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The updated 2022 Fédération Cynologique Internationale method may lead to changes in hip dysplasia grading in some dogs

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Objective
To compare Norberg angle (NA) measurements and hip dysplasia (HD) grades obtained from the same radiographs using the Fédération Cynologique Internationale (FCI) 2022 (FCI_{22}) and FCI 2006 methods (FCI_{06}).

Methods
This retrospective observational study included radiographs submitted for canine HD screening from March 17, 2023, through September 27, 2024. Radiographs meeting FCI quality standards were evaluated under both methods, with NA measurements and HD grades recorded accordingly. Grade changes were classified as upgraded, downgraded, or unchanged.

Results
Radiographs from 1,020 Australian Shepherds and 298 Boxers were reviewed. The mean Norberg angle measured according to the 2022 method (NA_{22}) was 0.7° lower than that measured according to the 2006 method (NA_{06}). Overall, 1,801 of 2,636 hips (68.3%) retained the same HD grade with the FCI_{22}. In Australian Shepherds, 350 of 2,040 hips (17.2%) were upgraded, and 257 of 2,040 hips (12.6%) were downgraded. In Boxers, 53 of 596 hips (8.9%) were upgraded, and 175 of 596 hips (29.4%) were downgraded. Reclassification occurred primarily among hips initially graded D in 2006 (D_{06}), with 286 of 347 hips (82.4%) reclassified.

Conclusions
Differences between NA_{22} and NA_{06} had limited impact on HD grading except for hips with near-threshold NA values. The FCI_{22} kept most HD grades unchanged. Across both breeds, upgrades occurred primarily among grade D hips. Breed differences in grade changes may reflect interbreed anatomical differences.

Clinical Relevance
The FCI_{22} method is unlikely to substantially alter HD grades in these 2 breeds. Borderline hips and breed-specific grading patterns may affect individual screening outcomes.

Keywords: hip dysplasia, FCI, gradation, boxers, Australian Shepherds

Canine hip dysplasia (HD) is one of the most common nontraumatic orthopedic conditions in dogs.[1,2] Coxofemoral joint laxity may lead to subluxation of the femoral head and development of osteoarthritis. Radiographic screening programs have been implemented to reduce the prevalence of HD in dogs, notably through the Fédération Cynologique Internationale (FCI) grading system introduced in 2006 (FCI_{06}).[3–5] Hip grades range from A to E, with A and B corresponding to a nondysplastic hip and C, D, and E corresponding to a moderately to severely dysplastic hip.[5] Because breeding recommendations are frequently based on these classifications, accurate HD screening has important implications for canine genetic selection and breed management and may have an economic impact for owners and breeders.[1,3,6]

The Norberg angle (NA) is one of the principal radiographic parameters used in FCI HD evaluation and quantifies the extent of lateral and dorsal

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coverage of the femoral head. Under the FCI_{06}, the angle is measured using the center of both femoral heads and the most craniolateral acetabular rim.[7] The NA cutoff value ranges from 90° to 105°. Higher NA values are generally associated with deeper acetabular coverage and improved joint congruity, whereas lower values are associated with increasing hip laxity and subluxation.[8]

In 2022, the FCI introduced an updated classification method (FCI_{22}). Compared with the FCI_{06}, the FCI_{22} incorporates additional radiographic criteria for HD assessment and modifies the anatomical landmark used for NA measurement by shifting the reference point from the most craniolateral acetabular rim to the cranial effective acetabular rim corresponding to the weight-bearing acetabular surface **(Figure 1)**. This revision was introduced because the former landmark could, in some acetabular conformations, include bony structures that do not contribute to the effective articular surface or even fall outside the functional articulation.[9–11] In addition, the FCI_{22} introduced the concept of NA threshold values "as reference" when assigning the final HD grade in selected borderline cases. To the best of the authors' knowledge, no study

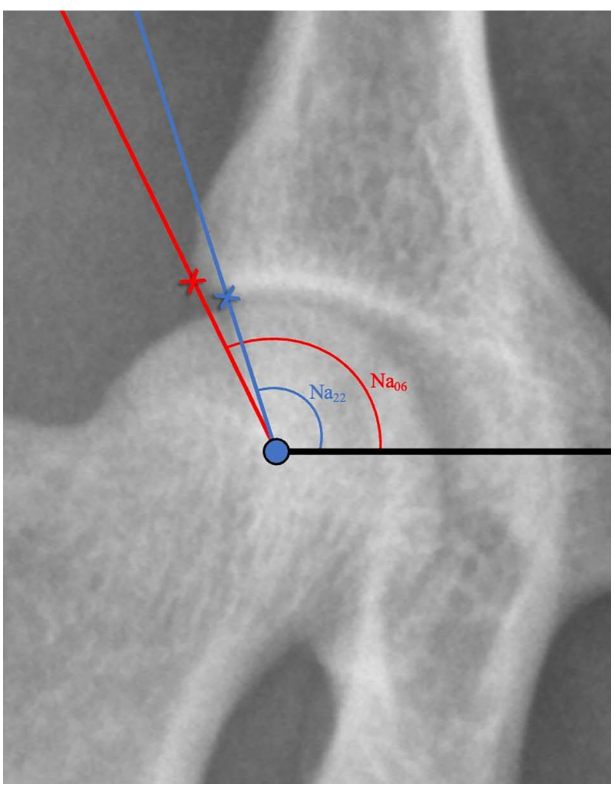

Figure 1—Comparison of the Norberg angle measurement methods on a ventrodorsal hip-extended radiographic view of the pelvis from a dog included among 1,318 Australian Shepherds and Boxers undergoing official hip dysplasia screening from March 17, 2023, through September 27, 2024. The Norberg angle measured according to the FCI_{06} method (NA_{06}, red) and according to the FCI22 method (NA_{22}, blue) are illustrated. The red cross indicates the most craniolateral point of the cranial acetabular rim, whereas the blue cross indicates the lateral limit of the acetabular subchondral bone plate in contact with the femoral head.

compared NA measurements and HD grades obtained using the FCI_{06} and FCI_{22} methods. Understanding how the updated method influences both NA measurements and final HD grading is important for interpreting official screening results and their potential impact on breeding decisions.

The objectives of the study were to (1) compare NA measurements and (2) compare HD grades obtained using the FCI_{22} and FCI_{06} methods in Boxers and Australian Shepherds undergoing official HD screening.

We hypothesized that the Norberg angle measured according to the 2022 method (NA_{22}) would be significantly lower than that measured according to the 2006 method (NA_{06}) in both breeds. We further hypothesized that application of the FCI_{22} method would result in changes in HD grade, particularly for hips with NA values close to established grading thresholds.

Methods

Inclusion and exclusion criteria

A retrospective observational study was performed on Boxers and Australian Shepherds presented for official HD screening from March 17, 2023, through September 27, 2024. All radiographs were uploaded to a web-based radiographic management platform (myVetsXL; VetZ GmbH). Only ventrodorsal hip-extended radiographs performed under sedation or general anesthesia and meeting established quality standards for HD assessment were included.[5,9,10] Radiographs were excluded if data were incomplete in the database. Left and right hips were assessed individually and anonymized using a unique identification number. Each hip was assessed by 1 experienced evaluator (EG), who has served as the panelist for these 2 breeds for several decades.

Norberg angle

For each dog, 2 NA measurements were obtained using NA_{06} and NA_{22} landmark definitions and were used for final grading under the corresponding FCI_{06} and FCI_{22} methods. The 2006 Norberg-Olsson angle was defined as the angle formed by the intersection of a line connecting the centers of both femoral heads and a line drawn from the center of the femoral head to the most craniolateral point of the cranial acetabular rim (Figure 1). The 2022 Norberg-Olsson angle was defined as the angle formed by the intersection of a line connecting the centers of both femoral heads and a line drawn from the center of the femoral head to the cranial effective acetabular rim, corresponding to the lateral limit of the acetabular subchondral bone plate in contact with the femoral head.

Application of the FCI_{22} upper NA threshold option

Under the FCI_{22} method, the NA_{22} threshold is provided "as a reference," allowing the panelist to adjust the HD classification when the overall radiographic appearance of the hip is more compatible with a higher grade than permitted by the measured NA_{22} value alone, including situations where the value lies close to a grading threshold. In such cases, the measured NA_{22} may be interpreted using the upper threshold value. This adjustment affects the final classification only and does not modify the recorded NA_{22} measurement. For example, if the measured NA_{22} is 99°, the recorded NA_{22} value remains 99°. However, when the overall radiographic appearance is considered more consistent with the higher category, the FCI_{22} method allows the evaluator to assign the final hip grade using the upper NA threshold (100°). Thus, the measured NA_{22} is not modified; only the final grade may differ.

No predefined numerical criterion (eg, 1°, 2°, or 3° below a threshold) automatically triggers application of the upper NA threshold. Instead, in eligible borderline cases, the final hip grade is assigned based on the overall radiographic assessment of the hip by the panelist as recommended by the FCI_{22} classification.

FCI reading methods

Hip radiographs were graded according to both FCI classification method (FCI_{06} and FCI_{22}) in Australian Shepherds and Boxers.[5,9] First, the official panelist systematically recorded all radiographic observations required by both classification systems for each hip, including NA measurements and all morphological features specified by both FCI methods. The recorded observations were subsequently used to assign the final hip grade according to each FCI classification method. For the FCI_{22}, the final grade was assigned by the panelist in accordance with the official 2022 FCI method, integrating the complete radiographic assessment. Conversely, for the FCI_{06}, the same recorded observations were entered into a predefined decision algorithm that strictly applied the official FCI_{06} grading criteria without any additional human intervention. For each hip, a classification letter followed by the corresponding guideline year was assigned (eg, a hip classified as grade C according to the 2022 FCI method was labeled C_{22}). Classification changes between the 2 methods were recorded for each hip. Hips were subsequently categorized as upgraded (reclassified to a less severe grade, eg, from grade C according to the 2006 FCI guidelines [C_{06}] to grade B according to the 2022 FCI guidelines [B_{22}]), downgraded (reclassified to a more severe grade, eg, from grade D according to the 2006 FCI guidelines [D_{06}] to grade E according to the 2022 FCI guidelines [E_{22}]), or unchanged. In addition, hips were grouped as nondysplastic (grades A and B) or dysplastic (grades C, D, and E).

Radiographic criteria

The FCI_{06} and FCI_{22} methods were applied according to the official recommendations.[5,9] The FCI_{06} method grouped these positions as medial/superimposed or lateral. Under the FCI_{22} method, the position of the femoral head center relative to the dorsal acetabular rim was classified as medial, superimposed, or lateral. Joint congruity and space narrowing were assessed. The assessment also included evaluation of medial and lateral densification of the acetabular subchondral bone plate as well as the identification of hip subluxation. In eligible borderline cases, the panelist could assign the final hip grade using the upper NA threshold as described above while leaving the measured NA value unchanged. Additional radiographic parameters were assessed using previously validated criteria.[10] These included the following:

- Assessment of femoral parallelism and pelvic symmetry with absence of internal rotation of the femurs;
- Evaluation of femoral head morphology or deformation, including the presence of osteophytes, such as circumferential femoral head osteophytes and femoral neck osteophytes (Morgan line);
- Assessment of acetabular shape and integrity (normal, deformed, or filled), with particular attention to cranial and caudal acetabular osteophytes; and
- Evaluation of the cranial and dorsal acetabular rims, graded as good or poor, with the cranial rim further described as encompassing, parallel, or nonencompassing relative to the femoral head

Statistical analysis

Statistical analyses were performed with R, version 4.4.2 (R Foundation for Statistical Computing). A P value ≤ .05 was considered statistically significant. The linear relationship between NA_{06} and NA_{22} for the 2 breeds was investigated using the Pearson correlation coefficient. The difference between NA_{22} and NA_{06} was regressed against the intercept effect and the breed effect using the following 1-way ANOVA model: difference = intercept + breed + error. The intercept effect represents the least-squares estimate of the overall mean difference between NA_{22} and NA_{06}, thus corrected from the imbalance of observations between the 2 breeds, and the breed effect estimates the mean deviation of each breed from the overall mean.

The null hypothesis of absence of relationship between FCI_{06} versus FCI_{22} was tested using a χ^2 test of independence applied on the contingency table crossing modalities of the FCI_{06} and FCI_{22} variables. To avoid low cell counts issues, the null distribution of the test statistic was approximated using parametric bootstrap simulations under the null hypothesis of independence (β = 100,000). The corresponding scaled deviations from the independence model of the null hypothesis of the contingency table were computed to investigate cells that highly contribute to the χ^2 statistic. For measuring the overall effect size, the Cramer V was used.[12]

To investigate whether or not reclassified hips were significantly more likely to be upgraded or downgraded, lack-of-fit χ^2 tests were performed with the null hypothesis of an equal probability of being upgraded or downgraded. More precisely, the observed sample proportions of upgraded and downgraded hips were computed and tested against the null hypothesis of equal population probability (0.50) of being downgraded or upgraded. In other words, it was tested if the observed sample proportions, given the sample size, are compatible with an equal population probability (0.50) of being downgraded or upgraded. Again, to avoid low cell counts issues, the null distribution of the test statistic was approximated using parametric bootstrap simulations under the null hypothesis (β = 100,000).

Results

Dog population

A total of 1,318 ventrodorsal hip-extended radiographs were reviewed (ie, 2,636 hips). The study population included 905 females (68.7%) and 413 males (31.3%). The population consisted of 1,020 Australian Shepherds (77.4%) and 298 Boxers (22.6%). The mean age was 22.7 ± 12.4 months (range, 12 to 135 months).

NA measurements

Norberg angle measurements obtained with the FCI_{06} and FCI_{22} methods were strongly correlated in both breeds, with a correlation coefficient of 0.91 in Australian Shepherds (t = 102.22; degrees of freedom [df], 2,038; P < .001) and 0.94 in Boxers (t = 67.93; df, 594; P < .001; **Figure 2**). Across the study population, NA_{06} values were significantly higher than NA_{22} values, with a mean difference of +0.7° (t = 122.27; df, 2,634; P < .001). The mean NA_{22} and NA_{06} were 102.6 ± 3.8° and 103.3 ± 3.9°, respectively. A statistically significant breed effect was identified (F = 8.95; P = .0028), indicating that the difference between NA_{06} and NA_{22} varied between breeds, with mean differences of +0.82° in Australian Shepherds and +0.61° in Boxers (P < .001; **Table 1**).

In the study cohort, the upper NA threshold was considered in 574 hips (21.8%). Among hips for which the FCI_{22} upper NA threshold option was applied to the 100° cutoff, the mean measured NA_{22} was 98.0 ± 1.0°, whereas hips for which the FCI_{22} upper NA threshold option was applied to the 105° cutoff had a mean measured NA_{22} of 103.7 ± 0.6°. Across all hips in which this option was applied, the mean difference between the measured NA_{22} and the applied upper threshold was 1.8 ± 1.0° (range, 1° to 7°). Among all hips, the application of the FCI_{22} upper NA threshold option occurred most frequently in grade D hips (10.7%), followed by grade B (7.7%), grade A (2.0%), grade C (1.1%), and grade E hips (0.3%). The rate of application of the FCI_{22} upper NA threshold option followed a similar distribution pattern in Australian Shepherds and Boxers, being applied most frequently in grade D hips (11.8% and 6.9%, respectively), followed by grades B (9.5% and 1.9%, respectively) and A (2.1% and 1.7%, respectively) and less commonly in grades C (1.0% and 1.3%, respectively) and E (0.4% and 0%, respectively).

Table 1—Mean (± SD) Norberg angle values measured with the 2006 and 2022 Fédération Cynologique Internationale hip dysplasia evaluation methods in 1,020 Australian Shepherds and 298 Boxers undergoing official hip dysplasia screening from March 17, 2023, through September 27, 2024.

Population	NA_{06}	NA_{22}
Australian Shepherds	103.0 ± 3.8°	102.2 ± 3.7°
Boxers	104.2 ± 3.9°	103.6 ± 3.9°
Boxers and Australian Shepherds	103.3 ± 3.9°	102.6 ± 3.8°

NA_{06} = Norberg angle according to FCI_{06}. NA_{22} = Norberg angle according to FCI_{22}.

Hip grade reclassification

Overall, 1,801 of 2,636 hips (68.3%) retained the same HD grade between FCI_{06} and FCI_{22} (χ^2 = 4,183;

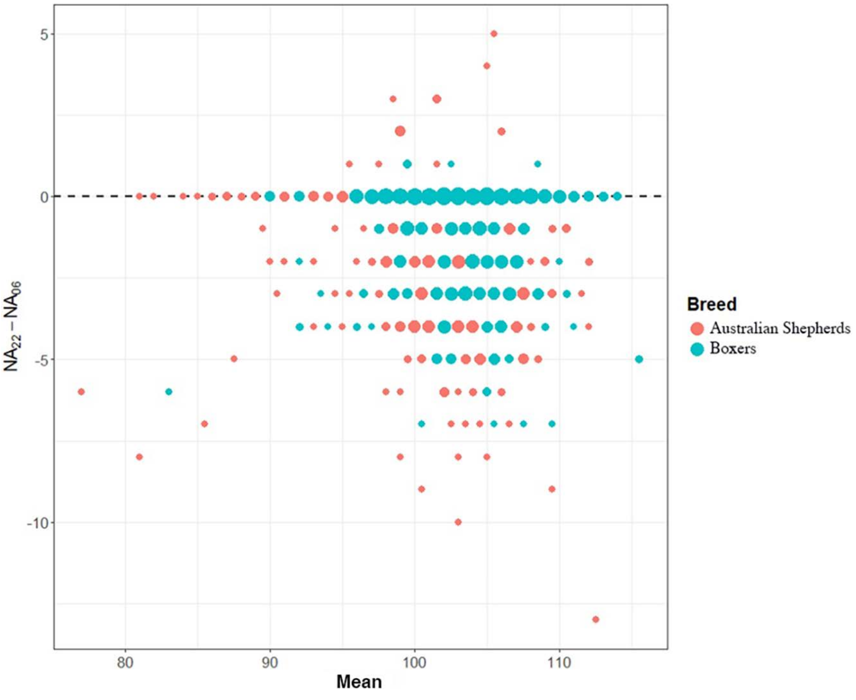

Figure 2—Bland-Altman plot comparing NA_{22} and NA_{06} measurements in Australian Shepherds and Boxers. The x-axis represents the mean of NA_{22} and NA_{06} measurements, and the y-axis represents the difference between both Norberg angles. Point size is proportional to the number of hips with identical NA_{06} and NA_{22} values.

Table 2—Distribution of hip dysplasia grades assigned with the 2006 and 2022 Fédération Cynologique Internationale hip dysplasia evaluation methods for the hips described in Table 1.

	A_{22}	B_{22}	C_{22}	D_{22}	E_{22}
A_{06}	616	347	0	0	0
B_{06}	105	907	80	0	0
C_{06}	0	4	207	5	0
D_{06}	0	171	115	61	0
E_{06}	0	0	0	8	10

Values represent the number of hips assigned to each grade.

A_{06} = Grade A according to the FCI_{06}; B_{06} = Grade B according to the FCI_{06}; C_{06} = Grade C according to the FCI_{06}; D_{06} = Grade D according to the FCI_{06}; E_{06} = Grade E according to the FCI_{06}. A_{22} = Grade A according to the FCI_{22}; B_{22} = Grade B according to the FCI_{22}; C_{22} = Grade C according to the FCI_{22}; D_{22} = Grade D according to the FCI_{22}; E22 = Grade E according to the FCI_{22}.

$P < .001$; **Table 2**). Overall, 432 hips were downgraded (16.4%), and 403 hips were upgraded (15.3%), with no statistically significant difference between downgrade and upgrade rate ($\chi^2 = 1$; $P = .334$).

At the breed level, 350 of 2,040 Australian Shepherd hips (17.2%) were upgraded, and 257 of those 2,040 hips (12.6%) were downgraded, whereas 53 of 596 Boxer hips (8.9%) were upgraded, and 175 of 596 hips (29.4%) were downgraded. For both breeds, the probability of retaining the original classification from FCI_{06} to FCI_{22} was statistically significant ($P < .001$; **Supplementary Figure S1**). Cramer V coefficients indicated a moderate to strong association between classifications in Australian Shepherds ($V = 0.63$) and Boxers ($V = 0.70$), with a stronger association observed in Boxers.

Among the 963 hips classified as grade A according to the FCI_{22} guidelines (A_{06}), 347 (36%) were downgraded to B_{22}. Of these, 154 hips had NA_{06} values > 105° but NA_{22} values < 105°, with no application of the FCI_{22} upper NA threshold option. A further 193 hips had NA values ≥ 105° and the femoral head center superimposed on the dorsal acetabular rim, which precluded assignment of grade A under FCI_{22}. Of these, 99 were Boxers (51.3%), and 94 were Australian Shepherds (48.7%).

At the population level, A_{06} hips showed a significantly higher probability of remaining unchanged than of being downgraded under the FCI_{22} classification (0.64 vs 0.36; $\chi^2 = 75.14$; $P < .001$). At the breed level, Australian Shepherds had a significantly higher probability of remaining classified as grade A according to the FCI_{22} method (A_{22}) than of being downgraded (0.68 vs 0.32; $\chi^2 = 95$; $P < .001$). In contrast, Boxers showed similar probabilities of remaining unchanged or being downgraded (0.52 vs 0.48), with no statistically significant difference ($\chi^2 = 0.26$; $P = .655$).

Among the 1,092 classified as grade B according to the FCI_{06} method (B_{06}), 105 (9.6%) were upgraded to A_{22}, with application of the FCI_{22} upper NA threshold option in all cases. Conversely, 80 hips (7.3%) were downgraded to C_{22} despite NA_{22} values > 105°, with the center of the femoral head positioned lateral to the dorsal acetabular rim. Among B_{06} hips, 26 Australian Shepherd hips (2.9%) were downgraded to C_{22} compared with 54 Boxer hips (27.3%). At the population level, the probability of upgrade versus downgrade for B_{06} hips undergoing reclassification under the FCI_{22} system did not differ significantly (0.57 vs 0.43; $\chi^2 = 3.38$; $P = .076$). At the breed level, Australian Shepherds showed a significantly higher probability of upgrade than downgrade, whereas the opposite pattern was observed in Boxers (0.79 vs 0.21 and 0.13 vs 0.87, respectively; $P = .001$).

No statistically significant difference was observed between upgrade and downgrade probabilities for grade C under the FCI_{22} classification ($P > .99$). Five of 216 C_{06} hips were downgraded to grade D according to the FCI_{22} method (D_{22}) (NA_{06} > 100°, NA_{22} < 100°), with the FCI_{22} upper NA threshold option not applied, whereas 4 hips (3 Australian Shepherds and 1 Boxer) were upgraded to B_{22} (NA_{06} and NA_{22} were > 100°), with the FCI_{22} upper NA threshold option applied.

Of the 347 D_{06} hips, 286 were upgraded (82.4%), with 171 in B_{22} (49.3%) and 115 in C_{22} (33.1%). No D_{06} hips were downgraded to E_{22}. The NA_{06} and NA_{22} values ranged from 93° to 99°. The FCI_{22} upper NA threshold option was applied in all upgraded hips. Within the study population and at the breed level, D_{06} hips undergoing reclassification systematically showed a higher probability of upgrade than downgrade under the FCI_{22} classification (1 vs 0; $P < .001$). **Supplementary Figure S2** describes 3 examples of grade D reclassification.

Among hips undergoing reclassification, no statistically significant difference was observed between upgrade and downgrade probabilities for grade E under the FCI_{22} classification ($P > .99$). Eight hips classified as grade E according to the FCI_{06} (E_{06}) in Australian Shepherds were upgraded to D_{22}, with the FCI_{22} upper NA threshold option applied to measured NA_{22} values ranging from 86° to 89°.

When hips were grouped into nondysplastic (grades A and B) and dysplastic (grades C, D, and E) categories, 1,975 of 2,055 nondysplastic hips (96.1%) remained nondysplastic under FCI_{22}, whereas 175 of 581 dysplastic hips (30.1%) were reclassified as nondysplastic. The proportion of nondysplastic hips remaining nondysplastic differed between Australian Shepherds and Boxers (98.4% and 87.8%, respectively; $P < .001$). The proportion of dysplastic hips remaining dysplastic differed markedly between breeds, with 272 of 429 dysplastic Australian Shepherd hips (63.4%) remaining dysplastic compared with 134 of 152 Boxer hips (88.2%; $P < .001$).

Discussion

To our knowledge, this study is the largest comparative analysis evaluating the impact of transitioning between 2 successive FCI HD screening methods in 2 purebred dog breeds. The first hypothesis was supported as NA_{22} values were significantly lower than NA_{06}. The second hypothesis was supported as changes in HD grade were observed in 31.7% of hips, with the greatest changes occurring among D_{06} hips.

One of the principal modifications introduced by the FCI_{22} method concerns the anatomical landmarks used for NA measurement. The FCI_{06} method used the most craniolateral acetabular protuberance as the reference landmark, which may have overestimated femoral head coverage by including bony structures that do not contribute to the effective articular surface and may extend beyond the functional articulation. In contrast, the FCI_{22} method references the cranial effective acetabular articular surface in contact with the femoral head, thereby providing a more relevant assessment of acetabular coverage.[9,11] This modification was intended to improve the anatomical and biomechanical relevance of the NA measurement by focusing on the effective weight-bearing acetabular surface.

In this study, NA_{22} values were consistently lower than NA_{06} values, although the mean difference remained below 1°. Despite statistical significance, this difference had minimal impact on HD grading at the population level as most hips retained their original classification. Australian Shepherds showed a greater mean difference between NA_{22} and NA_{06} than Boxers despite a strong linear correlation between NA_{06} and NA_{22} in both breeds. The discrepancies among NA values observed in both breeds in this study are consistent with earlier findings indicating that NA varies between individuals and cannot reliably discriminate between dysplastic and nondysplastic hips across breeds.[8,13–18] In particular, in dogs with NA values close to established grading thresholds (90°, 100°, or 105°), even small differences between NA_{06} and NA_{22} may influence their final classification. In 154 of the 963 A_{06} hips, the lower NA_{22} resulting from the change in anatomical landmark contributed to the downgrade to B_{22}. However, the overall effect of the change in NA measurement was small, with a mean difference of only 0.7° between NA_{06} and NA_{22}. Thus, although this difference could affect individual hips with NA values close to grading thresholds, its impact on HD grading was limited at the population level.

To limit the impact of small differences in NA near grading thresholds, the FCI_{22} method introduces the concept of NA threshold values "as a reference," allowing evaluators to consider the overall radiographic appearance of the hip rather than relying exclusively on fixed angular cutoff values. In this study, the term "application of the FCI_{22} upper NA threshold option" was used when the upper reference value was considered. This approach recognizes that the NA should be interpreted in conjunction with the other radiographic criteria used for hip grading, particularly in borderline cases, rather than as an isolated determinant of the final grade.

The upper NA threshold option allows borderline hips with otherwise favorable morphological characteristics to be assigned a higher grade. However, this does not mean that FCI_{22} only allows upgrading. Hips with poor joint congruity, insufficient dorsal acetabular coverage, acetabular deformation, subluxation, or osteoarthritic changes cannot be assigned a higher grade solely on the basis of their measured NA. The FCI_{22} method appears intended to promote a more integrative morphological assessment of the hip joint by incorporating additional radiographic features rather than strictly applying fixed NA thresholds.

The FCI_{06} grades were assigned using a predefined decision algorithm that strictly applied the 2006 grading criteria to these findings without further human intervention (eg, an $NA_{06} < 100°$ would preclude assignment of a grade better than D_{22}). In contrast, under FCI_{22}, the panelist integrated the overall radiographic appearance of the hip when assigning the final grade, with the NA becoming one component of the decision and the upper NA threshold option available in eligible borderline cases.

Of all the HD grades, grade D was the most affected by reclassification, with more than 80% of D_{06} hips being upgraded, primarily to B_{22} or C_{22}. Importantly, all upgraded D_{06} hips underwent application of the FCI_{22} upper NA threshold option. Illustrative examples of 3 hips with similar measured NA values but different overall morphology, resulting in different final FCI_{22} grades, are provided in Supplementary Figure S2. These findings suggest that the observed reclassification appears to be primarily associated with the change in NA scoring philosophy introduced by the FCI_{22} method rather than by the modification of the NA anatomical landmarks alone. Importantly, these 2 modifications act in opposite directions. The measured NA therefore remains an objective radiographic measurement, whereas the final FCI_{22} grade results from integration of this measurement with the overall morphological assessment of the hip as intended by the revised recommendations. Whereas the revised anatomical landmarks tend to produce slightly lower NA values and therefore potentially less favorable grades, application of the FCI_{22} upper NA threshold option in eligible borderline cases tends to upgrade morphologically sound hips compared to FCI_{06}. Consequently, the overall upgrading reclassification observed in this study reflects the combined effects of these 2 mechanisms rather than either modification alone. The relative contribution of each mechanism cannot be determined from this study design and would require a dedicated decision algorithm capable of independently applying each modification before quantifying their respective effects.

The second major modification introduced by the FCI_{22} concerns the position of the femoral head center relative to the dorsal acetabular rim. The FCI_{22} method includes a more detailed description of the position of the femoral head center relative to the dorsal acetabular rim, categorized as medial, superimposed, or lateral, whereas the FCI_{06} method grouped these positions as medial/superimposed and lateral. Consequently, under the FCI_{22}, hips with the femoral head center superimposed on the dorsal acetabular rim cannot be assigned grade A even when the measured NA is at or above 105°. Furthermore, hips with the femoral head center lateral to the dorsal acetabular rim cannot be assigned a grade better than C. This change was one factor that contributed to some of the observed downgrades, particularly among A_{06} hips. Overall, 347 of 432 downgraded hips were A_{06} hips downgraded to B_{22}. In 193 of these hips, downgrades were mainly associated with the more detailed assessment of femoral head position under FCI_{22}.

Several breed-specific anatomical characteristics were subjectively observed during radiographic evaluation and may hypothetically contribute to breed-related differences in HD grading, consistent with previous studies.[8,10,15] In Boxers, a more prominent craniolateral acetabular protuberance was qualitatively noted. Because the updated NA_{22} reference point lies medial to this structure, it was initially hypothesized that this breed would exhibit a greater difference between NA_{06} and NA_{22} measurements. However, the opposite pattern was observed, with a greater mean difference in Australian Shepherds than in Boxers (0.82° vs 0.61°, respectively). In addition, Boxers were occasionally observed to present a more irregular, or "S-shaped," acetabular contour, which may hypothetically affect the relative position of the femoral head center to the dorsal acetabular rim, potentially resulting in more frequent classification of the femoral head center as "superimposed on" or "lateral" to the dorsal acetabular rim and thereby influencing official scoring outcomes. This may partly explain the greater frequency of downgrading observed in Boxers compared to Australian Shepherds. However, these observations were not quantitatively evaluated in this study and should therefore be interpreted cautiously. Further morphometric investigations would be necessary to confirm whether breed-specific pelvic conformation influences FCI_{22} grading outcomes.

When hips were grouped into nondysplastic (grades A and B) and dysplastic (grades C, D, and E) categories, most hips retained the same classification following transition from FCI_{06} to FCI_{22}. From a breeding-selection perspective, the overall impact of FCI_{22} appears limited as most downgrades involved A_{06} hips reclassified as B_{22}, both grades considered as nondysplastic. However, dysplastic hips initially graded under FCI_{06} showed a higher rate of upgrade in Australian Shepherds than in Boxers under the FCI_{22} system. This finding suggests that the transition to FCI_{22} did not affect the dysplastic/nondysplastic distinction to the same extent in the 2 breeds. Although the clinical significance of this finding remains uncertain, it further supports the hypothesis that breed-specific pelvic morphology may influence the final grading under FCI_{22}.

The primary objective of this study was to evaluate the impact of the revised FCI_{22} method on hip classification rather than to assess the reproducibility, diagnostic performance, or reader agreement of the grading method. Both FCI classifications were based on the same radiographic observations recorded by the official panelist using the standard hip evaluation form, including all measurements and morphological findings required by both methods. These same observations were then interpreted according to either the FCI_{06} or the FCI_{22} grading system. Consequently, differences observed between classifications reflected the different grading systems themselves rather than differences in the radiographic interpretation. This distinction is important because FCI_{22} does not simply modify individual grading criteria but also changes the decision-making sequence. Our study was specifically designed to compare the consequences of these 2 grading philosophies under identical radiographic observations.

Several limitations should be acknowledged. First, only 2 breeds were evaluated, with a predominance of Australian Shepherds, which may limit extrapolation of the findings to breeds with different pelvic conformations. Second, radiographs were assessed by a single experienced official reader. This approach was chosen to ensure that both FCI classification systems were applied to an identical set of radiographic observations, thereby isolating the effect of the revised grading recommendations while avoiding additional variability arising from differences in radiographic interpretation or NA measurements between evaluators. However, inter- and intraobserver reproducibility were not investigated. Because application of the upper NA threshold involves integrated radiographic assessment, the frequency of its use may depend on reader interpretation. Previous studies[13,14,19,20] have highlighted limitations in the inter- and intraobserver reproducibility of the FCI_{06} classification, particularly regarding NA assessment. Whether the revised FCI_{22} method improves reproducibility remains to be determined.

Differences between NA_{22} and NA_{06} measurements were statistically significant but small, with a mean difference of less than 1°, and had limited impact on HD grading at the population level.

Overall, under the FCI_{22} method most hips retained the same HD grade. The revised method for measuring the NA resulted in significantly lower values than the FCI_{06} method but had limited impact on the final HD grade. However, some hips are reclassified; mostly D_{06} hips were upgraded through application of the FCI_{22} upper NA threshold option. The impact of FCI_{22} grading differed between breeds, with more frequent grade changes observed in Boxers than in Australian Shepherds. Downgrading was more frequent in Boxers, whereas Australian Shepherds were more frequently upgraded, suggesting a potential influence of breed-specific anatomical features.

The FCI_{22} places greater weight on the overall radiographic assessment when assigning the final grade, particularly in borderline hips. Long-term follow-up studies evaluating the clinical progression and breeding outcomes of reclassified dogs will be necessary to determine whether FCI_{22} classification provides a more clinically relevant assessment of HD than FCI_{06}.

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Supplementary Materials

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