



White paper

Intraoperative 3D imaging in orthopedic trauma surgery

Ready for routine care

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Intraoperative 3D imaging enhances patient outcomes and safety in trauma surgery

There are instances in trauma surgery, when conventional 2D imaging provides insufficient information and the best possible result cannot be reached. Because depending on the type and location of a fracture, it can be tricky to assess whether a screw or wire is positioned correctly.

Limitations of conventional 2D imaging

In joints with complex geometries, it can sometimes be difficult for surgeons to identify remaining steps and gaps on the joint surface based on 2D imaging alone. A postoperatively acquired 3D scan is required to see if implants are optimally positioned or not. This means that postoperative revision surgery might be necessary in at least some of the patients.

Improving outcomes with intraoperative 3D imaging

Intraoperative 3D imaging has long been advocated as a means to improve surgical outcomes, increase patient safety, and reduce postoperative revision surgeries in orthopedic traumatology. Despite its well-documented benefits, however, there are still surgeons who refrain from using it for various reasons – which span from individual experience to image quality, usability, and radiation exposure.

This white paper covers the benefits of 3D intraoperative imaging in trauma surgery with Cios Spin®. It is based on the vast experience of Jochen Franke, MD, Head of Acute Traumatology at BG Klinik Ludwigshafen and his team.

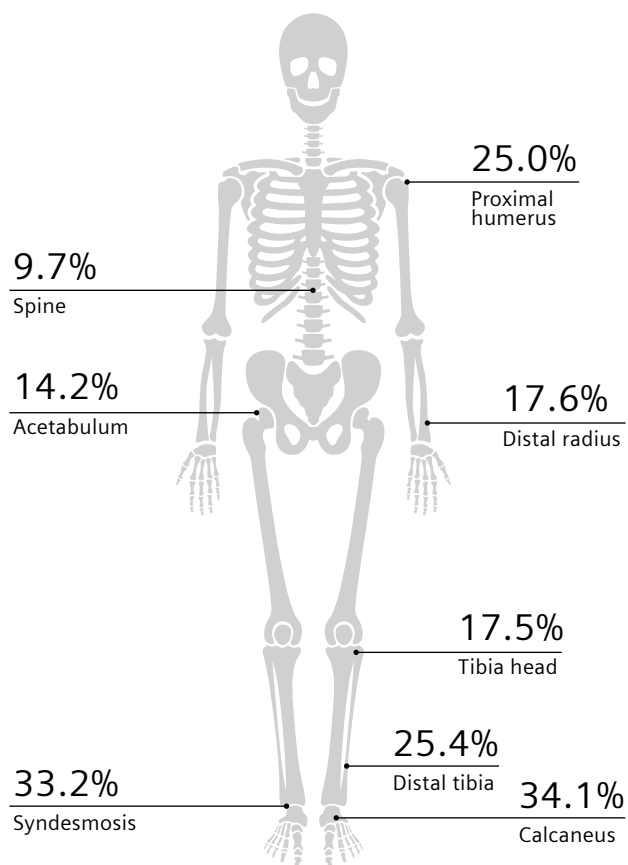


The 2D image gives the impression that the screw is correctly placed. The 3D scan with Cios Spin reveals the tip of the screw is in the joint (anatomical specimen).

Making a difference

Intraoperative 3D imaging has proved to be beneficial for patients. By applying 3D technology, it could be shown that an average of 20% of the cases that would normally have left the OR needed an intraoperative correction.¹⁾

In calcaneal fractures, unstable syndesmotic injuries, tibial head fractures, and distal radius fractures type C, revision rates are even considerably higher. Thanks to intraoperative 3D imaging, these cases could be corrected right away in the OR – without the need for a second operation.



Average intraoperative correction rate after an intraoperative 3D scan across various fracture locations



“Calcaneal fractures, ankle fracture with syndesmosis instability, tibial plateau fractures, and acetabular fractures are difficult to assess in 2D. In these patients, we use 3D as a matter of routine. We also choose 3D in complicated fractures at other locations, and in cases in which we are not convinced that a screw is really placed outside of the joint.”

Jochen Franke, MD, BG Klinik Ludwigshafen

¹⁾ Von Recum J et al., Traumatic fractures at various locations, Unfallchirurg 2012; 115:196-201

Intraoperative 3D imaging helps reduce postoperative revision surgeries

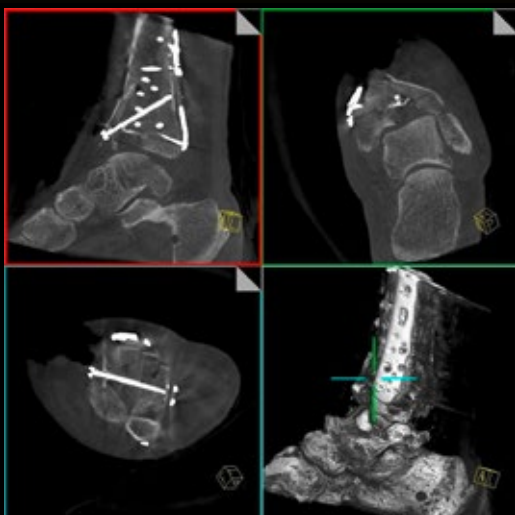
To assess the results of a surgery as quickly and reliably as possible, excellent image quality is of utmost importance. Due to the limitations of intraoperative 2D imaging in assessing the placement of an implant, screw, or a fracture reduction, a postoperative CT is typically required. By then it's too late for intra-operative corrections and patients would need to undergo a new anesthesia and surgery – with the risk of wound infection, longer hospital stay, etc.

High resolution with Retina 3D scan technology

With its Retina 3D scan technology, Cios Spin takes the 3D image quality provided by mobile C-arms to a level that matches conventional Computed Tomography. Retina 3D scan technology takes up to 400 images in 30 seconds, resulting in a maximum spatial resolution of 0.3 mm. This allows to confidently check the reduction of small bone fractures and to evaluate the correct placement of screws and implants independent of location directly in the OR.

Metal artifact reduction

Imaging patients with metal implants is always challenging. To improve image quality, Cios Spin features a metal artifact reduction algorithm (MAR) that can be selected as needed and that helps to increase therapeutic confidence in patients in which tiny anatomic details need to be visualized that are close to metallic objects. This can be especially useful in patients with metal implants very close to the joint surface.



CT-like 3D imaging of small bone fragments



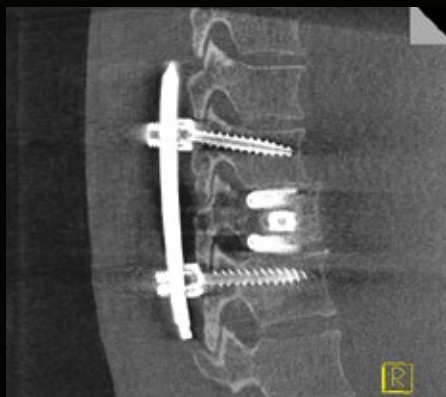
Clear intraoperative 3D images without metal artifacts

Powerful imaging for obese patients

A group of patients for whom image quality in intraoperative 3D imaging has traditionally been a big challenge is obese patients – especially in areas with dense tissue like the pelvis or lumbar spine. Cios Spin offers the power and tube current needed to deliver clear images. The C-arm also offers a dedicated program for obese patients that can be selected as needed.

“In obese patients, Cios Spin allows us to see details that we would not have seen before. Such details can provide treatment-critical information in some patients.”

Jochen Franke, MD, BG Klinik Ludwigshafen



Excellent visibility of details in obese patients

Case report:

Metal artifact reduction in a male patient with complex tibia head fracture

In a patient with a complex tibia head fracture, the bone fragments were repositioned using a metal plate and several screws. In addition, metal wire implants were necessary to keep a small fragment in place that could not be reached by a screw.



“To keep this fragment in place was important, because the meniscus would have degenerated quickly if we had left a step on the joint surface at this position,” says Jochen Franke, MD, of BG Klinik Ludwigshafen.

“The problem was that the wires had to be very close to the joint surface in order to be effective, but due to the metal artifacts on the 3D images, we were not really sure whether we succeeded to keep them below the bone cortex, outside of the joint.” The metal artifact reduction provided by the Cios Spin gave an immediate and definite answer: The wires were indeed below the bone cortex, and thus surgery could be completed successfully.



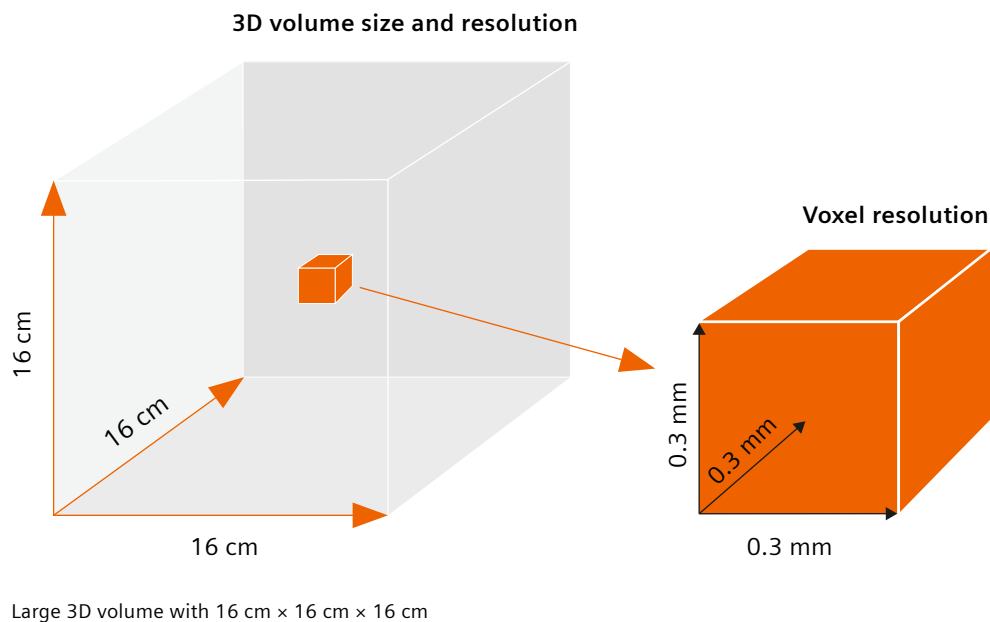
Seeing the entire picture

Especially when operating on the lumbar spine, it's essential that surgeons see as much as possible. Cios Spin offers surgeons an outstandingly large field of view: It's even possible to display all seven cervical vertebrae, including the beginning of the thoracic spine.

Large anatomical coverage

Cios Spin shows surgeons a large volume of the anatomical area that is covered by 3D – with a field of view of 16 cm × 16 cm × 16 cm. Compared with the predecessor system with 12 cm × 12 cm × 12 cm field of view, this is more than twice as much in terms of volume.

Generally, the 3D volume covered by conventional systems is big enough for calcaneal and many other types of fractures. But it can be suboptimal in areas with larger bones, most notably in patients with pelvic or spinal fractures. Especially for these cases, Cios Spin provides a large 3D volume.



"Another example is patients with fractures of the iliosacral joint on both sides. Even in a tall male patient, I can now display both sacroiliac joints in one plane of the 3D scan."

Jochen Franke, MD, BG Klinik Ludwigshafen



The entire iliosacral screw is visible in the 3D scan



The entire cervical spine is visible in the 3D scan

Developed with the needs of the surgeon in mind

With Cios Spin, the high level of accuracy does not result in longer procedure times. On the contrary, standard scanning time is as low as 30 seconds, regardless of the scan protocol, whether 100, 200, or 400 projections are chosen.

Fast intraoperative 3D imaging for daily routine

Even though trauma surgeons know about the potential benefits of intraoperative 3D imaging, some refrain from using it. Deficits in usability of non-isocentric intraoperative 3D imaging are among the reasons. For example, some trauma surgeons feel that preparing a 3D scan can be quite cumbersome. The concern of surgeons that the mobile C-arm collides with the patient or the surgical instruments surrounding the OR table due to space restrictions may also lead to low or no use of 3D scanning in daily routine. In some surgical procedures such as spine surgery, for example, the limited space between radiation source and detector in conventional 3D systems limits flexibility because the C-arm has to be right at the table more or less all the time.

“When we do fluoroscopy to identify the entry point for an implant or to place that implant in spine surgery patients, it is absolutely critical to have enough space to avoid collisions with the detector or even to become non-sterile.”

Jochen Franke, MD, BG Klinik Ludwigshafen



94 cm free space and predictable iso-centric 3D – advantage Cios Spin

With 94 cm, Cios Spin offers a considerably large distance between tube and detector compared to conventional systems. It provides trauma surgeons with the space they need. To implant a screw in a patient with sacroiliac joint fractures, for example, a bone drill under fluoroscopy is necessary to properly position the guidewire. For this, the surgeon needs as much space and freedom of movement as possible.

For these and other delicate situations where an implantation has to succeed on the very first attempt, intraoperative 3D imaging with Cios Spin offers the required precision and space that can help introduce intraoperative 3D imaging into daily routine.

In addition, the system's iso-centric approach of the 3D scan around the patient makes handling the process much easier: With the help of orthogonal laser points, the anatomy of interest can be placed in the center of the 3D scan – making the collision check quick, easy, and predictable.

“With Cios Spin [...] it becomes far easier to place implants in many situations. This is not only a matter of convenience, but also a matter of quality of care. Having more space for the surgeon increases patient safety.”

Jochen Franke, MD, BG Klinik Ludwigshafen



3D images in three planes immediately available in the OR after the 30 sec scan.



94 cm (36.9") open space – Cios Spin offers surgeons plenty of room.

The surgeon's little digital helper

Even in today's digitalized era, surgery remains a manual art. Software, however, can be used to facilitate parts of the craft. In fact, sophisticated post-processing tools can benefit both the surgeon and the patient.

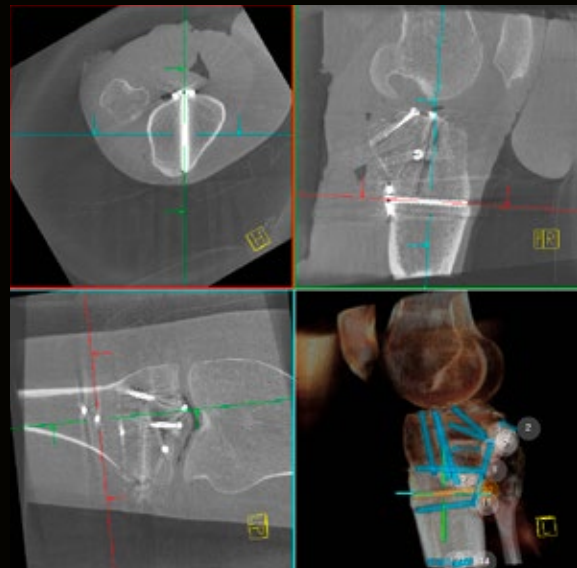


"Preparing the three relevant projections for four screws manually takes about several minutes or a little less. With the software application, this is a matter of seconds. Screw Scout helps me to save time, and it also increases patient safety because it reduces time of surgery."

Jochen Franke, MD, BG Klinik Ludwigshafen

Screw Scout

Screw Scout makes surgery more efficient and thus shorter: The algorithm automatically detects screws and presents them in the three relevant projections that are needed to assess correct positioning in a matter of seconds.





"In patients with femoral neck fracture, the k-wire has to be targeted under fluoroscopy right at the middle of the femur head. This means that the surgeon has to put the wire laterally on the bone and target a goal about 10 cm away. TargetPointer extends my instrument virtually, so that I can see exactly where I am zeroing in on."

Jochen Franke, MD, BG Klinik Ludwigshafen

Target Pointer

Another software tool that can help improve surgical accuracy is TargetPointer. The auxiliary tool displays an overlap trajectory in 2D projections. In other words: It shows a virtual extension of linear metal objects like k-wires, so that surgeons can see the location they're zeroing in on.



The patient's perspective

Medicine is for the patient, and so is surgery. So what exactly is the patient's perspective on 3D intraoperative imaging with Cios Spin?

High-quality surgical care

Depending on the location of a fracture, in about 20–40% of the cases in orthopedic traumatology findings can be detected with 3D, which would otherwise be missed with 2D.¹⁾ With intraoperative 3D imaging, findings can be corrected right away.

Without the use of intraoperative 3D imaging, many of these patients would need a second surgery to correct the misplacement – especially patients with intraarticular implant misplacement.

In some patients, implant misplacement can be seen later on the postoperative CT scans. In others, it will only become obvious weeks later, once the patient starts putting strain on the joint again. In both cases, a second surgical intervention may be necessary – which always has the additional risk of an infection and the building of scar tissue. And it also means a second hospital stay for the patient. However, not all patients with suboptimal surgical results would be offered a second intervention. In patients with remaining steps or gaps on the joint surface in a post-operative CT, for example, the surgeon would have to weigh the potential benefits of a postoperative revision with the risks of a second surgical intervention.

With intraoperative 3D imaging, this kind of trade-off is no longer necessary. Because if an implant misplacement is detected and corrected during the initial operation, there's no need for a second anesthesia and surgery.

“Revision surgery is a problem not only because the patient needs another hospital stay, but also because complication rates in revision surgeries are higher than in the initial surgery. Screw or implant misplacement might also have caused damage to the cartilage that is usually irreversible.”

Jochen Franke, MD, BG Klinik Ludwigshafen



Distal tibia, one of the anatomical regions where intraoperative 3D imaging helps avoid a revision surgery



“The big advantage of intraoperative 3D imaging is that I don’t have to balance the benefits of revision against the risks of a second intervention. It is a matter of fact that reducing a remaining step or gap can improve clinical outcome. But in many cases, surgeons would not go for a second surgery nevertheless. Intraoperative 3D imaging makes the decision far easier, and many patients will benefit. For me, this is a matter of personal quality standards.”

Jochen Franke, MD, BG Klinik Ludwigshafen

Case report: A 24-year old female patient with calcaneal fracture

The young woman suffered a complicated calcaneal fracture after jumping from a high place. A screw was inserted in order to hold a fragment in place that was part of the proximal joint surface. “We were convinced that this screw was well placed. Only thanks to the routine 3D imaging at the end of the procedure did we realize that the screw protruded 3 mm into the joint,” says Jochen Franke, MD, of BG Klinik Ludwigshafen. The screw was removed and replaced by another one

that was 5 mm shorter. “If we had not recognized this, it would certainly have caused severe pain, because the screw was on the proximal joint surface, an area with axial strain when standing or walking.”

Increased radiation exposure?

While it is true that intraoperative 3D imaging means additional radiation upfront, it is worth taking a closer look if this really equals increased overall dose for patients.

One of the reasons that are occasionally brought forward against intraoperative 3D imaging is that it increases radiation exposure of the patient. In many cases, however, it can make postoperative CT scans unnecessary.

"In the past, to assess fracture reposition and implant placement, we used intraoperative 3D imaging instead of postoperative CT imaging mostly in patients with fractures of the extremities, but not for hip and pelvic fractures. With Cios Spin, the image quality is so good that we can do without postoperative CT even in patients with pelvic and spine surgery. We turn to postoperative CT only in very special situations, for example to clarify whether there are small bone fragments within the joint in young patients."

Jochen Franke, MD, BG Klinik Ludwigshafen



The healthcare provider's perspective

What about costs? An investment into 3D imaging equipment is not exclusively an investment into better quality of care.

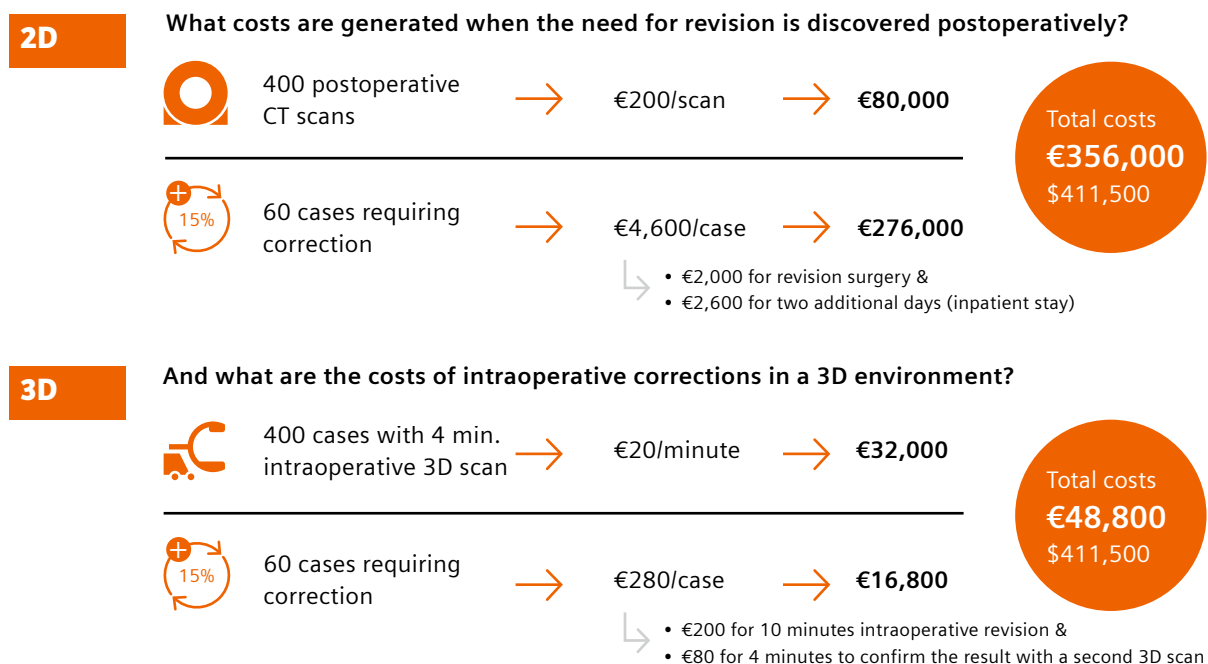
Less revision surgeries, lower costs

Intraoperative 3D imaging is also an investment that can help a hospital save money. In a large cohort study with 377 patients with calcaneal fractures, for example, the intraoperative revision rate amounted to approximately 40%.¹⁾ About half of these revisions were due to screw misplacement. In these patients, a postoperative revision would have been mandatory – resulting in additional costs for the hospital provider.

In an early cost-benefit analysis, surgeons of the Medizinische Hochschule Hannover (Medical University of Hannover) calculated how the reduction of postoperative revision surgeries translates into monetary

savings. The average cost of a postoperative revision surgery was € 2,383 at the time.²⁾ This means that – depending on the number of surgeries and the revision rate in the individual hospital – only a relatively low number of avoided postoperative revision surgeries per year is necessary to achieve return-on-investment. This is especially true when considering that a 2D C-arm needs to be purchased for trauma surgery anyway, so that return-on-investment should legitimately be calculated not on the total investment but on the difference between the prices of a 2D and a 3D system.

Business case sample calculation



Investment costs, revision rates, case mix and amount of procedures are exemplary and for illustration of the cost scheme. Data may vary for specific clinical settings and due to regional reimbursements schemes.

¹⁾ Franke et al, Calcaneal fractures, Bone Joint Surg Am 2014; 96:e72(1-7)2014

²⁾ Hüfner T et al. Unfallchirurg 2007; 110:14-21

Acute Traumatology at BG Klinik Ludwigshafen

BG Klinik Ludwigshafen is a large emergency care hospital that is part of BG Kliniken – Klinikverbund der gesetzlichen Unfallversicherung GmbH, a hospital group that belongs to the statutory accident insurance providers in Germany.





A hospital with a team of specialists

At the BG Klinik Ludwigshafen in Rhineland-Palatinate, Germany, intraoperative 3D imaging in trauma care has been used for almost 20 years. The hospital has recently expanded its mobile C-arm fleet with the Siemens Healthineers Cios Spin.

The BG Klinik Ludwigshafen has two main departments, one of which is the Department of Traumatology and Orthopaedics with 51 surgeons and 10 operating rooms in total. The department consists of six sections, among them Acute Traumatology.

Jochen Franke, MD, is Head of Acute Traumatology and has compiled one of the biggest intraoperative 3D imaging patient databases worldwide with more than 7,000 surgical interventions. In 2017 alone, Jochen Franke and his team – another two senior surgeons and six junior surgeons – performed trauma surgeries on 2,700 patients. They have ample experience with different mobile C-arm systems.

Jochen Franke specializes in complex joint surgery and injuries of the hip and pelvis, the wrist joint, the ankle joint and the foot, the elbow, knee, and the shoulder. He has been using 3D intraoperative mobile C-arm imaging since 2001. In many types of surgery, 3D has become part of the hospital's standard operating procedures.

Tables and literature overviews

Table 1: Intraoperative revision rates when 3D imaging is applied

	Publication	Study Characteristics	Key Results
Intraarticular fractures at various locations	Atesok K et al. Injury 2007; 38(10):1163-9	Intraoperative 3D evaluation of a series of 72 fractures (calcaneus, tibial plateau, tibial plafond, acetabulum, distal radius, ankle Weber-C, femoral head) in 70 patients.	Intraoperative revision in 11% of fractures, with a mean additional operative time of 7.5 minutes.
Traumatic fractures at various locations	Von Recum J et al. Unfallchirurg 2012; 115:196-201	Retrospective analysis of a prospective cohort with 1841 intraoperative control-scans following osteosynthesis.	Improvement of reduction or implant placement intraoperatively in 21.5% of patients (calcaneus 40.3%, upper ankle joint 20.9%, distal tibia 29%)
Intraarticular fractures at various locations	Kendoff D et al. J Trauma 2009; 66:232-8	Prospective cohort study with 248 consecutive patients with intraarticular fractures.	Immediate adjustment of reduction or hardware exchange in 19% of patients.
Acute unstable syndesmotic injuries	Franke J et al. J Bone Joint Surg Am 2012; 94:1386-90	Retrospective analysis of a prospective cohort of 251 consecutive patients with intraoperative 3D imaging who underwent syndesmosis stabilisation based on an intraoperative hook test.	Intraoperative 3D scan altered surgical outcome in 32.7% of patients. In 30.7% of patients, the reduction of syndesmosis instability could be improved, mostly by a better alignment of the fibula in the tibiofibular incisura.
Calcaneal fractures	Franke J et al. J Bone Joint Surg Am 2014; 96:e72(1-7)	Retrospective analysis of a prospective cohort of 377 consecutive patients with calcaneal fractures and intraoperative 3D imaging.	Intraoperative revision rate was 40.3%. An additional fracture reduction was performed in 19.6%. Based on the AOFAS score, postoperative joint surface congruence had a significant impact on clinical outcome in multivariate analysis.
Calcaneal fractures	Geerling J et al. J Trauma 2009; 66:768-73	Intraoperative imaging in 32 patients over a 2-year period.	Intraoperative improvement of reduction or screw placement in 41% of patients.

Elbow fractures	Schnetzke M et al. BMC Medical Imaging 2016; 16:24	Retrospective analysis of a prospective cohort of 36 patients with elbow surgery and intraoperative 3D imaging.	Immediate revision in 16.7% of patients due to detection of intra-articular screw placement (8.3%) or remaining intra-articular step of > 2 mm (8.3%).
	Publication	Study Characteristics	Key Results
Distal radius fractures	Schnetzke M et al. Arch Orthop Trauma Surg 2018; 138(4):487-93	Retrospective analysis of 307 out of 4515 patients with distal radius fractures who received intraoperative 3D scans, 85.7% of which had distal radius fracture type C.	Intraoperative 3D imaging revealed findings in 40.7% of patients that were not detected in 2D fluoroscopy, leading to an immediate revision in 17.6% of patients, most commonly reduction of the remaining steps (8.1%) and intraarticular screw placement (7.5%).
Tibial plafond fractures	Vetter SY et al. Foot Ankle Int 2016; 37(9):977-82	Retrospective analysis of 143 patients with intraarticular tibial plafond fracture	Intraoperative correction after 3D scan in 30% of patients, 24% of which were due to inadequate joint line reduction and 6% due to malposition of the implant.

Table 2: TargetPointer tool for 2D guidance

Publication	Study Characteristics	Key Results
Swartman B et al. Foot & Ankle International 2018; 39(4):485-92	Study in 20 cadaver foot specimen. 2D projection-based K-wire placement in sustentaculum tali by an experienced and an non-experiences surgeon with/without software assistance.	Number of placement attempts reduced from 3.2 to 1.2 (p=0,006) in inexperienced surgeons.
Swartman B et al. Injury 2017; 48:2068-73	Study with a proximal femur bone model in 20 artificial bones. 2D projection based K-wire placement by a surgeon with/without software assistance.	Significant reduction of attempts for optimal wire placement, duration of surgery, and fluoroscopy time.

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