

- 416 1. BSAVA. Inherited diseases and exaggerated characteristics position statement 2012
417 [https://www.bsava.com/Resources/Veterinary-resources/Position-statements/Inherited-
418 diseases-and-exaggerated-characteristics](https://www.bsava.com/Resources/Veterinary-resources/Position-statements/Inherited-
418 diseases-and-exaggerated-characteristics) (accessed 30th March 2018).
- 419 2. Gaines SA, Rooney NJ, Bradshaw JWS. The effect of feeding enrichment upon
420 reported working ability and behavior of kenneled working dogs. *Journal of Forensic
421 Sciences*. 2008;53:1400-1404.
- 422 3. British Veterinary Association. Health and welfare of brachycephalic dogs 2014
423 [https://www.bva.co.uk/news-campaigns-and-policy/policy/companion-
424 animals/brachycephalic-dogs/](https://www.bva.co.uk/news-campaigns-and-policy/policy/companion-
424 animals/brachycephalic-dogs/) (accessed 30th March 2018).
- 425 4. Rabbit Welfare Association and Fund. Brachycephaly not just a dog issue. *Veterinary
426 Record*. 2017;180:316.
- 427 5. UFAW. Genetic Welfare Problems of Companion Animals 2011
428 <https://www.ufaw.org.uk/rabbits/english-lop-overlong-ears> (accessed 30th March 2018).
- 429 6. Castle WE, Reed SC. Studies of Inheritance in Lop-Eared Rabbits. *Genetics*.
430 1936;21:297-309.
- 431 7. British rabbit council. British Rabbit Council breed standards 2016-2020 2016
432 [https://thebritishrabbitcouncil.org/Mono%20Breed%20Standards%20Book%20APRIL%2020
433 017%20small.pdf](https://thebritishrabbitcouncil.org/Mono%20Breed%20Standards%20Book%20APRIL%2020
433 017%20small.pdf) (accessed 29th April 2018).
- 434 8. Eatwell K, Mancinelli E, Hedley J, Keeble E, Kovalik M, Yool DA. Partial ear canal
435 ablation and lateral bulla osteotomy in rabbits. *Journal of Small Animal Practice*.
436 2013;54:325-330.
- 437 9. Harcourt-Brown F, Chitty J. BSAVA Manual of Rabbit Surgery, Dentistry and
438 Imaging. Quedgeley, Gloucester: BSAVA [British Small Animal Veterinary Association];
439 2013.
- 440 10. Csomos R, Bosscher G, Mans C, Hardie R. Surgical Management of Ear Diseases in
441 Rabbits. *Veterinary Clinics of North America: Exotic Animal Practice*. 2016;19:189-204.
- 442 11. Darwin C. *The variation of animals and plants under domestication*: O. Judd; 1868.
- 443 12. Cordero GA, Berns CM. A test of Darwin's 'lop-eared' rabbit hypothesis. *Journal of
444 Evolutionary Biology*. 2016;29:2102-2110.

- 445 13. Lennox AM, Kelleher S. Bacterial and Parasitic Diseases of Rabbits. *Veterinary*
446 *Clinics: Exotic Animal Practice*. 2009;12:519-530.
- 447 14. Vella D, Donnelly TM. Chapter 12 - Basic Anatomy, Physiology, and Husbandry. In:
448 Quesenberry KE, Carpenter JW, editors. *Ferrets, Rabbits, and Rodents: Clinical Medicine*
449 *and Surgery (Third Edition)*. Saint Louis: W.B. Saunders; 2012. p. 157-173.
- 450 15. Mayer Jr. Otolology of the Rabbit: Anatomy, Physiology, and Surgery Association of
451 exotic mammal veterinarians lectures and practical workshop 2011
452 <http://www.aemv.org/documents/2011-rAEMV%20-%2030709%20Guts.pdf#page=58>
453 (accessed 4th March 2018).
- 454 16. Campbell J, Coyner KS, Rankin SC, Lewis TP, Schick AE, Shumaker AK.
455 Evaluation of fungal flora in normal and diseased canine ears. *Veterinary Dermatology*.
456 2010;21:619-625.
- 457 17. Mancinelli E, Lennox AM. Management of Otitis in Rabbits. *Journal of Exotic Pet*
458 *Medicine*. 2017;26:63-73.
- 459 18. Chow EP. Surgical Management of Rabbit Ear Disease. *Journal of Exotic Pet*
460 *Medicine*. 2011;20:182-187.
- 461 19. Strain GM. Aetiology, prevalence and diagnosis of deafness in dogs and cats. *British*
462 *Veterinary Journal*. 1996;152:17-36.
- 463 20. Quinton J-F, Francois M, Laprais A, Prelaud P. Cytology of the external auditory
464 meatus in healthy domestic pet rabbits (*Oryctolagus cuniculus*). *Revue Medecine Veterinaire*.
465 2014;165:263-266.
- 466 21. Hayes HJ, Pickle L, Wilson G. Effects of ear type and weather on the hospital
467 prevalence of canine otitis externa. *Research in Veterinary Science*. 1987;42:294-298.
- 468 22. Perry LR, MacLennan B, Korven R, Rawlings TA. Epidemiological study of dogs
469 with otitis externa in Cape Breton, Nova Scotia. *The Canadian Veterinary Journal*.
470 2017;58:168-174.
- 471 23. Cafarchia C, Gallo S, Capelli G, Otranto D. Occurrence and Population Size of
472 *Malassezia* spp. in the External Ear Canal of Dogs and Cats Both Healthy and with Otitis.
473 *Mycopathologia*. 2005;160:143-149.
- 474 24. Lord B. Dental disease in the rabbit Part 2: Dental disease causes, clinical signs and
475 diagnosis. *Companion Animal*. 2011;16:39-42.
- 476 25. Meredith A. The Importance of Diet in Rabbits: The British Rabbit council; 2010
477 <https://thebritishrabbitcouncil.org/diet.htm> (accessed 29th April 2018).

- 478 26. Varga M. Chapter 5 - Dental Disease. Textbook of Rabbit Medicine (Second
479 Edition): Butterworth-Heinemann; 2014. p. 203-248.
- 480 27. Harcourt-Brown F. Dental disease in pet rabbits 1. Normal dentition, pathogenesis
481 and aetiology. In Practice. 2009;31:370.
- 482 28. Harcourt-Brown F. Diagnosis, treatment and prognosis of dental disease in pet
483 rabbits. In Practice. 1997;19:407.
- 484 29. Florin M, Rusanen E, Haessig M, Richter M, Spiess Bernhard M. Clinical
485 presentation, treatment, and outcome of dacryocystitis in rabbits: a retrospective study of 28
486 cases (2003–2007). Veterinary Ophthalmology. 2009;12:350-356.
- 487 30. Mosallanejad B, Moarrabi A, Avizeh R, Ghadiri A. Prevalence of Dental
488 Malocclusion and Root Elongation in Pet Rabbits of Ahvaz, Iran. Iranian Journal of
489 Veterinary Science and Technology. 2011;2:109–116.
- 490 31. Pet Food Manufacturer's Association. Rabbit Size-O-Meter 2013
491 https://www.pfma.org.uk/_assets/docs/pet-size-o-meter/pet-size-o-meter-rabbit.pdf (accessed
492 1st February 2018).
- 493 32. Colegrave N, Ruxton GD. Confidence intervals are a more useful complement to
494 nonsignificant tests than are power calculations. Behavioral Ecology. 2003;14:446-447.
- 495 33. Levine TR. A defense of publishing nonsignificant (ns) results. Communication
496 Research Reports. 2013;30:270-274.
- 497 34. Cabañes FJ, Vega S, Castellá G. *Malassezia cuniculi* sp. nov., a novel yeast species
498 isolated from rabbit skin. Medical Mycology. 2011;49:40-48.
- 499 35. McBrearty A, Penderis J. Transient evoked otoacoustic emissions testing for
500 screening of sensorineural deafness in puppies. Journal of Veterinary Internal Medicine.
501 2011;25:1366-1371.
- 502 36. Franklin KA. The Extent to Which Ear Morphology Affects Rabbit Health and
503 Behaviour [BSc (Hons) dissertation]: The Royal Veterinary College; Unpublished 2018.
- 504 37. Mactaggart D. Assessment and management of chronic ear disease. In Practice.
505 2008;30:450.
- 506 38. Besignor E, Jankowski F, Seewald W, Touati F, Deville M, Guillot J. Comparison of
507 two sampling techniques to assess quantity and distribution of *Malassezia* yeasts on the skin
508 of Basset Hounds. Veterinary Dermatology. 2002;13:237-241.
- 509 39. Mullan SM, Main DCJ. Survey of the husbandry, health and welfare of 102 pet
510 rabbits. Veterinary Record. 2006;159:103-109.

- 511 40. Mäkitaipale J, Harcourt-Brown FM, Laitinen-Vapaavuori O. Health survey of 167 pet
512 rabbits (*Oryctolagus cuniculus*) in Finland. *Veterinary Record*. 2015;177:418.
- 513 41. Fleming M, Burn CC. Behavioural assessment of dental pain in captive Malayan Sun
514 Bears (*Helarctos malayanus*). *Animal Welfare*. 2014;23:131-140.
- 515 42. Buschang PH. Masticatory Ability and Performance: The Effects of Mutilated and
516 Maloccluded Dentitions. *Seminars in Orthodontics*. 2006;12:92-101.
- 517 43. Koike S, Sujino T, Ohmori H, Shimazaki K, Fukuyama E, Kanai T, et al. Gastric
518 emptying rate in subjects with malocclusion examined by [¹³C] breath test. *Journal of Oral*
519 *Rehabilitation*. 2013;40:574-581.

520

521 [Figure Captions](#)

522

523 Figure 1. Frequency distribution of erythema scores in the ear canals of lop-eared and erect-
524 eared rabbits. Black bars indicate lop-eared rabbits; white bars indicate erect-eared rabbits.
525 Each ear was scored as follows: 0= pale pink, 1= pink, 2= dark pink, 3= red, and the added
526 total for both ears per rabbit is shown.

527

528 Figure 2. Frequency distribution of cerumen scores lop-eared and erect-eared rabbits. Black
529 bars indicate lop-eared rabbits; white bars indicate erect-eared rabbits. Each ear was scored as
530 follows: 0= normal low amount of cerumen, 1= mild amount of cerumen, 2= moderate
531 amount of cerumen, 3= large amount of cerumen, and the added total for both ears per rabbit
532 is shown.