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## **Rationale for opportunistic salpingectomy during gynecological surgery for a benign condition: a review of the available literature**

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1 **Prevalence of canine hip dysplasia in 17 breeds in France, a**  
2 **retrospective study of the 1993-2019 radiographic screening**  
3 **period**

4  
5 **Summary**

6 Canine hip dysplasia is a complex developmental disease of the coxo-femoral joint and one of  
7 the most common orthopedic conditions in dogs. Due to the genetic contribution, most of the  
8 programs fighting against hip dysplasia recommend selective breeding that excludes affected  
9 dogs. In France, the phenotypic screening of coxo-femoral joint conformation remains a  
10 strategy for breeders to establish selection decisions.

11 We compared the hip dysplasia prevalence in affected breeds over several periods of time to  
12 evaluate the effectiveness of the hip dysplasia control program in France.

13 17 breeds were studied, based on the assessment of 8022 dogs, during the 1993-2019  
14 screening period, which was divided into several intervals for analysis.

15 The prevalence varied widely from 8.8% (Hovawart) to 49.2% (American Staffordshire  
16 Terrier). It decreased over time in 10 breeds, the decrease being significant in the Picardy  
17 shepherd dog. An increase in prevalence was noted in 7 breeds, although the differences were  
18 not statistically significant.

19 Our results are in accordance with several recent studies showing that long-term selection  
20 policies may help decreasing the hip dysplasia prevalence in some breeds. The  
21 complementary use of more recent tools such as estimated breeding values and genomics  
22 would probably help breeders achieve more substantive results.

23

24 **Keywords:** Hip dysplasia, dog, phenotypic screening

25

## 26 **Résumé**

27 La dysplasie de hanche est une affection complexe de l'articulation coxo-fémorale  
28 particulièrement courante chez le chien. Compte tenu de l'héritabilité de l'affection, la plupart  
29 des programmes de lutte contre l'affection recommandent d'exclure les chiens affectés de la  
30 reproduction. En France, le dépistage phénotypique de la dysplasie de hanche est utilisé par  
31 les éleveurs dans leurs plans de sélection.

32 Afin d'évaluer l'efficacité du programme de contrôle de la dysplasie de hanche en France,  
33 nous avons étudié l'évolution de la prévalence de l'affection chez 17 races, sur la base de  
34 l'évaluation radiographique de 8022 chiens, au cours de la période 1993-2019 (divisée en  
35 plusieurs intervalles pour l'analyse).

36 La prévalence de la dysplasie de hanche varie de 8,8% (Hovawart) à 49,2% (American  
37 Staffordshire Terrier). Pour 10 races, elle a diminué au fil du temps, la diminution étant  
38 statistiquement significative chez le Picardy shepherd dog. Une augmentation de prévalence  
39 est observée pour 7 races, mais les différences ne sont pas statistiquement significatives.

40 Nos résultats sont conformes à plusieurs études récentes qui montrent que la politique de  
41 sélection des reproducteurs permet de diminuer la prévalence de la dysplasie de hanche dans  
42 un certain nombre de races. L'utilisation complémentaire d'outils plus récents tels que les  
43 valeurs estimées de reproduction et la génomique permettrait probablement d'obtenir des  
44 résultats plus conséquents.

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## 50 **Introduction**

51 Canine hip dysplasia (HD) is a complex developmental disease of the coxo-femoral joint and  
52 is one of the most common orthopedic conditions in dogs [1].

53 Osteoarthritis results from the varying degree of hip laxity of the coxo-femoral joint leading  
54 to subluxation of the femoral head, a shallow acetabulum and flattening of the femoral head  
55 [2]. These anatomical abnormalities lead to an inflammatory reaction with secondary  
56 degenerative joint disease associated with pain and lameness ranging from mild to severe  
57 [1,3]. The multifactorial characteristics of this medical condition are the results of genetic and  
58 environmental contributions (nutrition, growth rate, overall body weight). Studies have shown  
59 that the degree of heritability varies from 0.11 to 0.68 among different dog breeds [4].

60 Due to the genetic predisposition, excluding affected dogs from breeding has been shown to  
61 reduce the prevalence of HD [5]. The heritability of HD and the response to selection is  
62 however breed dependent. The higher the heritability, the greater is the expected genetic  
63 improvement over time when selective breeding is practiced [6].

64 In France, a program intending to reduce HD prevalence was introduced in 1971 under the  
65 responsibility of each breed club and supervised by the French Kennel Club (SCC: Société  
66 Centrale Canine) [7]. Currently, phenotypic screening for coxo-femoral joint conformation  
67 remains a strategy for breeders for making selection decisions [8]. Radiographic screening for  
68 HD is based on a conventional ventrodorsal hip extended radiograph in anaesthetized or  
69 deeply sedated dogs. According to the Fédération Cynologique Internationale (FCI), a five-  
70 class system is used in continental Europe, Asia, Russia and parts of South America (Table 1).  
71 The grades are defined descriptively based on the size of the Norberg angle (NA), depth of the  
72 acetabulum, degree of subluxation and signs of secondary joint disease [9].

73

74 The minimum age for official screening is 12 months, except in large and giant breeds, in  
75 which it is 18 months [7]. For each breed, an official reader is appointed by the breed club to  
76 analyse the radiographs. Several control programs have been conducted in different countries  
77 over the last 25 years, and their ability to reduce hip dysplasia has shown variable results.  
78 While several reports identified a decrease in HD prevalence [5,7,10-16], others failed to  
79 identify any significant progress [17-20].

80 The aim of our observational study was to compare the HD prevalence in affected breeds over  
81 several periods of time to evaluate the effectiveness of the hip dysplasia control program in  
82 France. This study is complementary of a first one [16], which was recently published and  
83 related to 10 other breeds, over the 1997-2017 screening period.

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## 94 **Materials and methods**

### 95 **Data**

96 From 1993 to 2019, 50955 standard radiographs of extended hindlimbs submitted by breeders or  
97 owners were evaluated independently by the same examiner (XXX) for HD assessment. All the  
98 data were computerized and recorded in a single electronic database to allow further analysis.  
99 For the present study, and for each selected breed, the incidence of each of the 5 scoring classes  
100 (Table 1) was extracted from the database for each year covered in this retrospective study.  
101 Breeds were excluded if the single panelist changed before the end (2019) of the study period, or  
102 if the total number of radiographs read per breed was insufficient (i.e. <200).

103

### 104 **Scoring protocol**

105 All dogs were scored according to the FCI 5 class grading scale (Table 1). Each joint was  
106 assigned to one of five grades (A-E) that are defined descriptively; the final grade refers to the  
107 worst joint. A and B are considered as normal joints (non-dysplastic), and grades C, D and E  
108 represent mild, moderate and severe dysplasia, respectively. To evaluate and compare the HD  
109 prevalence over time, each breed was divided into 2 cohorts, depending on the length of their  
110 screening period.

111

### 112 **Statistical analysis**

113 For each breed and each period, HD prevalence (expressed as %) was obtained by dividing  
114 the number of dogs that scored C-D and E by the total number of dogs evaluated for the  
115 breed.

116 Within each breed, HD prevalence was compared among the periods using their 95%  
117 confidence interval (95% CI) calculated by the Wilson/Brown method. The 95% CI assumes

118 binomial data. Statistical analyses were performed by one author (AB) using a commercial  
119 software program (Prism 6, GraphPad Software, La Jolla, USA, CA).

## 120 **Results**

121 Overall, 8022 records for 17 breeds were included in the study : American Akita,  
122 Altdeutscher Schaferhund, American Cocker Spaniel, American Staffordshire Terrier, Picardy  
123 shepherd dog, French pointer, Chow Chow, Czechoslovakian Wolfdog, Dalmatian, English  
124 Springer Spaniel, Blue Picardy spaniel, Picardy spaniel, Hovawart, Rhodesian Ridgeback,  
125 Giant Schnauzer, Schnauzer and Irish Setter.

126 The overall prevalence of HD was evaluated in each breed mentioned above. The study period  
127 extended from 1993 to 2019 for 8 breeds. For the remaining 9 breeds, the official panelist  
128 changed during the screening period, and the study period was therefore shorter, as listed in  
129 Table 2.

130  
131 The different periods of screening used to evaluate and compare HD prevalence over time in  
132 each breed are listed in Table 3.

133 The HD prevalence for each breed varied from 8.8% (Hovawart) to 49.2% (American  
134 Staffordshire Terrier). The overall HD prevalence associated with the FCI 5-class grading  
135 scale in all breeds is listed in Table 4. The overall HD prevalence is presented in Fig 1.

136 The prevalence of the different grades according to the FCI scale and prevalence of HD over  
137 the different periods of time are shown for each breed in Figs 2-18.

138  
139 A diminishing prevalence of HD was noted in 10 breeds in this study (Picardy shepherd dog,  
140 Blue Picardy spaniel, Czechoslovakian Wolfdog, Giant Schnauzer, American Akita,  
141 American Cocker Spaniel, Irish Setter, French pointer, Rhodesian Ridgeback, and Hovawart).



142 The decrease in HD prevalence (Table 5) was significant in the Picardy shepherd dog. In this  
143 breed, between 1993 and 2019, the HD prevalence dropped from 39.9% to 25.1%.

144

145 For all 10 breeds with a decrease in HD prevalence, a marked decrease in the D-E grades was  
146 noted, except for the Hovawart in which the C and D grades decreased (no E grade remained  
147 stable. For the Rhodesian Ridgeback, a decrease in the C grade in association with the D and  
148 grades was noted. For the American Akita, it was a decrease in C and E grades.

149

150 A non-significant increase in HD prevalence was observed in 7 breeds (American  
151 Staffordshire Terrier, Chow Chow, English Springer Spaniel, Schnauzer, Altdeutscher  
152 Schaferhund; Table 5).

153 In 3 of these 7 breeds with an increased HD prevalence, there was an increase in the C grade  
154 associated with a decrease in D grade (Altdeutscher Schaferhund, English Springer Spaniel,  
155 American Staffordshire Terrier).

156 A stable HD prevalence was observed for the Picardy spaniel and for the Dalmatian (for  
157 which it remains rather low).

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## 166 **Discussion**

167 A diminishing prevalence of HD was noted in 10 breeds in this study. Among them, the  
168 Picardy shepherd dog showed a significant change in HD prevalence over the study period.  
169 These results support the fact that a long-term purely phenotypic selection mode against hip  
170 dysplasia based on radiographic screening control might be efficient in decreasing the HD  
171 prevalence.

172 The increase in the C grade noted in 3 breeds (Altdeutscher Schaferhund, English Springer  
173 Spaniel, American Staffordshire Terrier) with an increased HD prevalence is difficult to  
174 explain, and the situation is most likely different from breed to breed. The altdeutscher  
175 schaferhund breed club forbids mating D or E scored individuals and strongly recommends,  
176 when using a C scored dog for breeding, to mate it with an A. As for the other breed clubs,  
177 there are no special breeding recommendations on their website, but the clubs try to promote  
178 both hip radiographic screening and using best scored dogs for breeding through selection  
179 grids, in accordance with the French Kennel Club.

180 We may consider that, for a while, the selection was potentially not strong enough in some  
181 breeds. We could also assume that, for the English Springer Spaniel, for instance, the increase  
182 in the B grade led to an increase in B to B mating (instead of A to A or A to B mating), which,  
183 due to the genetic recombination, could result in an increased risk of obtaining C scoring dogs  
184 in the offspring. However, the variation between the initial and final period in terms of HD  
185 prevalence noted in these breeds was 3%, except in the American Staffordshire Terrier (7%  
186 variation). Yet, this increase among the several periods remained slight and not significant.

187 A previous study demonstrated that when all dogs in a breed have nearly the same hip  
188 phenotype, almost no selection pressure can be applied to improve hip quality based on hip  
189 radiograph screening [14]. According to the results of the present study, this was potentially  
190 the case for the Picardy spaniel and the Dalmatian, which demonstrated slight changes in HD  
191 prevalence.

192 Overall, 12 breeds had a prevalence of moderate and severe HD (D-E grades) lower than 10%  
193 which is consistent with the results of a recent survey [21]. Five breeds (Picardy shepherd  
194 dog, Blue Picardy spaniel, Picardy spaniel, Chow Chow and American Staffordshire Terrier)  
195 had a prevalence of D-E grades lower than 25%. In these breeds, there is still a margin for  
196 improvement, though in the Picardy shepherd dog, Blue Picardy spaniel and Picardy spaniel  
197 the situation is not easy to handle because these breeds have a reduced number of individuals  
198 and breeders and thus a limited number of annual births. As for the Picardy shepherd dog for  
199 example [22], just after World War II, the breed was restored using some well typed  
200 individuals, crossbred with bouvier des Flandres. Two subjects issued from this selection can  
201 be found in the ancestry of current registred dogs [23]. Therefore it most likely that there is  
202 only a very slight genetic diversity in the small number of bergers picards. The total  
203 population was estimated around 1200 registred dogs in the 1990s. The number of annual  
204 births, these last 5 years, was between 138 and 210, averaging 5-6 puppies per letter.

205  
206 These results are consistent with previous studies indicating that selective breeding using  
207 classifications of hip joint phenotypes might improve hip conformation in several breeds of  
208 dogs [5,7,10-16], although other studies showed different findings, and the efficiency of using  
209 screening programs to reduce the prevalence of HD has been questioned [17-20].

210 These results must be interpreted with caution since the evaluation of coxo-femoral joint  
211 status is not mandatory for breeding in France [7]. In a 1993-2002 survey [24], it was

212 demonstrated that in France, only 2 to 19% of the dogs were screened for HD. Although the  
213 number of screened dogs has increased since this period, it is likely that, depending on the  
214 breed, a small fraction of all breeding dogs undergo a hip radiograph. Moreover, there is an  
215 unknown proportion of veterinarian (or owner) prescreening of the radiographs with obvious  
216 hip dysplasia, leading to the lack of presentation of the “worst” radiographs for official  
217 screening. Therefore, our data reflect only those dogs whose owners and breeders submitted  
218 radiographs for analysis. This proportion varies from 20 to 40% in Switzerland [25]. In  
219 Scandinavian countries, all breeding animals in control-program breeds are screened, and both  
220 dam and sire hip radiographs need to be submitted for screening to be registered by the  
221 Kennel Club [13,17,18]. In these countries, an HD control program gives a good overall  
222 prevalence for each breed. A study demonstrated that an improvement in hip quality can be  
223 achieved by selection based on the subjective scoring of radiographs when all dogs of a breed  
224 are evaluated [14].

225 Therefore, the lack of breeding restrictions in France and other countries [5] (United  
226 Kingdom, United States of America) and the associated lower scoring rate might explain the  
227 smaller degree of progress for some breeds. As previously mentioned, the true prevalence of  
228 HD could be higher than that depicted by our results because they reflect only the results of  
229 the radiographs submitted for official screening [7].

230 Most of the French breed clubs that are involved in a HD control program encourage breeders  
231 to have their breeding stock and offspring radiographed through a scoring grid which takes  
232 into account the fact that the dog and/or some of its offspring have been submitted to  
233 radiographic hip scoring and the results of the scoring. Every result from an official hip  
234 scoring that is communicated by the breed club to the French Kennel Club (SCC) is  
235 mentioned on the dog’s pedigree, which is now a 5-generation pedigree document. The result  
236 is also registered on an open access internet portal created by the SCC named LOF Select.

237 This portal enables breeders to access the characteristics of every registered dog, look for a  
238 breeding dog, and create virtual matings. Furthermore, the SCC is involved in a program to  
239 calculate and set up estimated breeding values, to help breeders choose their breeding stock.  
240 A project to create a reproductive ability certification, which would involve health  
241 characteristics (including hip status) is under study. It would undoubtedly increase the number  
242 of radiographed dogs.

243 The HD screening system is based on a subjective evaluation of radiographic findings.  
244 Panelist dependent variation is possible, and it has been demonstrated that significant intra-  
245 and inter-observer variation in classification may occur [26]. In our study, all breeds were  
246 evaluated by the same single panelist, which avoided interobserver variability, yet an  
247 intraobserver variability over the long study period cannot be totally excluded.

248 In our study, multiple anesthesia/sedation protocols were used. No standardized protocols  
249 have been proposed for performing hip radiographs, as it has been decided that, for security  
250 reasons, the best protocol is the one the veterinarian is comfortable using. A Scandinavian  
251 study [27] showed that acepromazine should not be used for sedation because it causes a very  
252 poor myoresolution. A study concerning the type of chemical restraint used by French  
253 veterinarians performing HD screening radiographs [28,29] showed that these protocols are  
254 acceptable based on the FCI standard requirements for HD screening.

255 A study demonstrated a strong association between the radiographic scoring of hip status and  
256 subsequent incidence of veterinary care and mortality related to HD in five breeds of dogs. It  
257 demonstrated that the selection of breeding stock based on the screening results with regard to  
258 hip status can be expected to reduce the risk of clinical problems related to HD [30] which  
259 also emphasizes the interest in and effect of selection based on hip radiograph screening to  
260 reduce the HD prevalence.

261 It is, however, unlikely that the HD prevalence can be reduced much further based only on the  
262 radiographic screening control. Several other approaches to assessing the coxo-femoral joint  
263 status have been proposed, such as hip joint laxity measurements (distraction methods,  
264 distraction Norberg angle) and the use of estimated breeding values.

265 Distraction methods were first described by the PennHip organization [31] and have been  
266 shown to be reliable screening methods for predicting hip joint degeneration [32]. A recent  
267 study [33] evaluated the correlation between the distraction angle (DI) and the distraction  
268 Norberg angle measured at 4 months of age, and the official FCI hip score determined at 12  
269 months of age. It was shown that the distraction Norberg angle had a fair correlation with the  
270 DI at 4 months and therefore reflects hip passive laxity. It also demonstrated that 98% of hips  
271 with a distraction Norberg angle higher than  $85^{\circ}$  at 4 months had an A, B or C FCI score at 12  
272 months of age. D and E FCI scores at 12 months cannot be reliably predicted from the 4-  
273 month value of DI or distraction Norberg angle.

274 To reduce the incidence of HD, many researchers have recommended the use of estimated  
275 breeding values (EBV) to improve the rate of genetic progress in terms of selection against  
276 HD [17,34,35,37].

277 A study showed that the EBV is more accurate and abundant than the phenotype [34] and  
278 provides more reliable information on the genetic risk of disease for a greater proportion of  
279 the population. An efficient selection mode is to include information about the hip status of  
280 relatives because the inheritance of HD is still unclear, and dogs with phenotypic normal hip  
281 joints may carry genes leading to HD in their offspring [36]. A recent study confirmed that  
282 using phenotypic health information and selecting sires and dams from pedigrees free from  
283 HD improves hip joint health and therefore reduces the HD prevalence [37,38].

284 There is a great deal of research based on genomics and distraction Norberg angle testing  
285 related to canine HD [39-42], some of which is linked to similar human pathology [43]. It is

286 beyond the scope of this study to address this very specific research area, but it is likely that,  
287 in the foreseeable future, new tools will complement radiographic examination of the coxo-  
288 femoral joint in order to prevent canine HD.

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## 302 **Conclusions**

303 This study confirms that long-term selection based on hip radiograph screening can be  
304 expected to reduce the HD prevalence in some breeds and that phenotypic selection for hip  
305 conformation may be effective, although it is dependent on the voluntary participation of  
306 breeders and owners. The true prevalence of HD in the breeds presented in this study is  
307 probably higher than those reported in our results. To achieve a further decrease in the HD  
308 prevalence, the use of EBV and genomic selection should be considered.

309

310

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334 **References**

335 Due to the large number of references about canine hip dysplasia, this review references are  
336 limited to the most appropriate to our study.

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