Inducing life-like fractures in cadaveric human specimens – the new fracture simulation machine of the Department of Orthopaedics and Trauma Surgery of the University Hospital of Cologne

Andreas Harbrecht, Jutta Knifka, Nadine Ott, Kilian Wegmann, Lars Peter Müller

Steady advances in the fields of surgical specialty combined with the public's ever-increasing awareness of surgical competence raise the bar for professional education. As in any surgical field, this is also true in orthopaedic trauma surgery. Educating trauma surgeons is complex, consuming time and financial resources, as besides lectures and theoretical items, many manual and practical skills also need to be taught to the future surgeons(1). Yet, it is not only future surgeons who need education, but also surgeons who have already finished their training. All surgeons should frequently inform themselves about newly developed techniques and implants in order to further specialize themselves(2-4). Various concepts to enhance surgical training have been introduced. The most common ones in orthopaedic trauma surgery are artificial bone samples that closely reflect the human anatomy. These samples can be fractured artificially by an osteotomy and fracture pieces are held together by tape. These specimens are not truly realistic, as they lack a soft tissue envelope.

More realistic samples are human cadaveric specimens. These models are often used for training of surgical approaches, rather than osteosynthesis, as no realistic fracture production procedures have yet been discovered. Ligaments, nerves and blood vessels can be dissected but reduction and fixation techniques, which represent the most demanding aspect of trauma surgery are lacking. Specimens with life-like fracture patterns would allow surgeons to have realistic training on these steps.

The fracture machine of the Department of Orthopaedic and Trauma Surgery at the University Hospital of Cologne has been upgraded to induce even more suitable realistic fracture morphologies around all larger joints of the human body. No damping mechanisms that exceed the damping effects of the specimen itself are needed whatsoever.

The portfolio of producible fractures ranges from mandibular fractures involving the lower jaw, midface fractures according to Le Fort II classification, proximal humerus fractures, finger fractures to the acetabular, femoral neck, pilon fractures and many more. The fracture production technique for complex intra-articular distal radius fractures has recently been published by our group(5).

The latest additions to the portfolio consist of realistic multi-fragmentary lower jaw head fractures and high-energy midface trauma (Fig. 1). These fracture morphologies form the basis of CMF trauma courses. The portfolio has also been expanded around the hip. As femoral neck and pertrochanteric fractures are among the most common fractures and society is aging, leading to an increased incidence of osteoporotic fractures, the realistic practice of such fracture-specific fixation techniques in a safe, non-harming environment is crucial to improve post-operative outcomes of subsequent real patients(6-8).

Proximal femur fractures can be achieved in our machine by introducing the axial force via the erected and adducted femur between 10 and 20 degrees. 10° adduction leads to a pertrochanteric fracture and 20° adduction to a femoral neck fracture. The specimens were cut with an industrial saw at midshaft level of the femur on both sides and an additional cut was performed at the level of lumbar vertebra body 3 in order to fit into the machine. Acetabular fractures are certainly among the most difficult fractures of the human body to operate on, combined with a high approach-related morbidity(9). With the new generation of our fracture machine, we have succeeded in producing realistic acetabular fractures (Fig. 2)(10).

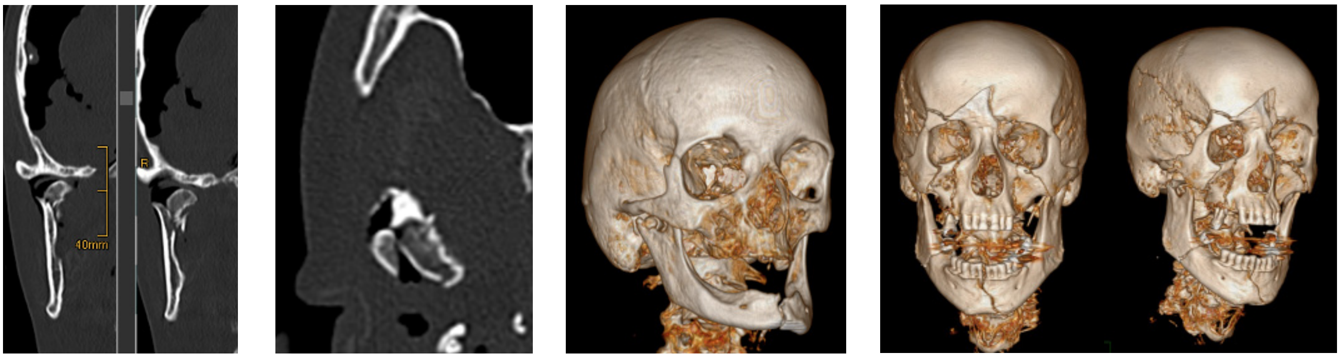
The contemporary mechanism of fracture production is performed by a falling test bench, which is displayed in Fig. 3. We use a drop weight that is guided by two bars. The drop weight hits with the desired kinetic energy onto an impactor that is guided into two holes in a crossbeam. The impactor therewith is driven into the specimen that is – depending on the anatomical region – fixed in specific positions below the impactor. The impact leads to a shortening or compression of the specimen. Dampers are not used. The amount of shortening of the specimen is only limited by the amount of applied energy itself.

The current mechanism allows for a shortening of 121 mm. All fractures can be induced in formalin-fixed specimens or, even more realistically, in fresh-frozen specimens. Cadaveric models remain the benchmark in realistic surgical training before operating on living patients.

As technical improvements are frequently being introduced to the market and sub-specialization becomes more and more necessary to guarantee an up-to-date treatment, every surgeon needs to continuously train on demanding and realistic exercise models. Surgical courses on cadaveric specimens are therefore the ideal course system to provide a significant amount of realistic teaching.

All new fracture morphologies created by the new generation of our fracture machine have been or are planned to be implemented in trauma surgery courses. The evaluation of such courses, as recently published by our group, profoundly enhances surgical training[11].

Fig. 1:



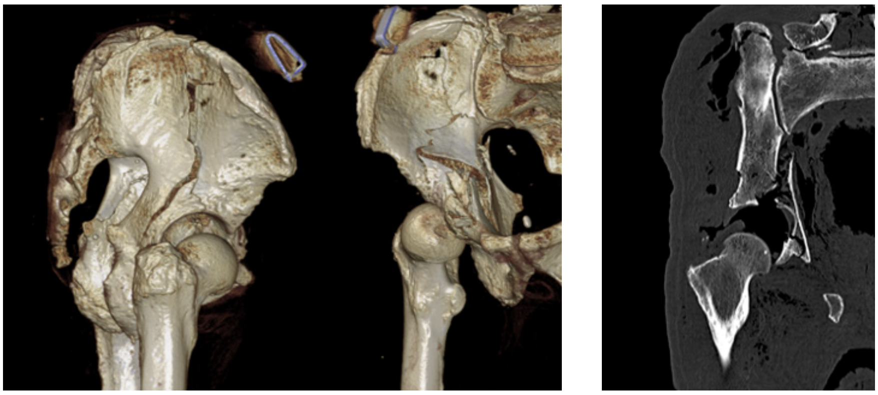
a) CT-scan coronary plane of a multifragmentary lower jaw head fracture

b) Axial plane of the afore-mentioned fracture

c) 3D reconstruction with medial lower jaw fracture and multifragmentary lower jaw head fracture, right

d) 3D reconstruction of a multifragmentary midface trauma Le Fort II and multifragmentary lower jaw fracture

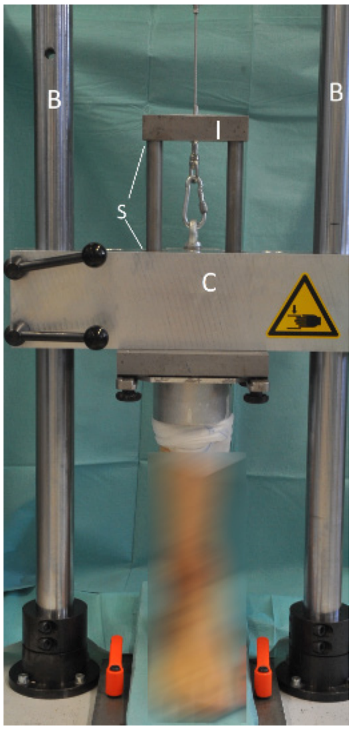
Fig. 2:



a) 3D reconstruction of a multifragmentary acetabular fracture on the right side of the specimen with involvement of both columns according to Letournel

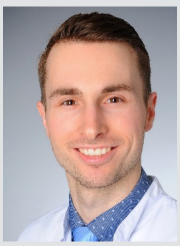
b) Coronary reconstruction of the aforementioned fracture in the center of the acetabulum

Fig. 3:



New generation fracture machine with a fixed lower leg for pilon fracture simulation; B = guiding beams, I = impactor, C = crossbeam, S = maximum of potential shortening = 121mm

ABOUT THE AUTHOR



Andreas Harbrecht
Main focus: Trauma, hand and elbow surgery at University of Cologne
Kerpener Str. 62
50937 Cologne
Germany

REFERENCES

1. *Pellegrini CA.*
Surgical education in the United States: navigating the white waters.
Ann Surg. 2006;244(3):335-42.

2. *Darzi SA, Munz Y.*
The impact of minimally invasive surgical techniques.
Annu Rev Med. 2004;55:223-37.

3. *Depres-Tremblay G, Chevrier A, Snow M, Hurtig MB, Rodeo S, Buschmann MD.*
Rotator cuff repair: a review of surgical techniques, animal models, and new technologies under development.
J Shoulder Elbow Surg. 2016;25(12):2078-85.

4. *Pennington DG.*
The impact of new technology on cardiothoracic surgical practice.
Ann Thorac Surg. 2006;81(1):10-8.

5. *Wegmann K, Harbrecht A, Hackl M, Uschok S, Leschinger T, Muller LP.*
Inducing life-like distal radius fractures in human cadaveric specimens: a tool for enhanced surgical training.
Arch Orthop Trauma Surg. 2019.

6. *Icks A, Arend W, Becker C, Rapp K, Jungbluth P, Haastert B.*
Incidence of hip fractures in Germany, 1995-2010.
Arch Osteoporos. 2013;8:140.

7. *Grisso JA, Kelsey JL, Strom BL, Chiu GY, Maislin G, O'Brien LA, et al.*
Risk factors for falls as a cause of hip fracture in women. The Northeast Hip Fracture Study Group.
N Engl J Med. 1991;324(19):1326-31.

8. *Ju DG, Rajaee SS, Mirocha J, Lin CA, Moon CN.*
Nationwide Analysis of Femoral Neck Fractures in Elderly Patients A Receding Tide.
Journal of Bone and Joint Surgery-American Volume. 2017;99(22):1932-40.

9. *Stockle U, Hoffmann R, Sudkamp NP, Reindl R, Haas NP.*
Treatment of complex acetabular fractures through a modified extended iliofemoral approach.
Journal of Orthopaedic Trauma. 2002;16(4):220-30.

10. *Judet R, Judet J, Letournel E.*
Fractures of the Acetabulum: Classification and Surgical Approaches for Open Reduction. Preliminary Report.
J Bone Joint Surg Am. 1964;46:1615-46.

11. *Wegmann K, Rausch V, Burkhart KJ, Hackl M, Leschinger T, Muller L.*
Advanced Surgical Trauma Care Course - Evaluation of a Fracture Simulation Course Concept with Intact Soft Tissue.
Z Orthop Unfall. 2019.

IBRA TRAINING CENTERS WORLDWIDE

THE WORLDWIDE NETWORK OF IBRA TRAINING CENTERS, WHICH SPECIALIZE IN BONE RESEARCH AND HEAD AND UPPER / LOWER LIMBS SURGERY

Upper Limbs

Argentina
Hospital Italiano, Buenos Aires
CLIMBA, Buenos Aires

Australia
John Hunter Hospital, Newcastle
Dandenong Hospital, Melbourne

Austria
Unfallkrankenhaus Wien Lorenz Böhler

Brazil
INTO Instituto Nacional de Traumatologia e Ortopedia, Rio de Janeiro
Beneficencia Portuguesa Hospital, São Paulo
Faculty of Medicine of the University of São Paulo
Albert Einstein Israelite Hospital, São Paulo

Chile
Clínica Santa María, Santiago

Colombia
Medellín Health Centers, Medellín

Germany
Elisabeth Hospital Ravensburg
Universitätsklinikum Köln
University of Würzburg

Italy
Policlinico of Modena
GB Rossi University Hospital, University of Verona
Galeazzi Orthopaedic Institute - Hand Surgery Unit, Milan

Netherlands
Maastricht University Medical Center

South Korea
Seoul National University Bundang Hospital
Korea University Anam Hospital

Spain
Centro Médico Teknon, Barcelona

Switzerland
Kantonsspital of St. Gallen

United Kingdom
Wrightington Hospital
Guy's and St Thomas' NHS Foundation Trust, London

USA
Badia Hand to Shoulder Center, Miami
Banner Good Samaritan Medical Center, Phoenix

Lower Limbs

Australia
John Hunter Hospital, Newcastle

Brazil
Paulista School of Medicine – Federal University of São Paulo
Albert Einstein Israelite Hospital, São Paulo

Germany
Hanover Medical School at Diakovere Annastift, Hanover

Spain
University Hospital of the Canary Islands

Switzerland
Swiss Ortho Center, Basel
Kantonsspital Winterthur

Head

Austria
Academic Teaching Hospital Feldkirch

Brazil
São Paulo State University
Hospital Samaritano, Higienópolis, São Paulo

France
University of Picardy Jules Verne, Amiens
University of Lille

Germany
University of Münster
University Hospital of Giessen and Marburg

Italy
Sapienza University of Rome

Switzerland
University Hospital of Bern (Inselspital)

United Kingdom
Sheffield Teaching Hospitals

For detailed information please visit our website.

→ www.ibra.net