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Letter to the Editor

Letter to the Editor on "Prediction of Knee Kinematics at Time of Noncontact Anterior Cruciate Ligament Injuries Based on Bone Bruises"

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Associate Editor Jane Grande-Allen oversaw the review of this article.

Abstract—The aim of the present Letter was to comment on the paper "Prediction of Knee Kinematics at Time of Noncontact Anterior Cruciate Ligament Injuries Based on Bone Bruises" from Shi *et al*. (Ann Biomed Eng, 2020, https://doi.org/10.1007/s10439-020-02523-y). Though the authors provided an extremely interesting paper on a debated topic in Sport Medicine, with a strong methodology and consistent results, caution should be used when drawing conclusions on Anterior Cruciate Ligament injury mechanism through the interpretation of such data.

Keywords—Bone bruises, Anterior Cruciate Ligament, Injury Mechanism, Knee Kinematics.

We read with enormous interest the paper "Prediction of Knee Kinematics at Time of Noncontact Anterior Cruciate Ligament Injuries Based on Bone Bruises" from Shi *et al.*[15] First of all, we congratulate with the authors for employing cutting edge technologies to shed light on an extremely debated topic in Sports Medicine, which is the mechanism of Anterior Cruciate Ligament (ACL) rupture. The authors created a 3D MRI-based model of the tibia and femur, which was positioned within the 3 spatial planes by matching the tibial and femoral bone bruises areas in the lateral compartment, in order to recreate the tibio-fermoral position "near the time of ACL injury".[15] Bone bruises are indeed believed to "represent a footprint of the impact at time of ACL injury"[15] and their study has been considered useful to gain insight into the mechanism of ACL injury.[9,10,14,16]

The authors found important and interesting findings: according to their model of lateral bone bruises matching, tibio-femoral impact occurs at an average flexion near 35° (as extrapolated from their Fig. 1), anterior tibial translation of 34.3 mm, external rotation near 10° and knee abduction (valgus) near 10°. This position, which significantly differed from the "resting" MRI position, is extremely consistent with the findings reported in a study with a similar methodology presented by our group at the Italian Congress of Orthopaedics and Traumatology (SIOT) in 2019[6] and scheduled as a free paper presentation at the 2020 European Society of Sports traumatology, Knee and Arthroscopy (ESSKA) Congress, which was not however presented due to the COVID-19 pandemic. According to our model, which included patients with both medial and lateral bone bruises (to increase matching accuracy) and that used the *in vivo* weightbearing condition (acquired through a Dynamic Roentgen-Stereophotogrammetric Analysis[1–4,13]) as reference baseline position, we found that bone bruises occur with a knee flexion above 30°, and with an average anterior tibial translation of 28.4 mm, external rotation of 13.7° and knee valgus of 10.6°.

Our values are extremely consistent with those of Shi *et al.*,[15] thus suggesting a similar behavior of the ACL injury mechanism either in the case of bone bruises involving the single lateral compartment or involving the medial and lateral compartments simultaneously. Thus, we strongly support their method and their results.

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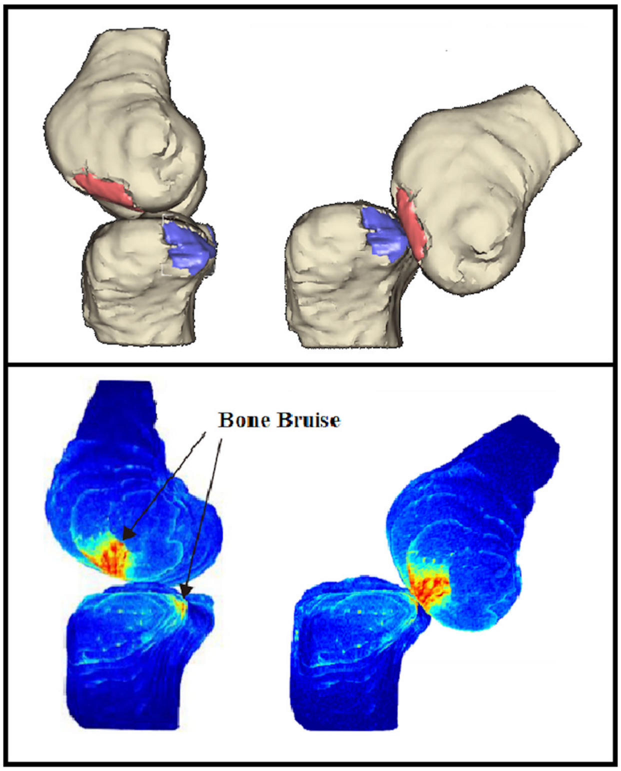

FIGURE 1. Knee position obtained in our research study [6] through MRI-based model-matching of the bone bruises (red for femur, blue for tibia) on medial and lateral compartments (top); knee position obtained in the study of Shi *et al.*[15] (bottom).

However, extreme caution should be used when interpreting such results. The authors indeed concluded that "excessive external tibial rotation when combined with knee flexion and extreme valgus may be the predisposing biomechanical factor to the ACL injury" and that these could be considered as "high-risk movement patterns for ACL injury", thus suggesting that "ACL injury prevention programs should focus more on constraining knee valgus and external rotation".

Drawing such conclusions from this biomechanical evidence could be misleading without examining in-depth the current knowledge of ACL injury mechanism. Indeed, one of the most reliable models, which more closely resembles the real *in vivo* condition, is the model described by Koga *et al.*[12] They have been the first and the only to investigate the ACL injury mechanism by applying a Mode-Based Image Matching (MBIM), which allowed them to analyze the tibiofemoral kinematics during *in vivo* noncontact ACL injuries in athletes by matching the 3D skeletal models with bi-dimensional images (obtained from video footages) according to anatomical landmarks. The authors were thus able to identify 3 distinct phases of the injury mechanism based on rotational and translational motions: (1) an initial phase of lateral compression when an axial and knee valgus loads are applied on the early-flexed knee; (2) a second phase when anterior tibial translation and internal rotation occurs, resulting in ACL rupture; (3) a final phase when anterior displacement and flexion increase, and external rotation occurs.

Examining the data provided by Koga *et al.*,[11,12] the plateau of anterior tibial translation (above 20 mm) seems to occur approximately between 50 and 100 ms after initial ground contact, thus after ligament rupture, with knee flexed above 30° and when tibial rotation is reversing from internal to external rotation. This translational and rotational pattern described in the late phase of injury mechanism seems consistent with the pattern reported by matching bone bruises.

Thus, it is our opinion that bone bruises occur AFTER ACL rupture, when the tibial and femoral motion is guided by the abnormal kinematics due to the ligamentous injury and the traumatic inertial energies, exposing to contact articular surfaces that would not be normally overlapped during physiological motion. In our opinion, with the current knowledge, it is thus not appropriate to formulate recommendations on ACL injury prevention based on models obtained from bone bruises matching. Further *in vivo* studies are needed to accurately determine the exact moment of bone bruises occurrence, ideally matching 3D-MRI knee models with *in vivo* ACL injury video captures in media exposed athletes.[5,7,8] We agree that such task would be extremely complex, but hopefully in the near future technological development will allow us to deepen our knowledge in this fascinating and barely explored topic.

CONFLICT OF INTEREST

No benefits in any form have been or will be received from a commercial party related directly or indirectly to the subject of this manuscript.

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