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ArtiFacts

ArtiFacts: Femoroacetabular Impingement—A New Pathology?

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From the Column Editor,

In ArtiFacts, *we tend to explore what the material culture in orthopaedics tells us about the evolving practice of orthopaedic medicine. In this month's guest column, we are taking a slightly different tack. Rather than looking at a medical device, we will examine a pathological specimen that challenges a contemporary assumption.*

Using modern methods of examination, Moritz Tannast MD and his clinical research team in collaboration with the Anthropological Institute in Zürich, Switzerland, analyzed the bones of an approximately 5000-year-old specimen and discovered clear macroscopic features of a cam-type femoroacetabular impingement deformity—a condition typically found in high-level athletes of the 20th and 21st centuries.

Indeed, the science in this column is intriguing. But the presentation, which includes a number of images and a supplemental video, truly makes this a fascinating story for the reader.

— Alan Hawk BA

Buried underneath one of the oldest excavation sites in Schweizersbild, Switzerland (Fig. 1A–B), lay the well-preserved skeletal remains of a male subject (Fig. 2) from the Neolithic Age (approximately 10,000 years to 2000 years BCE). Jakob Nüesch, a natural scientist and teacher, first discovered the Neolithic cemetery in the so-called "cave of Schweizersbild" in 1891 [5]. Many of these bones have been studied by anthropologists using classical methods for reasons of scant interest to surgeons [6, 8, 11]. But recent analyses on one skeleton from this dig, which we have performed in collaboration with the Anthropological Institute in Zürich, Switzerland, may answer a timely orthopaedic question: Is femoroacetabular impingement (FAI) a new condition [3, 19, 23]—a product of 20th-century sports and activity demands [13, 20]—or has it always been a part of human skeletal pathomorphology?

A note from the Editor-in-Chief:
I am pleased to present the next installment of ArtiFacts. *In this month's guest column, Moritz Tannast MD and his team examine the skeletal remains of an approximately 5000-year-old man first discovered in one of the oldest excavation sites in Switzerland in 1891.*
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The other authors certify that neither they, nor any members of their immediate families, have any commercial associations (such as consultancies, stock ownership, equity interest, patent/licensing arrangements, etc.) that might pose a conflict of interest in connection with the submitted article.
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Each author certifies that his or her institution approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.

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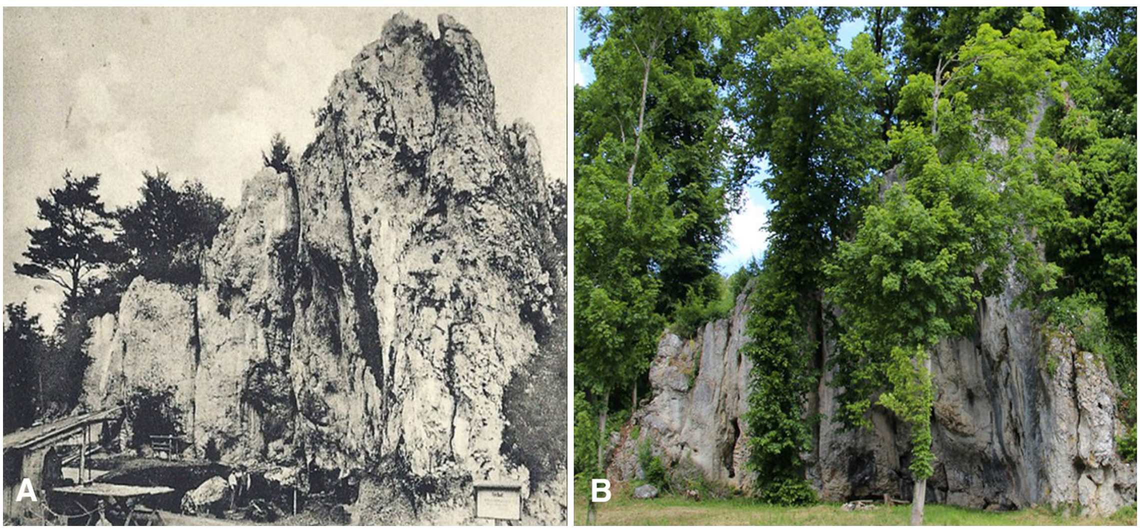

Fig. 1A–B (**A**) The original excavation site at Schweizersbild (Switzerland) is shown around the year 1891. (Published with permission from Kantonsarchäologie Schaffhausen). (**B**) The excavation site is now used as a recreation area. (Published with permission from Moritz Tannast MD.

The skeleton in question—that of a 30- to 50-year-old male, with an estimated height of 169 cm, who lived (according to carbon-14 dating) some 5002 ± 65 years ago [6, 11]—displays clear macroscopic features of a cam-type deformity in his right femur (Fig. 3A–B), a morphology that has been considered by some to be relatively "new" [3, 19, 23]. As a result of such a cam-type deformity, FAI has been attributed to rigorous high-level sports activities [13, 20], which were brought to a professional level in the 20th and 21st century [2]. Although some consider FAI a pathoanatomy attributable to our modern civilized population, this skeleton suggests otherwise.

In order to prove that the cam-type deformity of this old specimen would lead demonstrably to an inclusion-type of cam-FAI, we performed an extensive analysis of this specimen using modern computerized methods that had been developed recently in the field of anthropology [10] and orthopaedic surgery [15, 16, 25] to analyze the skeletal remains that have been available for more than a century. Our approach was to reconstruct a full three-dimensional (3-D) model of the hip, animate the femoroacetabular motion, and correlate the location of impingement zones with macroscopic and radiographic damage.

First, we reconstructed a full 3-D model of the pelvis based on the available fragments with established anthropological methods. Using standard CT, we obtained a 3-D surface model of the fragments with the visualization software AVIZO (version 8.0.1 Standard edition, VSG, USA). The two innominate bones were reconstructed and then reassembled in virtual anatomical space with Generalized Procrustes Analysis (GPA) after

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Fig. 2 The preserved skeletal remains of the male subject are shown. The available skeletal elements include portions of the ilium, ischium, the tibial proximal ends, the femurs, the right humerus, various ribs, and a second right metacarpal.

Fig. 3A–B (**A**) The macroscopic view of the proximal femur shows a typical tongue-type extension of the anterior femoral head-neck junction. (**B**) The axial view reveals an anterior asphericity of the femoral head-neck junction with loss of offset.

setting 31 landmarks and 11 curves. A sacrum from an adult male subject was used as reference during this process. In GPA, a set of landmark configurations is rotated, translated, and scaled in order to minimize the squared deviation between specimens. As a result, a digital 3-D full pelvic model was reconstructed based on the

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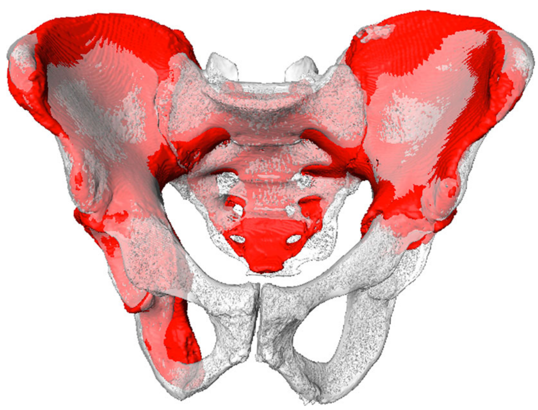

Fig. 4 We reconstructed a full virtual pelvic 3-D model based on the found fragments of the excavation site. The actual surfaces (red—included is the sacrum used as reference during the reconstruction) and the reconstructed pelvis (white) are largely overlapping.

original fragments from the excavation site (Fig. 4). The femur was computed semiautomatically using Amira visualization software (Version 5.4; Visage Imaging Inc, Carlsbad, CA, USA) and repositioned manually by using the linea aspera, and the medial and lateral borders of the bone as references.

The second step consisted of the virtual 3-D motion analysis of the reconstructed model with a previously developed and validated software (HipMotion, University of Bern, Switzerland) [25]. This software uses a sophisticated motion algorithm (the "equidistant method") [16], which

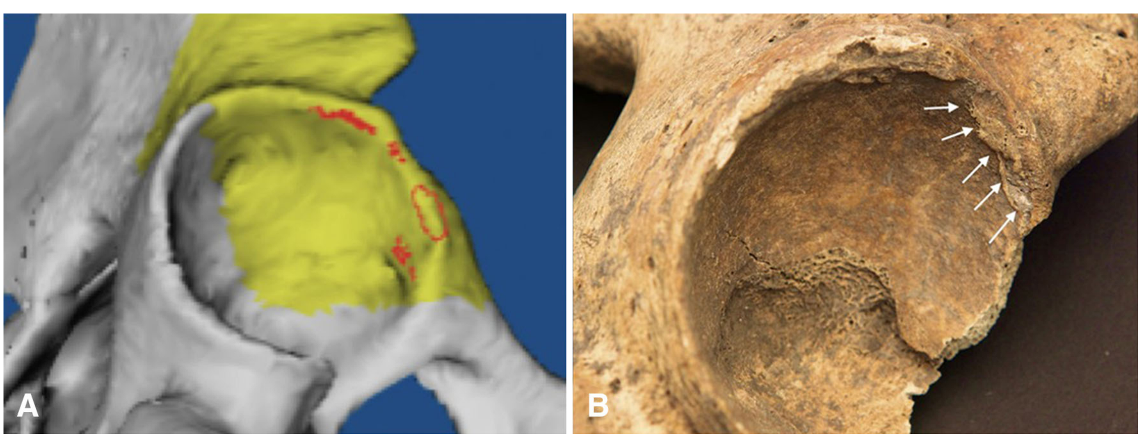

Fig. 5A–B (**A**) The calculated acetabular impingement zones of our virtual three-dimensional simulation are shown. (**B**) The acetabulum clearly shows early degenerative lesions (arrows) in the anterosuperior quadrant corresponding well to the detected impingement zones.

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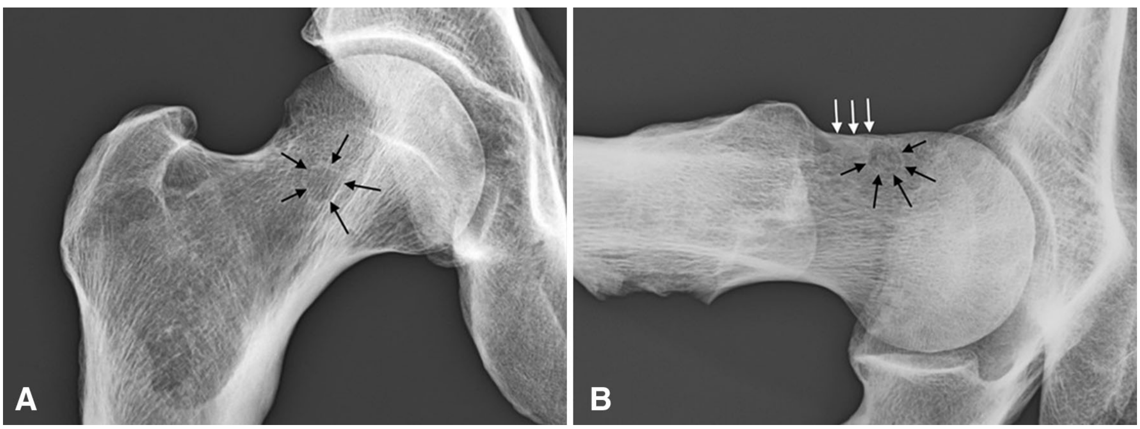

Fig. 6A–B (**A**) The AP radiograph of the hips reveals the presence of a herniation pit (arrows)—a fibrocystic degenerative lesion—at the aspherical portion. (**B**) The cross-table axial radiographs shows the herniation pit (black arrows) at the zone of asphericity and—as typically seen in cam-type FAI—an increase of the subcortical bone density (white arrows).

allows a motion analysis even in cases with surface irregularities [24]. The reference coordinate systems were the anterior pelvic plane (defined by the anterior superior iliac spines and the pubic tubercles [26]) and the femoral axis (defined by the hip and knee center with the femoral condyles as frontal reference [25]). Seventy-eight percent of all anterior acetabular impingement points were located in the anterosuperior quadrant with a maximum between 1 o'clock and 2 o'clock (Fig. 5A). The most frequent location of the femoral impingement zones was anteriorly between the 2 o'clock and 3 o'clock position where the tongue-type extension at the femoral head-neck junction can be found (Video 1; supplemental materials are available with the online version of *CORR*®).

Next, we took macroscopic and radiographic analyses of the degenerative changes of the hip joint. The macroscopic analysis was done according to standard osteoarcheological criteria [7, 18, 27]. On the acetabular side, there were thin layers of new bone formation in the anterosuperior quadrant as a sign of early joint degeneration with osseous proliferations and erosions of the acetabular rim. The location corresponded exactly to the detected impingement zones of the virtual simulation (Fig. 5B). There were no advanced degenerative changes of the acetabulum such as large osteophyte formations. The other available joints for this specimen lack signs of degenerations excluding a systemic process. On the femoral side, there were no macroscopic signs of degeneration. There was no relevant pitting of the articular surface neither of the socket nor the femoral head. The conventional radiographs of the proximal femur show the presence of a cystic lesion at 2:30 on the clock corresponding to the femoral location of impingement and consistent with the "herniation pit" seen classically in FAI (Fig 6A). The axial radiographic

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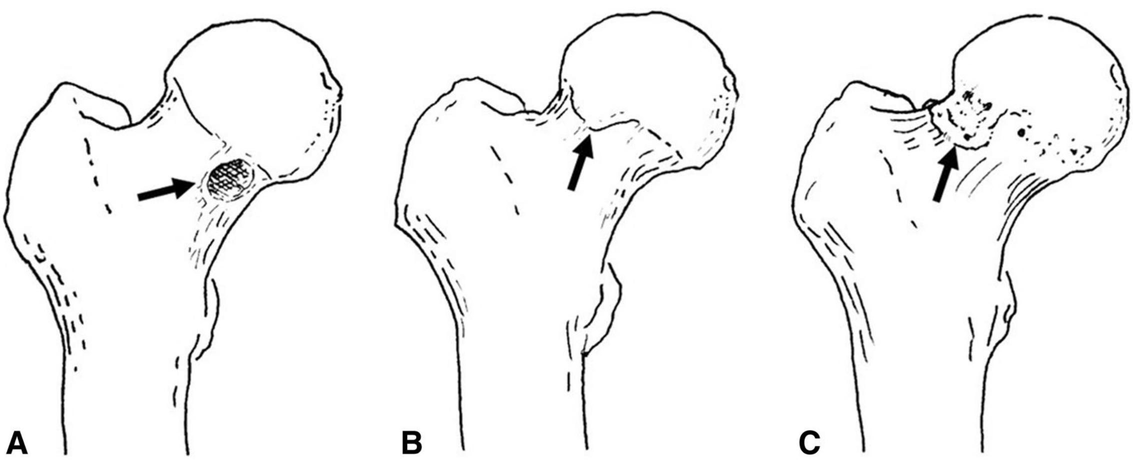

Fig. 7A–C One of the first historical pictorial reports of cam-type defomities and early osteoarthritis signs are shown [4]: Fossa of Allen (**A**), Poirier's Facet (**B**), plaque formation on the anterior femoral head-neck junction (**C**). (Reprinted with permission from University of Massachusetts Department of Anthropology).

view and the reconstructed radial cut from the CT-scan further revealed a zone of clearly increased cortical density (Fig. 6B). This corresponds well to the finding of patients with cam-type FAI and might be the result of an increased subcortical stress from the impingement or an early sign of degeneration [7, 18, 22, 27]. The radial CT-reconstruction at 3 o'clock revealed an epiphyseal angle of 64°, indicating that the source of the cam-type deformity is an extended femoral epiphysis [1]—the most commonly found etiology of cam-deformities in contemporary studies [1, 21].

Our analysis shows that this specimen from the Neolithic period presented with a femoroacetabular-type impingement due to a cam-type deformity as a result of an extended epiphysis. The relationship between activity and osteoarthritis from another osteoarcheological study [12] correspond well to the dynamic concept of osteoarthritis and the activity-related development of cam-type deformities. The presentation of the deformity, the damage pattern, and the intraosseous pathologies are entirely comparable to the present-day reports. FAI, therefore, has existed ever since men invented the wheel (approximately 3500 BCE) or hieroglyphs (approximately 3000 BCE). To the best of our knowledge, the earliest reports on a FAI pathology (Fig. 7A–C) were dated from 1883 (Allen's fossa [9]), 1901 (iliac imprint [17]), and 1911 (Poirier's facet [14]). However, the chronological age of approximately 5000 years of our specimen far predates even these historical reports. It provides evidence that the analysis of older osteological collections to investigate a more recently described pathomechanism is reasonable to consider. The FAI concept is therefore not "new" [3, 19, 23] but rather "recently described."

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