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Femoral Head and Neck Excision: A Retrospective Study in 108 Dogs

Krystalli Androniki[1]*; Sideri Aikaterini[2]; Kazakos M George[1]; Papaefthymiou Sofianos[1]; Savvas Ioannis[3]; Anatolitou Anthi[1]; Prassinos N Nikitas[1]

[1]Surgery & Obstetrics Unit, Companion Animal Clinic, School of Veterinary Medicine, Faculty of Health Sciences, Aristotle University, Thessaloniki, Greece.

[2]Clinic of Surgery, Faculty of Veterinary Science, School of Health Sciences, University of Thessaly, Karditsa, Greece.

[3]Anesthesia and Intensive Care Unit, Companion Animal Clinic, School of Veterinary Medicine, Faculty of Health Sciences, Aristotle University, Thessaloniki, Greece.

Abstract

Femoral Head and Neck Excision (FHNE) is a simple and non-reversible surgical procedure in which the entire femoral head and part of the femoral neck are removed obliquely. This allows for the formation of a functional pseudarthrosis consisting of dense fibrous connective tissue lined by a synovial membrane. This surgery provides pain relief for dogs suffering from severe hip-joint disease. This study included 108 client-owned dogs that underwent FHNE in 2006-2017. The hypothesis was that the weight-bearing time of the limb is affected by the chronicity of the disease that led to FHNE, the postoperative physical therapy, the administration of analgesics, and the controlled activity, while it is not affected by the animal's age and body weight. The results show that the final weight-bearing time of the limb is negatively affected by the chronicity of the disease, while age and body weight do not affect it. No positive correlation was found in regard to the limitation of activity, administration of analgesia, and performance of physical therapy. The most frequent diseases that led to FHNE were hip luxation and aseptic necrosis of the femoral head, while the rarest were acetabular fractures and hip dysplasia.

Keywords: Dog; Femoral head and neck ostectomy; Lameness.

Abbreviations: FHNE: Femoral Head and Neck Excision; TIWB: Time of Initial Weight Bearing; TFWB: Time of Final Weight Bearing; ANFH: Avascular Necrosis of the Femoral Head.

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Correspondance: *Androniki Krystalli, Surgery & Obstetrics Unit, Companion Animal Clinic, School of Veterinary Medicine, Faculty of Health Sciences, Aristotle University, 11 Stavrou Voutyra str. GR- 54627 Thessaloniki, Greece.*

Tel: +302310-994499; Email: andronikikr@yahoo.gr

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Introduction

Coxofemoral conditions have high prevalence in dogs, and there are several options for their treatment [1-3]. Total hip replacement has been accepted as a surgical approach for a variety of conditions, while juvenile pubic symphysiodesis and double or triple pelvic osteotomy are contemporary solutions for dogs younger than one year old with hip dysplasia. Femoral Head and Neck Excision (FHNE) is a commonly performed surgical procedure for the coxofemoral joint [4-6].

FHNE was originally introduced in orthopedics by Girdlestone for the treatment of tuberculosis and septic arthritis of the hip in human medicine [7,8]. It was quickly accepted by veterinary surgeons for painful conditions of the hip joint in dogs and cats. FHNE is indicated for disorders such as hip dysplasia, Avascular Necrosis of the Femoral Head (ANFH), osteoarthritis of the coxofemoral joint, comminuted acetabular or femoral neck fractures, fractures of the femoral head, chronic or non-reducible hip luxation, and failed total hip arthroplasty [9-11].

During FHNE, the femoral head and neck are removed by an osteotomy at the junction of the femoral neck and metaphysis just medial to the greater trochanter without including the lesser trochanter. The aim of this resection is to limit bony contact between the femoral head and acetabulum, allowing the formation of a fibrous pseudoarthrosis lined by a synovial membrane [5,9,12-15]. As the surgery's result is non-reversible, it is considered as a "salvage" procedure [1,3]. Some of the complications associated with FHNE are shortening of the limb, muscle atrophy, patellar luxation, damage to the sciatic nerve or its entrapment, decreased range of motion of the hip, continued lameness, and reduced exercise endurance [9,10,16,17].

According to previous studies, the outcome of FHNE seems to be highly variable and is influenced by several factors, such as the surgical technique, patient-related characteristics, and postoperative care [17-20]. Surgical factors include atraumatic soft tissue handling during the surgical approach, sufficient resection of the femoral neck, and a smooth resected surface. Deep gluteal and biceps femoris muscle slings have been developed to prevent bony contact between the pelvis and femur, and some surgeons suggest capsulorraphy and resection of the lesser trochanter as well [17,21-26].

The patient's weight and age and the disorder's chronicity are also considered to affect the prognosis [27-29]. Postoperatively, controlled exercise, aggressive analgesic administration, and early physical therapy contribute to the success of the procedure [9,18,27,30-35]. However, most information in the literature is usually contradictory because of confounding factors, including the owners' subjective views of outcomes, lack of objective criteria, and differences in postoperative physical therapy [6].

The object of this retrospective study was to examine the perioperative parameters that influence the outcome of the postoperative gait of patients (age, body weight, disease that necessitated FHNE and its chronicity, physical therapy, and controlled physical activity postoperatively). We hypothesized that the limb's time to weight-bearing postoperatively is affected by the chronicity of the disease, postoperative physical therapy, administration of analgesics, and controlled activity and that it is not affected by the age and body weight of the patient.

Materials and methods

The study retrospectively examined clinical records of client-owned dogs that presented to the Surgery and Obstetrics Unit at the Companion Animal Clinic, Department of Veterinary Medicine, Aristotle University of Thessaloniki, Greece, and were subjected to FHNE because of coxofemoral diseases between September 2006 and July 2017. Each dog owner answered a dog-mobility questionnaire (Table 1) to provide additional data about the patients.

The initial examination included the recording of the history of the dog (its nature, occurrence and type of lameness, physical activity, presence of pain, and type and quantity of food), along with a physical and orthopedic examination and gate evaluation based on a six-grade scale (Table 2). The criteria for inclusion of animals in the study were:

- Post-operative follow-up or communication with the owner for a period of ≥1 year from surgery.
- Good general health condition during FHNE.
- Lameness of the affected limb due only to the coxofemoral disease that necessitated FHNE. Any other cause was excluded (e.g., neurological disorder, osteoarthritis of stifle or tarsal joint).
- Grade of the non-affected limbs' lameness ≤ 2 degrees.

A craniolateral approach to the hip was performed in all cases. After transection of the joint capsule and the round ligament, the limb was luxated and externally rotated outwards by 90°. However, in some cases, the ligament was already torn. Osteotomy of the femoral neck was achieved using an osteotome, and any rough edges were removed with a rongeur or bone rasp [1,6]. All surgeries were led by the same surgeon.

The dogs were housed for 1 day in our clinic, where intravenous antimicrobial and analgesic drugs were given. In the postoperative period, non-steroidal anti-inflammatory drugs were administered for 7 to 10 days. Significant limitation of physical activity for 4 weeks and passive range-of-motion exercise until the limb's time of final weight bearing were also advocated. The postoperative clinical evaluation of the operated limb was assessed using a six-grade scale.

Two main parameters were used in this study. The first was the Time of Initial Weight Bearing (TIWB) of the limb, which refers to the moment during the postoperative period of FHNE when the animal first begins using the limb, albeit with varying degrees of lameness (partial weight bearing). The second was the Time of Final Weight Bearing (TFWB) of the limb. TFWB signifies the moment in the postoperative period of FHNE (maximum follow-up period: 1 year) when the limb exhibits full weight bearing or displays the least amount of lameness possible (partial weight bearing), which remained unchanged until the study's completion.

Dog owners answered a questionnaire (Table 1) by phone. The questionnaire comprised 15 questions. These questions were related to compliance with post-operative instructions, the patient's current well-being and physical function, and the owner's satisfaction with the outcome. The owners were asked about the type and frequency of physical therapy, the method and duration of restraint of the dog, and the efficacy of the analgesic. In addition, the limb's TIWB, TFWB, and the grade of lameness after exercise were determined. Finally, the owners were asked to assess their dog s' quality of life, possible changes in its behavior, and the dog's progress.

Statistical analysis

Data were summarized by calculating the absolute and relative frequencies (percentages), measures of central tendency (mean and median values), and measures of variance (minimum and maximum values and standard deviations). The association between quantitative variables and parameters was examined by evaluating the magnitude and statistical significance of Pearson's correlation coefficient *r* for linear covariation and Spearman's rank correlation coefficient *rho* (ρ) for general monotonic covariation. In all hypothesis-testing procedures, the significance level was predetermined at α=0.05 ($p \leq 0.05$). All statistical analyses were performed with the software IBM SPSS Statistics ver. 23.0.

Results

From September 2006 to July 2017, the medical records of 182 cases that had undergone FHNE were obtained from the registry of the Companion Animal Clinic. Only 108 of them met the inclusion criteria of our study. In 23 cases, it was impossible to collect the required data because of dog owners' reluctance to answer the questions or because their phone number was not valid. In 51 cases, there were coexisting orthopedic disorders in the operated limb or other limbs.

One dog included in the study initially presented with right hindlimb lameness due to a femoral head fracture, but ANFH of the left limb was also noted. That dog was initially subjected to FHNE in the right limb. After 8 months, it presented to the Companion Clinic with lameness in the left hindlimb because of ANFH, which underwent FHNE as well. This dog was counted as two cases due to the long period of time between these two surgeries. As a result, our study consists of 108 cases and 107 dogs. Most of the 108 cases were male (n=65, 60.2%) and non-neutered (n=97, 89.8%), [43 were female (39.8%), and 11 were neutered (10.2%)]. Most dogs were of mixed breed (Table 3).

Age

The mean age of patients when the surgery was performed was 12 months. The youngest patient was 3 months old, and the oldest was 156 months old. No statistically significant correlation was detected between age and the limb's final weight bearing by both Pearson's *r* test (*r*=-0.123, *p*=0.235) and Spearman's *rho* test (*rho*=-0.007, *p*=0.946).

Weight

The dogs' mean weight was 14.6 kg, with the lightest weighing 2.1 kg and the heaviest weighing 50 kg. Both Pearson's *r* test (*r*=0.018, *p*=0.860) and Spearman's *rho* test (*rho*=-0.144, *p*=0.164) did not detect a statistically significant correlation between body weight and TFWB of the operated limb.

Disease necessitating FHNE

Hip luxation (n=35, 32.4%) and ANFH (n=32, 28.7%) were the most frequent indications for FHNE (Table 4). Only between ANFH and the limb's TFWB showed a weak but statistically significant correlation according to Pearson's *r* (*r*=0.223, *p*=0.030) and Spearman's *rho* test (*rho*=0.238, *p*=0.020). ANFH correlated with increased TFWB.

Disease chronicity

The duration of pre-existing lameness ranged from 1 to 1800 days (mean 70.5, median 30). The preoperative gait evaluation showed grade 5 lameness in the majority of dogs (48 dogs, 44.4%), grade 3 lameness in 26 dogs (24.1%), grade 4 lameness in 17 dogs (15.7%), grade 2 lameness in 16 dogs (14.8%), and grade 1 lameness in one dog (0.9%). Both the Pearson test (*r*=0.346, *p*=0.001) and Spearman test (*rho*=0.388, *p*<0.001) revealed a delay in the limb's final weight-bearing as the duration of preoperative lameness increased.

Physical activity restriction

Physical activity restriction was applied to 94 dogs (87%). Table 5 shows the restriction type used by dog owners. According to their responses, restriction was considered beneficial for 74 dogs (78.7%), possibly beneficial for 18 dogs (19.2%), and not at all beneficial for 2 dogs (2.1%). Neither the Pearson analysis (*r*=-0.051, *p*=0.620) nor Spearman analysis (*rho*=0.023, *p*=0.823) detected any statistically significant correlation between the duration of restriction and the limb's TFWB.

Physical therapy

Recommended physical therapy was applied to 64 dogs (59.3%) and lasted between 7 and 730 days (mean 29.7, median 15, ± standard deviation 73.8). Many dog owners used more than one type of physical therapy. According to them, physical therapy was beneficial for 53 dogs (82.8%), probably beneficial for 9 dogs (14,1%), and not beneficial for 2 dogs (3.1%). No statistically significant correlation was detected between the duration of physical therapy and the limb's TFWB by both Pearson's test (*r*=-0.043, *p*=0.681) and Spearman's test (*rho*=-0.068, *p*=0.514).

Analgesia

All dogs received postoperative analgesia, and according to the majority of owners, it was effective for 72 dogs (66.7%), questionable for 24 dogs (22.2%), and not beneficial for 12 dogs (11.1%). Spearman's statistical test did not show any correlation between the duration of analgesia administration and the limb's final weight bearing (*rho*=0.134, *p*=0.217). However, Pearson's *r* test showed a positive, weak, and statistically significant correlation between these parameters (*r*=0.247, *p*=0.021).

Time of final weight bearing of the limb

The range of TFWB of the limb undergoing FHNE was 30-365 days (mean 126, median 120).

Postoperative progress

Three years postoperatively, 94 dogs (87%) had a full recovery of motor activity, 7 dogs (6.5%) showed grade 2 lameness, 6 dogs (5.6%) showed grade 1 lameness, and only one dog (0.9%).

showed grade 3 lameness. After exercise, 46 dogs (42.6%) showed varying grades of lameness, which decreased after rest. Grade 3 lameness appeared for most of them.

The activity level increased in 18 dogs (16.7%), remained stable in 79 dogs (73.1%), and decreased in 11 dogs (10.2%). Movement speed increased in 19 dogs (17.6%), did not change in 76 dogs (70.4%), and decreased in 13 dogs (12%). According to 11 owners (10.2%), their dogs' willingness to play increased, and one (0.9%), noticed a decrease, but the most of them (88.9%) did not observe any change. Friendly behavior towards people and other animals improved in two dogs (1.8%) and remained unchanged in the rest of them (98.1%). Finally, dogs' exercise endurance increased in 20 cases (18.5%), remained unchanged in 76 cases (70.4%), and decreased in 12 cases (11.1%).

Overall, lameness was fully resolved in 55 dogs (50.9%), 48 dogs (44.4%) showed great improvement, 4 dogs (3.7%) showed little improvement, and one worsened (0.9%). According to the answers of questionnaire, most owners (81.75%) noticed that their dog's quality of life was the same as before surgery, 21 observed progress (19.4%), and 6 (5.55%) noticed a deterioration. The majority of them would make the same decision again for their dog (102 respondents, 94.4%) and would also recommend it to another dog owner if needed (103 respondents, 95.4%).

Table 1: Questionnaire.

A/A: ....

Registration number: ....

Presentation date: .... **Surgery's date:** ....

Owner: ....

Phone number: ....

Dog's characteristics: Male ☐ Female ☐ Neutered ☐

Age: ....Breed: ....

Name: ....Weight: ....

Disease:

Hip luxation ☐

Avascular necrosis of the femoral head ☐

Fracture of Femoral Head ☐

Hip Dysplasia ☐

Fracture of the Acetabulum ☐

Hip Osteoarthritis ☐

Completed questionnaire: Yes ☐ No ☐

1. Preoperative lameness

1.1 Duration:........................

1.2 Grade: ⓪ ① ② ③ ④ ⑤

2.Postoperative lameness

2.1 When did the dog begin limb's weight-bearing?

2.2 When did the limb exhibit full weight bearing?

2.3 Lameness grade 3 years postoperatively ① ② ③ ④ ⑤

3. Postoperative analgesia

3.1 Yes ☐ No ☐

3.2 Administration's duration:.................................

3.3 Grade: ⓪ ① ② ③

3.4 Was analgesia useful? Yes ☐ No ☐ Possibly

4.Postoperative restriction

4.1 Yes ☐ No ☐

4.2 Duration:..................

4.3 Restriction's kind:.........................

4.4 Was restriction useful? Yes ☐ No ☐ Possibly

5.Physical therapy

5.1 Yes ☐ No ☐

5.2 Kind: Passive movements ☐ Swimming ☐ Bathtub ☐

5.3 Frequency:................................

5.4 Duration: ....

5.5 Was analgesia beneficial? Yes ☐ No ☐ Maybe ☐

6. Does the dog appear lameness after exercise?

6.1 Yes ☐ No ☐

6.2 Grade: ⓪ ① ② ③ ④ ⑤

6.3 Does the lameness reduce after rest? Yes ☐ No ☐

7. Assessment of dog's postoperative clinical condition

1. Worsening ☐
2. Stable ☐
3. Small improvement ☐
4. Great improvement ☐
5. Full recovery ☐

8. Other questions

8.1 Do you think that your dog's quality of life is the same as before?

....

8.2 If you could decide again, would you make the same decision?

....

8.3 Would you recommend this treatment to someone you know for his dog?

....

9. Differences in dog behavior/activity after surgery

Behavior/Activity	Reduction	Stable	Increase	I don't know
9.1 Activity grade	☐	☐	☐	☐
9.2 Movement speed	☐	☐	☐	☐
9.3 In the mood for playing	☐	☐	☐	☐
9.4 Physical condition	☐	☐	☐	☐
9.5 Mood	☐	☐	☐	☐
9.6 Friendly attitude towards people	☐	☐	☐	☐
9.7 Friendly attitude towards other animals	☐	☐	☐	☐
9.8 Endurance	☐	☐	☐	☐

Table 2: Lameness scale.

Degree of Lameness	Limb's weight bearing				Characterization of lameness
	Description	Stance	Walk	Run	
0	Full (normal) weight bearing	......	......	......	Absence
1	Partial weight bearing: hardly visible	......	......	......	Light
2	Partial weight bearing: easily visible	......	......	......	Mild
3	No weight bearing: intermittent, sporadic (≤1:5) *	......	......	......	Moderate
4	No weight bearing: intermittent, frequent (>1:5) *	......	......	......	Severe
5	No weight bearing: continuous	......	......	......	Not functional
Degree of lameness = (S + W + R)/3					

*: limb lift frequency per 5 steps

Table 3: Distribution of dogs' breed submitted to femoral head and neck excision.

Breed	Number of dogs	Percentage of dogs *(%)*
Mongrel	29	26.9
Yorkshire terrier	13	12
Maltese	9	8.3
Pincher	7	6.5
German Shepherd Dog	6	5.6
Greek Harehound	4	3.7
Golden Retriever	4	3.7
Greek Shepherd	4	3.7
Poodle	3	2.8
Epagneul bretton	3	2.8
Pekingese	2	1.9
Jack Russel Terrier	2	1.9
Pointer	2	1.9
Pug	2	1.9
King Charles Spaniel	2	1.9
Kurzhaar	2	1.9
Setter	2	1.9
Rottweiler	2	1.9
American Pitbull	2	1.9
Jura hound	1	0.9
Bullmastiff	1	0.9
Bullterrier	1	0.9
French Bulldog	1	0.9
Cane Corso	1	0.9
Fox terrier	1	0.9
Chow-chow	1	0.9
Barak hound	1	0.9
Total	***108***	***100***

Table 4: Percentage distribution of orthopaedic conditions necessitated FHNE.

Condition	Occurrence	Percentage distribution (%)
Hip luxation	35	32.4
Avascular necrosis of the femoral head	31	28.7
Fracture of Femoral Head	25	23.2
Hip Dysplasia	10	9.2
Fracture of the Acetabulum	4	3.7
Hip Osteoarthritis	3	2.8
Total	***108***	***100***

Table 5: Distribution of restriction's kind used in dogs necessitated to FHNE.

Kind of restriction	Number of dogs	Percentage of dogs *(%)*
No running and jumping, short leashed walks	77	81.9
No restriction	14	13
Cage rest and short leashed walks	8	8.5
Indoor restriction	4	4.3
Dog leashing and short leashed walks	3	3.2
Restriction to a small place, free to run and jump	2	2.1
Total	***108***	***100***

Discussion

FHNE and the correlation of its success with parameters concerning the dogs has been a subject of study over time. However, regardless of their values, these parameters cannot ensure full gait recovery. This should be expected as gait recovery largely depends on the postoperative management in terms of both appropriate veterinary instructions and the owners' compliance with them. The aim of this study was to identify and evaluate the effect of both pre-operative factors (such as body weight, age, the disease that necessitated FHNE and its chronicity) and post-operative factors (such as the restriction of physical activity, the administration of analgesia, and the performance of physical therapy) in the animal's gait progress.

Table 6: Correlation between parameters and final limb's weight-bearing.

	Final weight-bearing	
Parameters	Pearson test	Spearman test
Age	r = -0.123 p = 0.235	rho = -0.007 p = 0.946
Weight	r = 0.018 p = 0.860	rho = -0.144 p = 0.164
Chronicity	r = 0.346 p = 0.001*	rho = 0.388 p < 0.001*
Physical therapy	r = -0.043 p = 0.681	rho = -0.068 p = 0.514
Restriction	r = -0.051 p = 0.620	rho = 0.023 p = 0.823
Analgesia	r = 0.247 p = 0.021*	rho = 0.134 p = 0.217

*statistically significant difference

FHNE consists of resection of the femur's head and part of the neck, resulting in the formation of a pseudoarthrosis by a dense fibrous tissue between the pelvis and the resected femur. The aim of this is to prevent contact between the pelvis and the resected femur, which would cause pain and lameness. The surgical technique and two factors in particular play an important role in the outcome and the speed of gait recovery. First, atraumatic soft tissue manipulation and minimal disruption of the gluteal muscles are required to ensure better support of the anteriorly and dorsally displaced femur. Second, adequate removal of the femoral neck and smooth ostectomy surface are thought to reduce the bony contact and pain, particularly in the early postoperative period, while the pseudoarthrosis is forming [10,36-38].

Various modifications have been proposed to improve the results of the FHNE technique, such as the placement of fat or muscular pads or flaps between the ostectomy surface and acetabulum [10,18,39-41], as well as joint capsule suturing [17,18,41]. However, their effectiveness is controversial. In our study, the classic technique was applied to all cases and led by the same surgeon. Therefore, the surgical technique was not included in the parameters studied.

Data analysis of the animals presented to the Orthopedic Department of the Companion Animal Clinic was carried out by studying their clinical records. The data include animals' preoperative condition, such as body weight and age, as well as the grade and duration of lameness at the time of the initial examination. Due to owners' inability to present their animal for re-examination, the postoperative follow-up was approached based on a questionnaire, which contained a calibrated scale for the assessment of the potential lameness, the owners' compliance with the limitation of animal's activity, the administration of analgesia, and the physical therapy application.

Unfortunately, the reliability and validity of the responses cannot be confirmed. However, similar scientifically accepted published studies have also been based on the collection of data by questionnaires [10,12,30,33,42-45,39,46-48]. Therefore, this procedure makes the results subjective and acceptable with reservations, but the importance of these studies should not be diminished.

When assessing the outcomes at 3 years after surgery, gait recovery was complete in 87% of cases, while 13% had mild lameness, and one dog had intermittent weight-bearing lameness. This outcome may be due to both the owner's non-compliance with postoperative instructions and to the presence of bony protrusions on the ostectomy surface. Lins et al. [49] stated that a dog that underwent FHNE had a recurrence of pain at 60 days after surgery, and the surgery was repeated to remove osteophytic formations in the neck area contacting the pelvis. This can occur due to an improper angle of the femoral neck ostectomy, resulting in residual bony protrusions.

Generally, persistent lameness is reported to be the result of pain, weakness, limb-length difference, altered muscle-activity pattern, iatrogenic entrapment, or sciatic nerve injury [3,6,30,50-54]. The radiographs in our study showed the formation of bony prominences on the ostectomy surface several months after surgery, particularly in animals with delayed limb weight-bearing. However, the presence of these protrusions was not always related to the appearance or grade of limb lameness. In conclusion, the postoperative progress of FHNE is unpredictable, and both clinically and radiologically, the results of the tests mentioned should not be correlated.

According to the owners' responses, TFWB of the operated limb ranged from 30 to 365 days, which is similar to the reported range of 60 to 365 days postoperatively [10,16,17,29,69]. The results of our study regarding the positive role of FHNE in gait recovery are consistent with the literature [28], while in some cases, they exceed the rates of other studies [45]. However, a publication from the University of Munich examined 66 dogs and 15 cats that underwent FHNE and graded the recovery of gait based on objective criteria (gait analysis corridor, range of passive movements of the joint). The recovery of gait was graded as unsatisfactory in 42% of animals at 4 years postoperatively. This result is not consistent with either the percentage of animal owners who declared they were satisfied (96%) with the development of FHNE [17], or with other studies based on questionnaires [10,12,30,33,39,42-48]. In our study, 94.4% of owners would make the same decision due to the overall improvement in the quality of life of their dogs.

When the owners were asked about the grade of lameness after exercise, they reported no lameness in the majority of cases, while the lameness was grade 3 in the rest of the cases. In each case, lameness decreased after rest. These results are also compatible with other studies, which have associated lameness with humidity, low temperature, and intense exercise. These conditions are favorable for the clinical findings of osteoarthritis [6,10,17,28,33].

The correlation between age and the postoperative development of patients that underwent FHNE is a controversial point in the literature. In our study, the statistical analysis showed no correlation between them, which is compatible with some of the literature [55,17]. However, some researchers positively support this relationship, even when it is not statistically proven [6,29,30,55]. This association could be related to degenerative joint disease, of which the progression depends on age and the underlying cause, making it confounded with chronicity (Table 6).

A positive correlation between the disease's chronicity and the limb's final weight-bearing was observed in this study and in all of the published literature [6,17,28-31,33]. Chronicity is almost synonymous with preoperative lameness and reduced function of muscles due to secondary osteoarthritis. Therefore, chronicity is expressed by muscle atrophy. Postoperatively, the muscles have to move the painful operated limb. If muscles are already atrophic, their strain will be even greater, and the recovery time will be longer [6,28,29].

The statistical relation between the underlying disorder that necessitated FHNE and the outcome was proven to be significant in only the case of ANFH, which seems to delay the final recovery. A similar correlation has not been reported in the literature. However, some small dog breeds return to function more slowly. In some cases, this is due to muscle atrophy associated with chronic ANFH or a lower pain threshold of the animal [28].

Another patient-related factor is body weight. Its reduction is a significant measure in the conservative treatment of most orthopedic diseases as it also reduces the strain on affected joints. The outcome of FHNE is often considered to be related to the dog's size [4,56], and there is general agreement that small animals cope better with the absence of the hip joint [30,55,57]. A basic theory is that more weight must be supported by pseudoarthrosis in large dogs, which could lead to pain and more pronounced displacement of the proximal resected femur craniodorsally during the limb's weight-bearing. This would have negative effects on walking [10,28,30,34,37]. Another theory suggests that the anatomical remodeling with the new bone formation after FHNE is greater in large dogs as the contact between the femoral neck and acetabulum is increased due to the weight exerted on them [56].

Many studies report better postoperative results in dogs weighing up to 20 kg [55,58], but this is not always confirmed by other researchers [29,31], even when objective evaluations are used [17]. In our study, no statistical correlation was found between body weight and the limb's final weight-bearing. Therefore, although it is generally accepted that FHNE is a great alternative in cats and small dogs, and there is no doubt that the change in gait is more easily detected in large dogs, it may not necessarily be related to reduced joint function [28,30,36-38].

Regarding the postoperative instructions, the importance of the restriction of physical activity on the outcome was evaluated. In the case of FHNE, strict restriction is contraindicated. For dogs undergoing FHNE, early use of the limb should be encouraged; otherwise, the fibrous tissue will limit the range of motion of the hip joint. According to Grisneaux et al. [59], owners are instructed to keep the duration of walks to 10 minutes for the first month postoperatively. Afterwards, a gradual increase in duration (but not in intensity) is recommended. This is suggested to achieve the formation of dense fibrous tissue and the stabilization of the resected joint, as well as to avoid joint ankylosis by the permanent contraction of the muscles. However, this parameter was not shown to be statistically related to the time of final weight bearing.

In the same way, physiotherapy is used to recover the hip's normal range of motion and consequently prevent muscle atrophy [10,59,60]. Physical therapy exercises should be started within 48 hours after FHNE [61], but its effect is considered favorable even when its start is delayed [62]. Initially, passive flexion and extension movements of the false joint are performed, and after 2-3 weeks, active weight-bearing activities are begun (e.g., overcoming obstacles, swimming, and hydrotherapy) [6,10,25,36-38]. However, the long-term benefit of all these exercises should not be assumed because in many patients, these manipulations may worsen the pain at the site of surgical healing [63].

The results of swimming as a physical therapy exercise are also considered doubtful for FHNE. While its application is recommended by many scientists after surgical wound's healing [4,6,10,16,64], some authors indicate that it does not affect passive range of motion and particularly the extent of pseudarthrosis [65-67]. In contrast, the effect of underwater treadmills is commonly accepted as they promote cardiovascular function and joint mobility while improving muscle strength and endurance [62,67,68]. Obese patients or those with significant muscle atrophy need a more intensive physical-therapy program with massage and walking exercises for the pelvic limbs [28]. In our study, dogs that underwent physical therapy had a higher TFWB than those that did not, but this difference was not significant.

Although many studies have reported contradictory information regarding the outcome of FHNE, we consider that our study contributes to the enrichment of this literature by adding information about the association of factors that have been insufficiently studied, such as the underlying disease necessitated FHNE. However, one limitation of the present study is the lack of objective criteria for postoperative progress evaluation. Furthermore, there was large variation in breed, age, and body weight, and the majority of dogs were small or medium sized.

In addition, incomplete or biased recall of events by the owners is possible due to the length of time that passed between surgery and completion of the questionnaire. However, this is a limitation in all owner-based studies, and the information obtained is still considered valuable. An important advantage of this work is the large size of the sample that met the inclusion criteria. However, in order to evaluate all the factors that influence the postoperative outcome of dogs that undergo FHNE, it is considered necessary to study populations of animals that are chosen based on objective criteria and compared with control groups.

Conclusion

A dog's age and body weight, postoperative activity restriction, physical therapy, and the administration of analgesics do not affect the outcome of FHNE. The disease's chronicity and, by extension, muscle atrophy negatively affect the progress after surgery. Hip luxation and ANFH are the most frequent indications of FHNE, while acetabular fractures and hip dysplasia are the rarest. To the best of our knowledge, this is the first study to show a positive correlation between the limb's final weight bearing and ANFH.

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