Study on the Association of Proximodistal Patellar Position and Canine Gait

Summary of PhD thesis

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Motion analysis is used to analyse the mechanical function of humans or animals in motion. There are two main techniques for motion analysis: kinetic analysis and kinematic analysis. Kinetic motion analysis measures the force generated during movement, while kinematic motion analysis measures the spatial movement of body segments. Kinetic motion analysis often involves force plates or pressure mattresses to measure the ground reaction force. Kinematic motion analysis considers the body as rigid segments connected at the joints and records the angular alteration, angular velocity, segmental movement, and segmental velocity. Motion analysis in the field of veterinary medicine was first performed by Muybridge in 1877, when he photographed and analysed the trotting horse. Recently, in the clinical field of small animals, inverse dynamics analysis of walking or trotting dogs with cranial cruciate ligament rupture, fragmented medial coronoid process, or hip dysplasia has been conducted. These studies have proven that motion analysis would be useful in the diagnosis of orthopaedic diseases and in examining postoperative recovery. However, it has not yet been widely applied in clinical practice, and reports on small dogs are particularly limited.

Patellar luxation is one of the most common orthopaedic diseases in small animals. In humans, patella alta, a condition in which the patella is displaced proximal to the trochlea, has been suspected to lead to patellar luxation or treatment failure due to loss of support from the trochlear ridge. Children with patella alta who have cerebral palsy have been reported to walk with a crouch gait, walking with their knees flexed in the stance phase. Dogs with medial patellar luxation (MPL) have been reported to have greater patellar ligament length to patellar length ratio (PLL/PL) than dogs without patellar luxation. This suggested an association between patella alta and MPL in dogs as well. However, there have no reports on motion analysis on dogs with MPL or patella alta performed to date, and it is unclear whether dogs have gait characteristics associated with these conditions. Moreover, the proximodistal patellar position in dogs has been discussed mainly with PLL/PL, and other indices have not been adequately investigated. Additionally, no study has examined the association between proximodistal patellar position and patellar motion during stifle joint flexion or extension.

In Chapter 2, the morphological factors other than the PLL/PL were examined accordingly with the proximodistal position of the patella and proximodistal patellar positions were compared between dogs with MPL and dogs without patellar luxation. Using mediolateral radiographs of 99 hindlimbs of 71 small dogs on the stifle joint flexed approximately 90 °, the effect of distal femoral morphological factors was studied using multiple linear regression analysis. The patella was positioned more proximally as the patellar ligament became longer, trochlear length became shorter, femoral condyle became smaller, or trochlear became more perpendicular to the long axis of the femur. When grouping radiographs into MPL and control groups, patellar position in the MPL group was not significantly more proximal than that in the control group despite the fact that the MPL group was suggested to have shorter trochlea and femoral condyle dysplasia. Furthermore, mediolateral radiographs of 50 hindlimbs of 29 small dogs on maximum stifle extension showed that the MPL group had a significantly greater maximum stifle extension angle, and its proximal patellar position was significantly more proximal than in the control group. This indicates the possibility of a functional patella alta in which hyperextension of the stifle joint displaces the patella proximally over the trochlear region, even if the proximodistal patellar position relative to the stifle joint angle is normal. In such cases, extension of the stifle is likely to move the patella proximally over the support of the trochlear ridge and make the patella more susceptible to medial or lateral luxation.

In Chapter 3, we focussed on the length of the quadriceps muscle, which is the stifle extension mechanism. Twelve healthy beagle dogs were anaesthetised and computed tomographic images were taken with various hindlimb positions to evaluate the effects of hip flexion-extension, hip adduction-abduction, and stifle flexion-extension angles on the quadriceps muscle length to femoral length ratio (QML/FL) and PLL/PL using multiple linear regression. The QML/FL was found to increase with hip extension and stifle flexion, whereas PLL/PL was not affected by any joint angle. The coefficient of the hip adduction-abduction angle on the QML/FL was small, indicating that its effect on the QML/FL was small. The final model with a log plot had a slightly larger coefficient of determination than the linear plot, suggesting that slight changes in joint angles had a more pronounced effect on the QML/FL in position with hip flexion and stifle extension where the quadriceps muscles were more relaxed than extended. Since the PLL/PL does not change with joint angles like the QML/FL does, it was concluded that the association between the patella and femoral trochlea does not change with alteration of hip joint angle if the stifle joint angle is constant.

In Chapter 4, an inverse dynamics analysis was performed on four healthy beagles during trotting to evaluate the joint angle, joint moments, and joint power of the stance phase. Shoulder, elbow, carpal, metacarpophalangeal, hip, stifle, metatarsal, and metatarsophalangeal joints were examined. In this study, compared to previous ones, shoulder, elbow, and carpus joint moments and powers had several differences, probably derived from the measurement system. However, joint moments and powers of hindlimb joints showed a similar pattern in previous studies of Labrador retrievers but showed a slight difference from those of Greyhounds. It was concluded that the shape of the dog had a greater effect on the joint moment and power than the size of the dog.

Based on the joint angle movement of healthy beagles analysed in Chapter 4, we analysed the stifle joint movement of dogs with MPL and that of dogs without patellar luxation during trotting in Chapter 5. Its association with imaging indices related to proximodistal patella position was also evaluated. In gait analysis, the maximum joint extension and flexion angles and the range of motion of the stifle joint during the stance and swing phases were observed. Radiographic images were taken with the stifle joint angle at approximately 90 ° and in hyperextension while the stifle was extended with compression of the tibia from the cranial side. The PLLL/PL was measured on the images with the stifle flexed, based on a previous report by Mostafa. The hyperextension angle, proximal patellar position, and distal patellar position were measured on the images with the stifle hyperextended. Results of multiple linear regression showed that the maximum stifle flexion and extension angle during the stance phase were significantly decreased as the PLL/PL became greater or the proximodistal patellar position during hyperextension became more proximal. It was noticed that the crouch gait, reported with human patella alta, was also observed in dogs. The PLL/PL and proximodistal patellar positions were not significantly different between healthy beagles and dogs with MPL despite having a significant effect on gait. These indices might be associated with the angular decrease of the stifle joint during the stance phase, regardless of MPL.

Finally, in Chapter 6, gait analysis was carried out on four healthy beagles in a custom-made orthosis to limit the stifle flexion angle and evaluate the effect of different stifle restriction levels on the ground reaction force. The fixed orthosis with strong joint restriction or unfixed orthosis with weak joint restriction were placed on the right hindlimb, and the ground reaction force during trotting was evaluated after a one-month familiarisation period. The peak vertical force, vertical impulse, peak propulsive force, peak propulsive impulse, peak braking force, and peak braking impulse were compared between the gaits using multiple linear regression analysis, including trotting velocity as an independent variable. The ground reaction force changed in both hindlimbs in the gaits with orthosis compared to the gait without orthosis. Vertical ground reaction force was changed with both fixed and unfixed orthosis; however, the peak vertical force of the right hindlimb with fixed orthosis increased, while that with unfixed orthosis was decreased. Furthermore, the function of the right hindlimb with fixed orthosis was shifted into propulsive as the peak propulsive function and propulsive impulse were significantly increased and braking impulse was significantly decreased, meanwhile the function of the left hindlimb was shifted into braking as the peak propulsive force decreased and peak braking force increased. In contrast, there was no significant change in the fore-aft ground reaction force with unfixed orthosis. When the range of motion of the stifle joint is strongly restricted, the impact on landing increases and the gait pattern changes, which could increase the load on some joints.

In conclusion, we have shown that the distal femoral morphology affects the proximodistal patellar position, and the hyperextension of the stifle joint might displace the patella proximal to the trochlea in small dogs with MPL. It was also demonstrated that the length of the quadriceps muscle varies with the angle of the hip and stifle joints, while the length of the patellar ligament does not. These results indicate that functional patella alta, in which the patella exceeds the femoral trochlea proximally during stifle extension. The gait analysis study suggested the possibility of a crouch gait associated with proximally positioned patella. With the strong restriction of the stifle joint range of motion, the ground reaction force may change, which could lead to the load on other joints.

The results of this study indicate that functional patella alta may be seen in small dogs with MPL, possibly in association with crouch gait and these present gait changes would be expected to result in load changes other than stifle joint.