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Arthroscopic cam resection reduces femoroacetabular contact pressure

a cadaver study

From NOVA Medical School, Lisbon, Portugal

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Aims
Arthroscopic cam resection in femoroacetabular impingement syndrome leads to clinical improvement, but biomechanical studies on the effect of surgical intervention are scarce. In this study, we compared the femoroacetabular contact pressure (CP) in an intact cam morphology and after arthroscopic cam resection. The hypothesis was that arthroscopic cam resection decreases the femoroacetabular CP.

Methods
A cadaveric study was performed on nine hips with a cam morphology (α angle > 60°). CP was assessed using a new hip-specific device and an intracranial pressure (ICP) sensor. These evaluations were performed during hip arthroscopy, in the intact joint and after cam resection, with the joint in different positions. These measurements were normalized and reported as a percentage of the native intact joint.

Results
A statistically significant difference in the mean CP measured with the hip-specific device was observed before and after cam osteoplasty at 0° (41.2% (SD 29.7%); p = 0.014), 30° (54.5% (SD 16.6%); p = 0.011), 60° (39.8% (SD 23.0%); p < 0.001), 80° of flexion (36.3% (SD 22.1%); p < 0.001), and 80° of flexion with 20° of internal rotation (26.0% (SD 22.4%); p < 0.001). The ICP sensor is very fragile and difficult to handle in hip arthroscopy. Consequently, we limited the evaluations using this sensor to five hips. A statistically significant difference in the CP was found before and after cam osteoplasty at 80° of flexion (57.6% (SD 29.1%); p = 0.004).

Conclusion
This biomechanical study evaluated a new hip-specific device to intraoperatively measure the CP in arthroscopic surgery. It showed a significant decrease in the CP after arthroscopic cam resection with the joint in different positions. At 80° of flexion with 20° of internal rotation, a typical position to detect hip impingement, the CP was reduced to 26% after arthroscopic cam resection. The intraoperative measurement of CP provides surgeons with feedback to evaluate the effectiveness of the osteoplasty.

Bone & Joint Research

Article focus

- The authors developed a hip-specific device for measuring the femoroacetabular contact pressure in hip arthroscopy and tested it on cadavers with cam morphology.
- Most femoroacetabular impingement (FAI) surgeries are performed arthroscopically, where achieving precise arthroscopic cam resection remains a considerable technical challenge.
- Intraoperative evaluation of femoroacetabular contact biomechanics can provide valuable insight in the assessment of the femoral osteoplasty.

Key messages

- Using the developed hip-specific device, significant decreases in the contact pressure were observed after arthroscopic cam osteoplasty across different joint positions.
- Intraoperative measurement of contact pressure can show improper biomechanical restoration following cam resection, allowing for immediate correction during the procedure.

Strengths and limitations

- This is the first study to assess the femoroacetabular contact pressure intraoperatively during arthroscopic cam resection, using a device specially designed to measure femoroacetabular contact pressure in arthroscopic surgery.
- A complete body model was used, aiming to replicate the typical scenario of hip arthroscopy for FAI cam correction.
- The contact pressure was evaluated with a hip-specific device in nine hips, while the contact pressure measurement with the intracranial pressure sensor was limited to five joints due to the damage of several sensors.

Introduction

In femoroacetabular impingement syndrome (FAIS) with cam morphology, contact pressures and forces are often increased in the anterosuperior segment of the acetabular cartilage, leading to chondrolabral pathology and ultimately contributing to the onset of early osteoarthritis.[1-5] Additionally, in non-pathological hips, the femoroacetabular contact force (CF) and pressure (CP) are increased in the anterior and superior segments of the acetabulum.[6,7]

Outcome studies have shown good-to-excellent clinical outcomes with arthroscopic treatment of FAIS, but studies on the effect of surgical intervention on the joint biomechanics are scarce.[3,8-10] Femoroacetabular CF and CP can be measured in open cadaveric surgery with thin-sheet multiplexed grid-array transducers.[1,7,11] Due to their size, these sensors cannot be used in arthroscopic surgery, and an extensive approach and a wide capsulectomy are needed to introduce and fix the sensor in the joint.[1,11-16]

The surgical treatment of FAIS is predominantly performed arthroscopically, and achieving precise arthroscopic cam resection remains a considerable technical challenge. Intraoperative measurement of femoroacetabular CP during arthroscopic surgery can play a critical role in assessing the effectiveness of osteoplasty and potentially reducing the risk of residual deformity, a common cause of FAIS surgery revision.[17] Identifying inadequate biomechanical restoration intraoperatively should alert the surgeon to re-evaluate the osteoplasty, as further correction may be necessary.

Recently, a hip-specific device designed to measure femoroacetabular CP during arthroscopy has been introduced, offering potential advancements in the intraoperative evaluation of hip contact biomechanics.[18]

This cadaveric study aimed to: a) measure the femoroacetabular CP in hip arthroscopy using a new hip-specific device; b) compare the CP in the intact cam morphology condition and after arthroscopic cam resection; and c) compare to the femoroacetabular CP measured with an intracranial pressure (ICP) sensor in the same settings. We hypothesized that arthroscopic cam resection decreases the femoroacetabular CP compared to the intact cam morphology.

Methods

Specimen selection

The protocol study was approved by the Institutional Ethics Research Committee of NOVA Medical School.

In total, 20 hips from ten donated fresh-frozen full-body cadavers were imaged; nine hips with cam morphology from five cadavers met the study's inclusion criteria and were included in the comparative biomechanical analysis. The cadavers were preserved with an embalming solution and maintained in a freezer at 4° to 6°C; the thawing procedure was standardized for all specimens.[19]

C-arm fluoroscopic imaging (OEC One CFD; GE Healthcare, USA) was used to assess joint space and the presence of osteoarthritis, the α angle was measured in the Dunn 45° view, and the centre-edge angle of Wiberg (CEA) in a hip anteroposterior view. The pelvic tilt and rotation were standardized in all images, and the visualization of the pubic symphysis allowed for the correction of the pelvic lateral inclination. All radiological measurements were performed by the same author (PD) using a free open-source medical image viewer (Horosproject.org, Nimble Co LLC d/b/a Purview, USA).

The inclusion criterium was the presence of a cam morphology with an α angle greater than 60°.[20-22] The exclusion criteria were previous hip surgery or fracture, evidence of osteoarthritis (Tönnis grade > 1),[23,24] acetabular dysplasia or overcoverage (CEA < 25° or ≥ 40°, respectively).[21,24,25]

The mean age of the specimens was 76.8 years (63 to 86; SD 8.7), and the specimen characteristics are presented in Table I.

Arthroscopic setup

The complete cadaver was placed in the supine position on a dissection table, which enabled the use of fluoroscopic imaging. Hip arthroscopy was performed using the initial access to the peripheral compartment technique and periportal capsulotomies.[26,27] The proximal anterolateral portal was used as a viewing portal in the peripheral compartment, and the mid-anterior portal was used as a working portal. The transition zone at the 1 to 2 o'clock position in the acetabulum was identified and marked with a radiofrequency device (AMBIENT HipVac 50 IFS 4.6 mm 50° Suction; Smith & Nephew, UK).[28] This region is located below and lateral to the anteroinferior iliac spine, and the sensors were placed in this same area for all measurements to allow for comparable results.[28] The

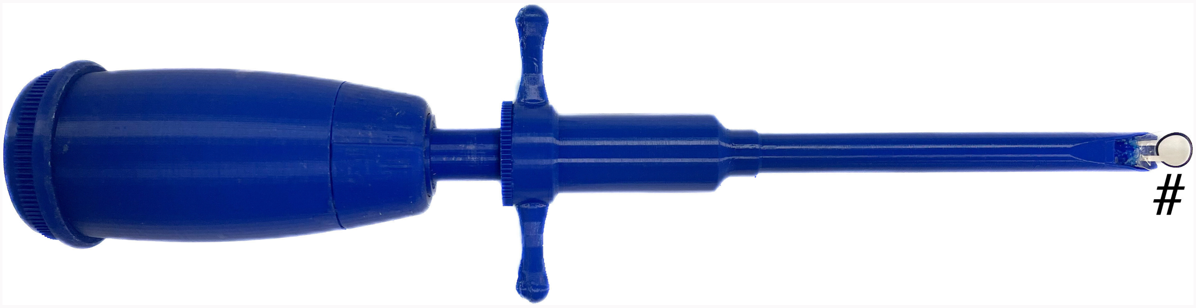

Fig. 1
The hip-specific device for measurement of the femoroacetabular contact pressure in hip arthroscopy. #, force-sensitive resistor exposed.

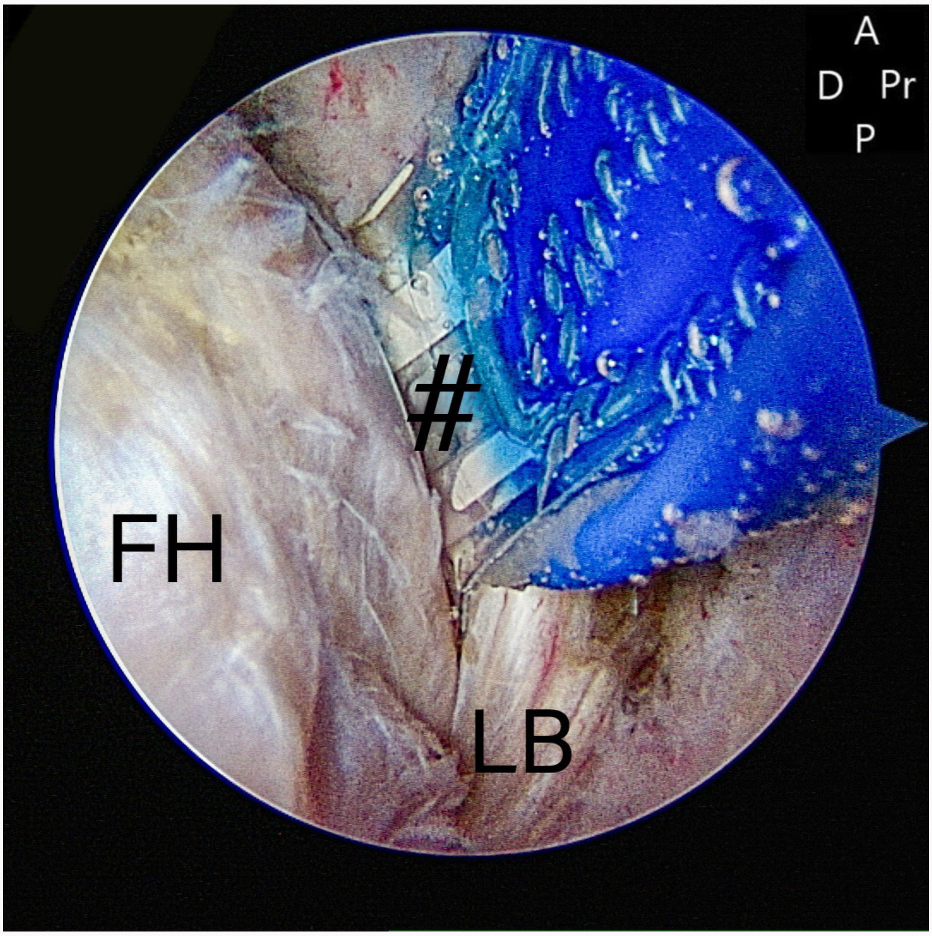

Fig. 2
Arthroscopic image of the peripheral compartment of a left hip, viewed proximally from the proximal anterolateral portal. The hip sensor was inserted between the anterosuperior acetabulum and the femoral head. A, anterior; D, distal; FH, femoral head; LB, labrum; P, posterior; Pr, proximal; #, hip sensor.

mid-anterior portal was used sequentially to introduce each of the measuring devices – the hip-specific device as well as the ICP sensor – in the hip peripheral compartment. Manual traction was applied to create joint distraction, allowing the introduction of each of the devices in the central compartment for subsequent measurements under arthroscopic control.[28]

The femoral osteoplasty was performed with a 5.5 mm round burr (Smith & Nephew, USA), with the hip in variable degrees of flexion and rotation depending on the areas that we needed to access.[27]

Biomechanical testing
The primary outcome was the femoroacetabular CP, measured using the hip-specific device. It incorporates a force-sensitive resistor (FSR) (FlexiForce A201, 100 lbs; Tekscan Inc, USA), which has a small size (diameter of sensing zone 9.53 mm), is ultra-thin (0.203 mm), flexible, and with adjustments of the drive voltage and resistance of the feedback resistor can measure up to 445 N (Figures 1 and 2).[18,29] In addition to its reduced thickness, which allows for insertion into the femoroacetabular space, the FlexiForce A201 FSR sensor was chosen for its small sensing area. This design

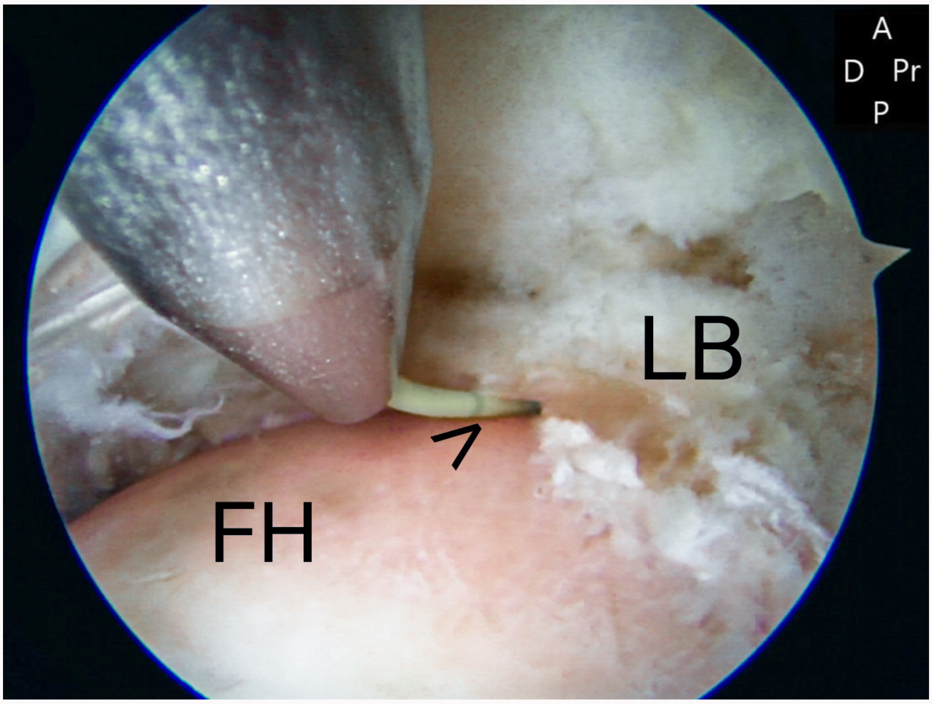

Fig. 3
Arthroscopic image of the peripheral compartment of a left hip, viewed proximally from the proximal anterolateral portal. The intracranial pressure (ICP) sensor was inserted between the anterosuperior acetabulum and femoral head. A, anterior; D, distal; FH, femoral head; LB, labrum; P, posterior; Pr, proximal; >, ICP sensor.

ensures complete coverage of the sensing area at the selected hip positions while avoiding excessive curvature, thereby replicating the calibration conditions and minimizing errors in contact force estimation. Moreover, FlexiForce FSR sensors are known for their superior accuracy and low measurement variability compared to other commercial options, resulting in greater reproducibility.[18,30–32] It should be noted that FSR sensors measure the force transmitted across their sensing area and do not capture the total joint contact force. Therefore, contact pressure was calculated under the assumption that the entire sensing area (71.33 mm^2) was in contact and was compared across the different tested positions. The FSR sensors were calibrated using a universal testing machine, Instron 5544 (Instron, USA), and an individual calibration curve was obtained for each sensor.[18]

The secondary outcome was the femoroacetabular CP evaluated with an ICP microsensor (Codman microsensor transducer; Integra LifeSciences Production Corporation, USA) (Figure 3). This is a miniature strain gauge pressure sensor mounted on a titanium case and connected to a flexible nylon tube with wires.[33,34] The sensor has a maximum diameter of 1.3 mm in the probe tip, and according to the manufacturer's specifications, it can be damaged when exposed to pressures over 0.166 MPa.[34] Although the ICP sensors were not designed to be used in the hip, Kaya[35] described a technique for hip CP measurement in hip arthroscopy using an ICP sensor. The transducer was zeroed at atmospheric pressure, and the external monitor was calibrated before use in each joint, as per the manufacturer's instructions.[34]

The evaluations with both devices were performed under standardized conditions in the intact joint with a cam morphology and after arthroscopic cam resection. For the measurements, the hip was positioned at 0°, 30°, 60°, and 80° of flexion, as well as 80° of flexion combined with 20° of internal rotation (IR) (F0°, F30°, F60°, F80°, and F80°/20° IR, respectively) (Figure 4).[28] A digital goniometer (Digital angle finder, Model HG08763B; OWIM GmbH, Germany) was used to measure hip flexion and rotation accurately. To ensure the same loading in the different conditions, a constant axial load of 50 N was applied to the knee and measured with an axial force measuring unit that was developed to house a compression load cell (FX29, TE Connectivity, Switzerland).[12,18,28] The axial load was applied to measure the CP using the hip-specific device, with the joint positions F30° and F60°. We found in

Table I. Characteristics and imaging findings of the cadaveric specimens.

Variable	Data
Mean age, yrs (SD)	76.8 (8.7)
Mean height, cm (SD)	167.6 (6.5)
Sex: male/female	2/3
Laterality: left/right	5/4
Mean α angle, ° (SD)	69.6 (7)
Mean post-arthroscopic osteoplasty α angle, ° (SD)	53.4 (1.8)
Mean centre-edge angle of Wiberg, ° (SD)	35.2 (2.3)
Tönnis grade: Grade 0/Grade 1	4/5

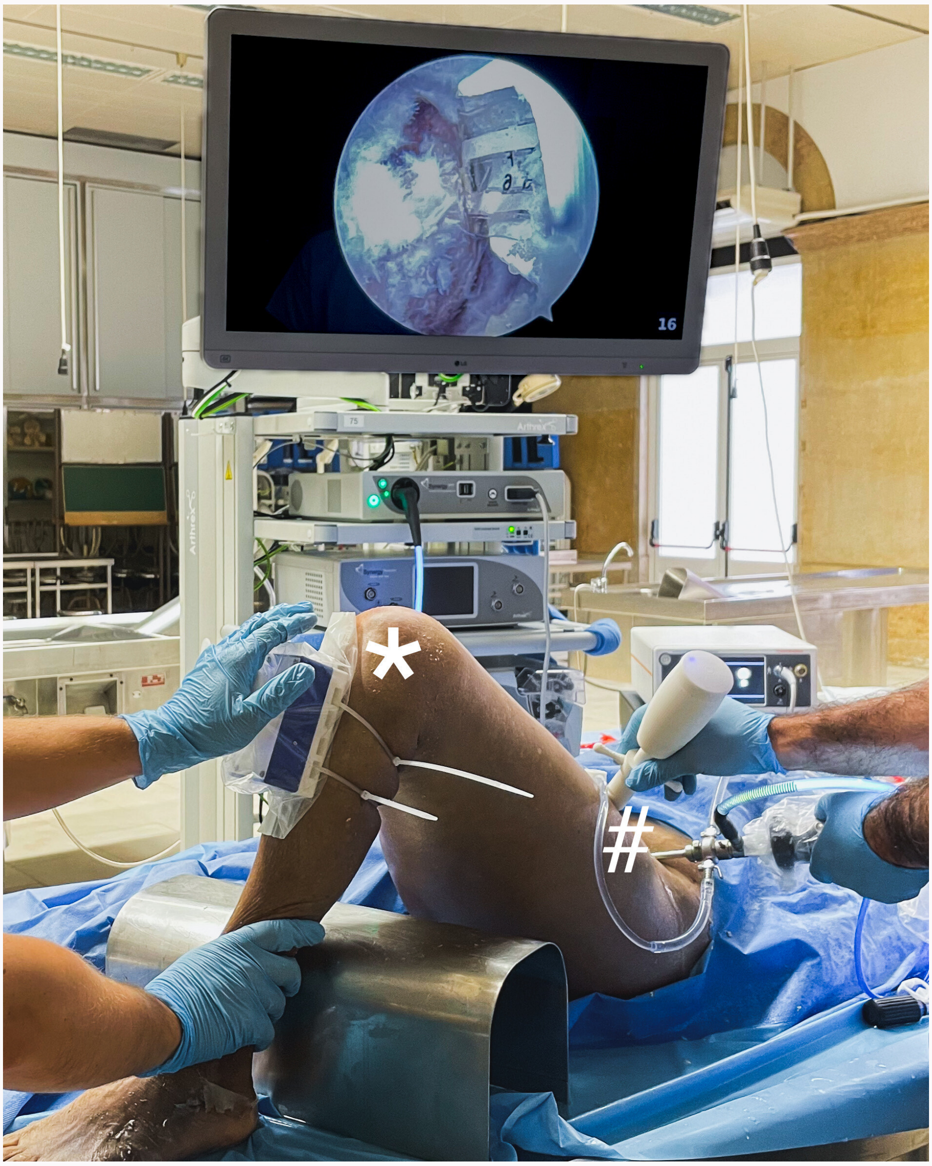

Fig. 4
The hip sensor is inserted through the mid-anterior portal and placed within the central compartment under arthroscopic control. The arthroscopic camera is positioned in the proximal anterolateral portal. The knee load cell is secured to the anterior surface of the proximal leg, and the assistant applies an axial load (50 N) to ensure uniform loading conditions. *, knee load cell; #, hip-specific device.

preliminary tests that at 0°, applying an axial load at the level of the knee was not feasible, and for the settings F80° and F80°/20° IR, the axial load shifted the femoral head posteriorly, thereby reducing the anterior femoroacetabular contact.[28]

Although dynamic measurements of CP are possible, our focus was on static measurements at predetermined joint positions to ensure reproducibility, and a new sensor was used for each joint.

Intraoperative arthroscopic imaging and multiple fluoroscopic views were performed to confirm adequate cam resection.[36] All the arthroscopic procedures and measurements were performed by the first author (PD), an experienced arthroscopic hip surgeon.

Statistical analysis

The sample size was based on the availability of specimens and prior studies using piezoresistive load sensors, which use five to ten specimens.[1,7,13–16,37] These studies have only reported normalized data without providing absolute values, compromising the ability to perform an a priori sample size calculation.

The CP was recorded before and after cam resection with both devices. The measurements were performed three times for each condition in each specimen, and the average value was used for statistical analysis. To account for the differences between the specimens (size, cam morphology, and acetabular coverage), these measures were normalized and are reported as a percentage of the native intact joint.

Statistical analyses were performed using statistics software (SPSS Statistics v.29; IBM, USA), with significance defined as $p < 0.05$.

The variables were assessed for normal distribution using to Kolmogorov-Smirnov test. When the assumption of normality was met, the paired *t*-test was used, and in cases of non-normality, the Wilcoxon signed-rank test was performed. The null hypothesis was that there would be no differences

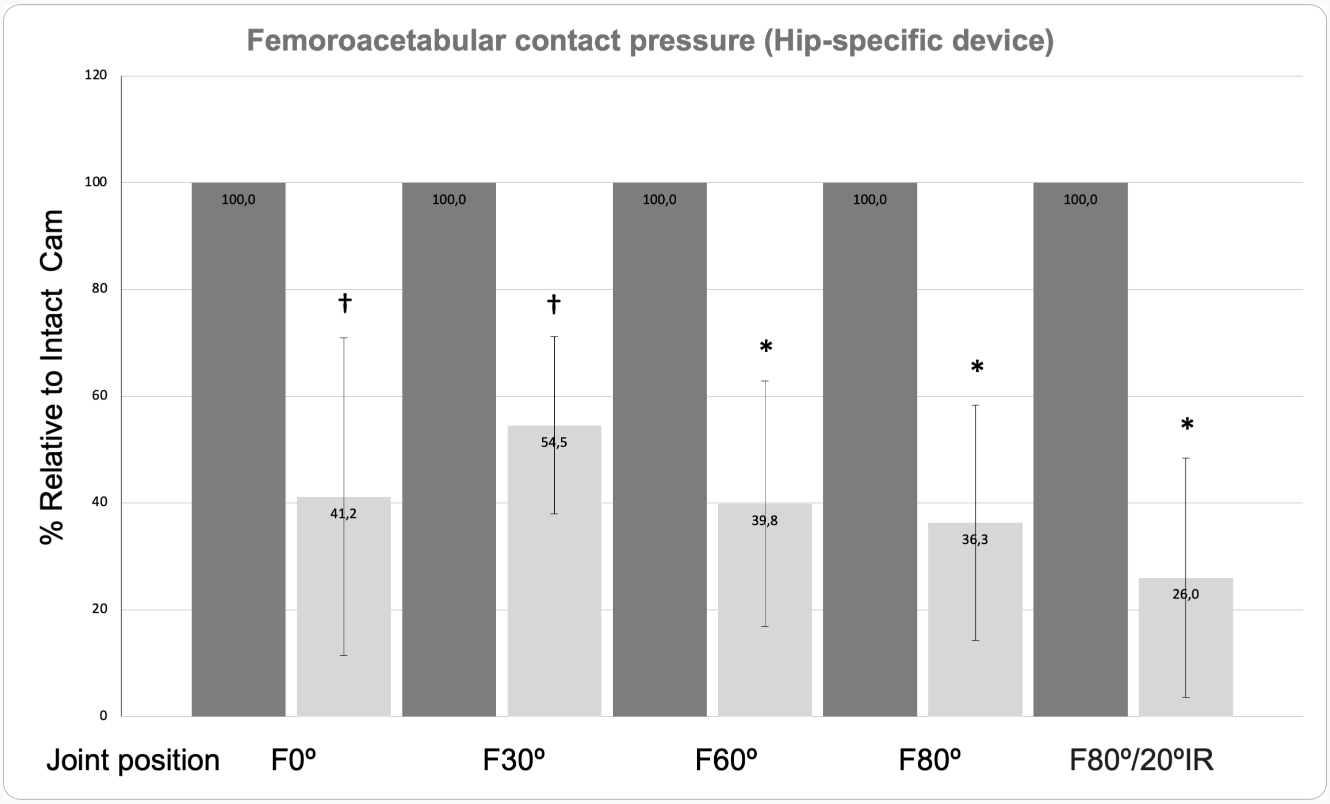

Fig. 5
Normalized femoroacetabular contact pressure measurement with the hip-specific device in intact cam morphology (100%) and after femoral osteoplasty at different joint positions (0º, 30º, 60º, 80º of flexion, and 80º of flexion combined with 20º of internal rotation). †Significant difference compared to the native cam ($p < 0.05$). *Significant difference compared to the native cam ($p \leq 0.001$).

in the CP in the intact joint with a cam morphology and after arthroscopic cam resection.

Results

There was a statistically significant difference between the mean α angle in the native joint and post-arthroscopic femoral osteoplasty (69.6° (SD 7°) vs 53.4° (SD 1.8°); $p < 0.001$, paired *t*-test).

We observed minimal femoroacetabular contact in three joints following cam resection at F80/20, leading to very low CP values.

Contact pressure measurement with the hip-specific device

The femoroacetabular CP was measured with the hip-specific device in nine hips. Statistically significant differences in the normalized CP were detected before and after cam osteoplasty with the hip at 0° (41.2% (SD 29.7%); $p = 0.014$, paired *t*-test), 30° (54.5% (SD 16.6%); $p = 0.011$, Wilcoxon signed-rank test), 60° (39.8% (SD 23.0%); $p < 0.001$, paired *t*-test), 80° of flexion (36.3% (SD 22.1%); $p < 0.001$, paired *t*-test), and 80° of flexion combined with 20° of internal rotation (26.0% (SD 22.4%); $p < 0.001$, paired *t*-test) (Figure 5).

We also analyzed the femoroacetabular CP for the different positions. Higher CP were registered when the hip was flexed at 30° and 60°. In the intact joint, statistically significant differences were observed between joint positions F30 versus F80, and F60 versus F80 with lower pressures when the joint was positioned at 80° of flexion (Supplementary Table i). Following cam resection, statistically significant differences were found across different joint positions, with lower CP with the joint at 80° of flexion and 80° of flexion with 20° of internal rotation (Supplementary Table ii).

Contact pressure measurement with the intracranial pressure sensor

With the hip at 30° and 60° of flexion, the CP exceeded the ICP pressure limits, even without any applied axial compression force. Therefore, in these positions, we could not obtain appropriate results because the CP values surpassed the maximum pressure threshold of the device; the measurements with this device had to be limited to the positions F0°, F80°, and F80°/20° IR.

The sensor was introduced between the femoral head and the acetabulum, and the joint was adjusted to the desired position for the measurements. Due to its tubular shape, this sensor rolls, advances, or retracts with the movement of the joint. Maintaining the sensor position for repeated measurements under each condition proved challenging.

The ICP sensor demonstrated considerable fragility, becoming damaged when the joint was mobilized with the sensor in situ under joint loading conditions. Given the damage of several ICP sensors and their substantially high cost, we were compelled to limit this sensor's evaluations to the first five hips.

A statistically significant difference in the normalized CP was found before and after cam osteoplasty with the hip at 80° of flexion (57.6% (SD 29.1%); $p = 0.043$, Wilcoxon signed-rank test). For the joint positions F0° (58.5% (SD 31.6%);

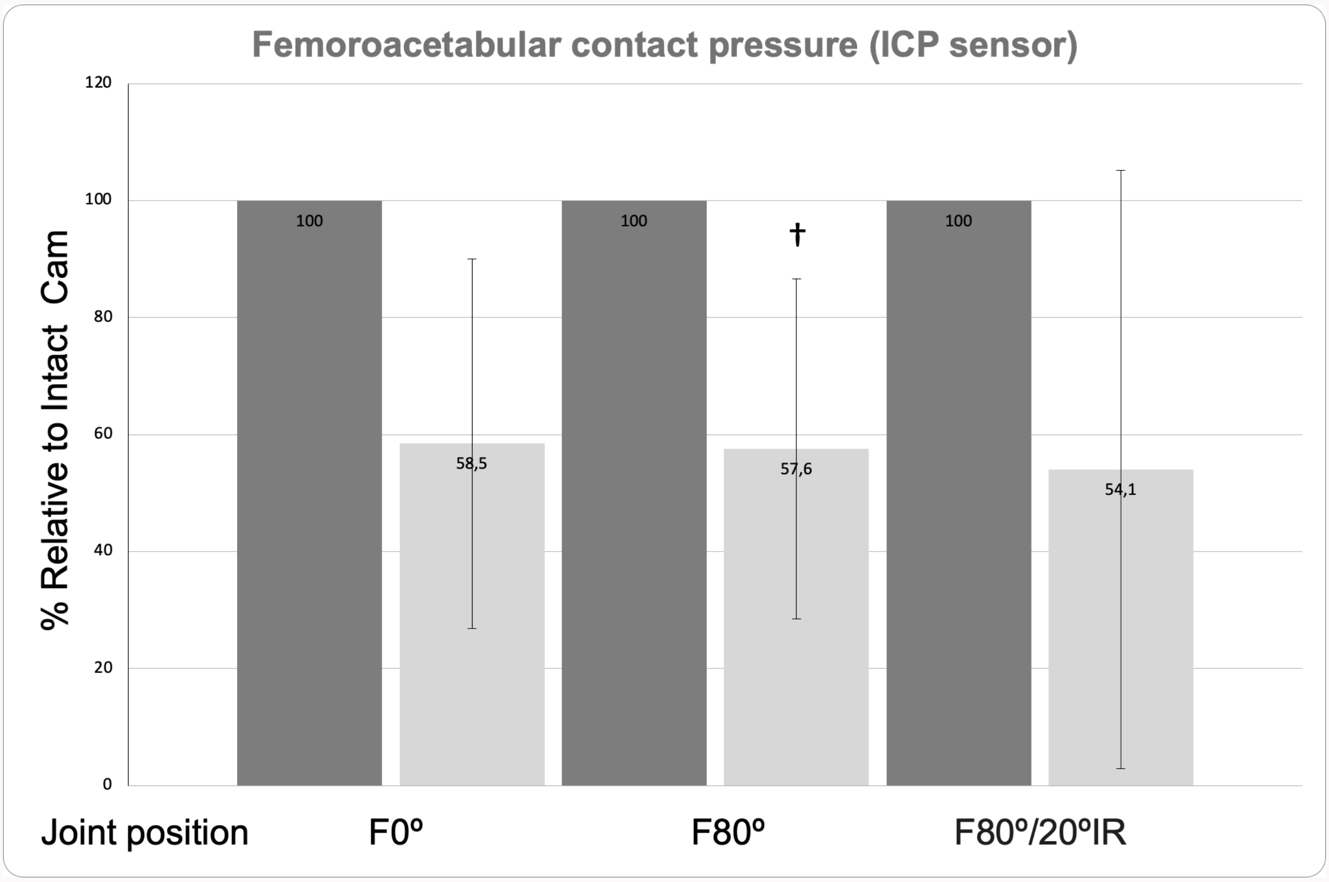

Fig. 6

Normalized femoroacetabular contact pressure measurement with the intracranial pressure (ICP) sensor in the intact cam morphology and after femoral osteoplasty at different joint positions (0º, 80º of flexion, and 80º of flexion combined with 20º of internal rotation). †, Significant difference compared to native cam ($p < 0.05$).

p = 0.245, paired samples *t*-test) and F80°/20° IR (54.1% (SD 51.2%); p = 0.080, Wilcoxon signed-rank test), the differences were not significant (Figure 6).

We also compared the femoroacetabular CP for the different positions, and in the intact joint, no differences in the CP were found between the joint positions (Supplementary Table iii). After cam resection, the CP was superior at 80° of flexion compared to 80° of flexion combined with 20° of internal rotation (Supplementary Table iv).

Discussion

The most notable finding of this study was that the femoroacetabular CP decreased after arthroscopic cam resection in the cadaver. The device, specially designed to measure the femoroacetabular CP in arthroscopic surgery, showed significant differences in the normalized CP after femoral osteoplasty in different joint positions (0°, 30°, 60°, 80° of flexion, and 80° of flexion combined with 20° of internal rotation). Previous cadaveric biomechanical studies on FAIS were conducted using open surgery.[1,12-16] To date, no study has evaluated the effects of cam resection in arthroscopic surgery, which is the primary surgical treatment for FAIS. According to our hypothesis, arthroscopic cam resection decreases the femoroacetabular CP, as measured by the hip-specific device, compared to intact cam morphology throughout the joint positions studied. However, the hypothesis regarding the decrease of CP measured with an ICP sensor was only confirmed when the hip was positioned at 80° of flexion. This finding was based on a smaller sample size.

With the hip joint positioned at 0° and 30° of flexion, a significant decrease in CP was observed following cam resection ($p < 0.05$). The reduction was more pronounced at 60° and 80° of flexion, as well as at 80° of flexion combined with 20° of internal rotation ($p \le 0.001$). At lower degrees of hip flexion, the impact of the cam morphology on CP is less notable. However, with a mean centre-edge angle of Wiberg of 35.2°, the cam morphology could still influence CP at lower degrees of hip flexion. Cam over-resection could potentially explain the decrease of the CP at 0° and 30° of flexion, however this possibility was ruled out through fluoroscopic imaging. Moreover, Bhatia et al[14] reported decreased CP and peak force after acetabular rim trimming with 20° of hip extension.

In cadaver open surgery, Suppauksorn et al[1] found that normalized CP following complete cam resection was lower than the native cam state and partial cam resection. The percentage of CP reduction after complete cam resection at 80° of flexion and 15° of internal rotation was 17.4% with an applied joint load of 700 N. In the present study, in a comparable position, the CP reduced to 26% with no axial load. Suppauksorn et al[1] found no statistically significant difference in the peak force among the three testing conditions (intact, partial, and complete cam resection) with the joint positioned at 80° of flexion and 15° of internal rotation. However, higher peak forces were observed in the partial cam resection than in the complete resection condition. Possible explanations are that although the specific region of interest was similar in the two studies, in our work, we used a sensor with a smaller sensing zone (sensing area: 71.33 mm^2), we did not measure peak forces, and no axial load was applied in the joint positions F80° and F80°/20° IR. These significant differences in joint loading may have a substantial impact on contact biomechanics.

Van Houcke et al[38] evaluated peak cartilage contact stress using discrete element analysis and demonstrated that peak joint stress normalized after adequate arthroscopic cam resection. In the study by Van Houcke et al,[38] it was observed that before cam resection, with the hip positioned at 90° of flexion and subjected to a compression force of 750 N, increasing internal rotation led to an exponential rise in contact stress, particularly in the posteroinferior region and, to a lesser extent, in the anterolateral region of the acetabulum. In contrast, our study found no statistically significant difference in CP at the anterosuperior region of the acetabulum in the native state, whether the joint was positioned at 80° of flexion with 0° or 20° of IR. However, it is important to note that no axial load was applied in this joint position, as doing so would shift the femoral head posteriorly, thereby reducing the anterosuperior femoroacetabular contact.

As joint position influences the femoroacetabular CP, in our study, we analyzed the impact of cam resection in five different joint positions, which compares favourably with previous research in hip biomechanics.[1,7,12-14,16] We found higher CP in the intact joint, and after cam resection with the joint at 30° and 60° of flexion, with an axial compression force of 50 N and even without applying axial load. Bhatia et al[14] observed that with the intact rim (mean LCEA of 35.7°), the peak forces doubled at 60° of flexion (37 N) compared to the 20° extension position (18 N). We found in the intact joint a statistically significant difference in the CP between F30 and F80 and between F60 and F80. However, following cam resection, statistically significant differences were also noted for F0 and F80, as well as F0 and F80/20. This observation suggests that cam resection reduced the CP, impacting the F80 and F80/20 positions to a greater extent.

We also used an ICP sensor (Codman microsensor transducer) to evaluate the femoroacetabular CP, and while a statistically significant difference was found between the intact cam state and after arthroscopic cam resection with the hip at 80° of flexion, no differences were observed for the joint positions F0° and F80°/20° IR. The ICP microsensor was selected as a comparator device because the only study in the literature measuring CP in the arthroscopic treatment of FAIS used an ICP sensor.[35] Kaya[35] used a different ICP sensor for hip contact pressure measurement in hip arthroscopy and stated that the CP of the patients with cam FAIS were elevated in hip flexion, and that cam correction decreased the CP during forceful hip flexion. Unfortunately, no results were provided. We encountered several challenges with the use of the ICP sensor. CP exceeded the ICP sensor limits at 30° and 60° of hip flexion, compromising the evaluations in these joint positions. Additionally, maintaining the sensor position for repeated measurements proved challenging, potentially resulting in inaccurate results with significant variability in repeated readings for the same joint position and condition. Furthermore, the sensor's fragility resulted in damage during use, limiting the measurements with this sensor to five hips.

Correct cam resection improves joint biomechanics;[1,38,39] however, it may also disrupt the labral sealing effect, increase the free intracapsular volume, augment medial-lateral translation of the femoral head, and contribute to microinstability when the hip is at 90° of flexion.[40] In another robotic testing platform study, cam removal increased hip internal rotation at 90° of flexion, reduced torque resistance in flexion and IR, and improved the loading on the chondrolabral junction.[41] In three joints, we observed that following cam resection at F80°/20° IR, femoroacetabular contact was limited, resulting in significantly low CP values.

The embalming technique used in the anatomy department preserves both tissue flexibility and passive joint mobility.[19] Hip arthroscopy performed on specimens treated with this method has demonstrated results comparable to those observed in fresh-frozen cadavers, making it a valuable tool for teaching and training purposes. While embalmed cadavers may exhibit increased soft-tissue stiffness and reduced elasticity – factors that can influence biomechanical behaviour – all biomechanical measurements in this study were compared within the same specimen. Additionally, results were normalized to the intact joint to account for specimen variability.

The initial access to the peripheral compartment technique facilitates the use of the hip device and its introduction into the central compartment to perform the measurements in different joint positions. To accurately compare the femoroacetabular CP before and after cam resection, the measurements should be performed in the exact same location in the anterosuperior acetabulum.[28]

Obtaining a precise arthroscopic cam resection remains a considerable technical challenge, and residual postoperative deformity is one of the most common reasons for revision surgery in FAIS patients.[17,42,43] Cam under-resection is a major cause of persistent pain and symptoms following surgical treatment of the FAIS, and may require additional femoral osteoplasty for correction.[17,42,43] Conversely, cam over-resection can result in the loss of the labral suction seal, joint instability, and an increased risk of fracture, making it challenging to manage.[44,45] The concept of intraoperatively assessing CP offers a promising approach to verify the improvement in joint biomechanics following arthroscopic cam resection, which may help to detect inaccurate resection. The hip device used for CP evaluation demonstrated a significant reduction in CP across different joint positions after the cam resection.

The adequacy of femoral osteoplasty can be assessed intraoperatively through direct arthroscopic visualization, arthroscopic controlled impingement test, and fluoroscopic imaging.[46] However, these techniques have shortcomings, such as the intraoperative impingement test, which can be challenging due to compromised visualization with increasing hip flexion,[46] and the perineal post used in hip arthroscopy, which may restrict terminal hip flexion and internal rotation. Additionally, the fluoroscopic control exposes the surgical team and the patient to additional radiation,[47] and multiple views are required to check the proximal femur morphology.[36]

To the best of the authors' knowledge, there is currently no medical device for measuring hip CP in hip arthroscopy. There are several advantages and innovations presented in this biomechanical study. This is the first cadaver study to assess the femoroacetabular CP intraoperatively during arthroscopic cam resection while maintaining the integrity of the passive soft-tissue constraints (hip capsule and periarticular soft-tissues). Furthermore, a complete body set-up was used instead of a hemipelvis, aiming to replicate the typical scenario of hip arthroscopy for FAIS cam correction.

This study also, however, presents several limitations. The evaluation of CP with the hip device was performed on nine hips, while CP measurement with the ICP sensor was limited to five joints, due to the damage of several sensors. Nevertheless, the sample size in this study is comparable to that of most hip biomechanical studies conducted on cadavers, which typically use five to ten specimens.[1,7,13–16,37,48]

The CP measurements were limited to the anterosuperior acetabulum in all testing conditions, the region most affected by cartilage and labral damage and elevated stress in cam FAIS.[2,4,7] The force-sensitive resistor used in the hip device only allows the evaluation of the joint CP. Pressure-sensitive films can measure the femoroacetabular CP distribution in different areas, and multiplexed pressure sensor mats also allow dynamic CP and CF measurement and the creation of contact pressure maps.[7] However, the size of these two types of sensors precludes their use in arthroscopic surgery.

The cadaver specimens were from elderly donors, potentially having a distinct pattern of joint disease compared to young patients with cam FAIS. We only included specimens with limited joint degeneration (Tönnis 0 and 1). However, the donor information did not specify any hip-related symptoms.

In this study, adequate cam correction relied on arthroscopic imaging and fluoroscopic control, employing multiple views used in most arthroscopic hip surgeries,[49] and a significant decrease in the α angle was achieved.

We did not measure the femoral torsion in our study, and different degrees of torsion can have an impact on the pattern of the impingement. Satpathy et al[48] showed that at 90° of hip flexion, femoral retroversion significantly increased posteroinferior peak pressures. In Meyer et al's study,[37] the joint was tested in the heel strike position. The peak pressure was located in the anterosuperior area, and they did not find any significant change in the average peak contact stresses measured in the different femoral versions (0°, 15°, and 30°).[37] The major difference in the testing conditions, namely hip flexion, may explain the differences in the peak pressure location and the absence of the effect of the femoral torsion on the peak pressure magnitudes.

This study presents a hip-specific device designed to intraoperatively measure the femoroacetabular CP in arthroscopic surgery, providing the surgeon with real-time data to assess biomechanical restoration following cam resection. When an improper decrease of CP is detected, the femoral osteoplasty can be immediately reassessed and adjusted during the procedure. This approach can potentially reduce the incidence of residual postoperative deformity, a common reason for revision surgery in FAIS patients.

The hip-specific device might also be used to evaluate the CP in other conditions, such as in pincer impingement, different labral statuses (intact, tear, repair, and reconstruction), and in assessing diverse labral repair or reconstruction techniques.

In conclusion, this work evaluated the femoroacetabular CP in arthroscopic surgery using a hip-specific device. This device showed a significant decrease in the CP after arthroscopic cam resection in different joint positions. At 80° of flexion with 20° of internal rotation, a typical position to detect hip impingement, the CP was reduced to 26% after cam resection. The ICP sensor used for the femoroacetabular CP evaluation showed a significant difference in the CP after cam resection with the hip at 80° of flexion. It proved very fragile, with a low range of pressures, and we had difficulty maintaining its position as the joint was mobilized.

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Supplementary material

Tables presenting comparative data on femoroacetabular contact pressures across various joint positions, measured with a hip-specific device and an intracranial pressure sensor, in both the intact hip and following arthroscopic cam resection.

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Data sharing

All data generated or analyzed during this study are included in the published article and/or in the supplementary material.

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