Influence of intraoperative reduction quality on functional outcome and quality of life in treatment of tibial plafond fractures: a retrospective case-control study

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Research article

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Abstract

Background The aim of the study was to evaluate the impact of reduction quality, using intraoperative 3D imaging, on quality of life and functional outcome in the operative treatment of tibial plafond fractures.

Methods A group of patients with tibial plafond fractures was postoperatively examined. The operative treatment was performed between September 2001 and October 2011 under reduction control using an intraoperative 3D C-arm. A categorization with regard to the type and the size of joint surface irregularities was carried out after intraoperative reduction. Postoperative results were evaluated using: Olerud and Molander (O & M) score, Short-Form-36 (SF-36) score, leg circumference, movement deficit, Kellgren and Lawrence grade of osteoarthritis, and pain intensity.

Results 34 patients with osteosynthetically treated tibial plafond fracture could be re-examined. Reduction quality had the greatest influence on functional result measured by the O & M score (P=0.001) and the PCS domain of the SF-36 score (P=0.018). Significant differences with regard to O & M score (P=0.000), SF-36 score (P=0.001 to P=0.02; without MCS domain), circumferential difference below the knee joint gap (P=0.012), movement deficit (P=0.001), grade of osteoarthritis (P=0.005) and pain (P=0.001) could be verified under consideration of the reduction quality. The group with the preferred reduction also showed a better result for clinical follow-up and quality of life. Conclusions Despite other relevant factors, it appears that reduction quality - which can be analyzed with intraoperative 3D imaging - plays the most important role in postoperative quality of life and functional outcome.

Background

Tibial plafond fractures occur in approximately 5 per 100,000 people and account for about 5 to 7% of all tibial fractures.[1] More than 30% of all tibial plafond fractures are associated with high-velocity trauma, which makes operative treatment challenging due to the complex fragment dislocation and severe soft tissue damage.[2] An anatomically incorrect reduction, in the sense of axial deviation or graduation of the joint surface, leads to a relevant functional limitation of joint movement and premature arthrosis.[3–6] Therefore, operative intervention with anatomical reconstruction of the joint structures is often indispensable to achieve a satisfactory clinical outcome.[5, 7–9]

The intraoperative assessment of the articular surface and implant placement with conventional fluoroscopy is demanding. Studies using the cadaver model have shown that, even under optimal conditions, the analysis of the joint surface and implant placement using conventional fluoroscopy may not be sufficient.[10–12] The current gold standard for preoperative planning and postoperative assessment of reduction quality and implant placement is computed tomography (CT), which is not regularly available for intraoperative evaluations.[13]

Postoperative complications in tibial plafond fractures are well known and described in detail in the literature.[14, 15] Postoperative detection of a relevant fragment dislocation or implant misplacement therefore usually leads to revision surgery. A reliable intraoperative examination regarding the quality of
reduction should make it possible to recognize and correct a malalignment already during the present operation.

Intraoperative 3D imaging using a mobile C-arm can be used to assess the reduction result and implant placement to identify intraoperative conditions requiring correction.[16–21] Several studies have already demonstrated that the use of intraoperative 3D imaging may lead to a relevant intraoperative revision rate between 14.6 and 36% of the cases, despite the lack of evidence of malreduction or implant misplacement in conventional fluoroscopy.[18–20, 22, 23]

Furthermore, only a few studies exist that have investigated the functional outcome and health-related quality of life after operations due to tibial plafond fractures, without referring to the quality of reduction. [24, 25] A study investigating the postoperative outcome of tibial plafond fractures, taking into account the reduction quality using intraoperative cone-beam CT, has not yet been conducted.

The aim of the study was to investigate the influence of reduction quality in the operative treatment of tibial plate fractures, depending on type and size of the joint surface irregularity, using intraoperative 3D imaging, on quality of life and functional outcome.

Methods

In the scope of a retrospective, monocentric study, a group of patients with tibial plafond fractures, classified as AO/OTA type B and C according to the preoperative CT data, was postoperatively examined. The operative treatment was performed between September 2001 and October 2011 under reduction control using an intraoperative 3D C-arm (cone beam CT) (Siremobil-Iso-C–3D, Arcadis-Orbic–3D; Siemens Healthcare GmbH, Erlangen, Germany). The surgical interventions were performed by experienced surgeons from a level I trauma center. The therapeutic procedure included immobilization with a cast or the application of an external fixator, especially in cases of poor soft tissue conditions. The operative treatment included open reduction and internal fixation followed by an intraoperative cone beam CT to analyze reduction quality. If the reduction or implant placement was unsatisfactory, an intraoperative revision was performed and the cone beam CT scan repeated (Figure 1). Only the final 3D image data set after the final surgical procedure was included in the study. The overall rate of intraoperative revision of the reduction or implant placement - based on intraoperative cone beam CT imaging - was 29.2% in total. The follow-up period was at least 2 years. The following exclusion criteria were also applied: concomitant injuries of the same extremity, spinal injuries with neurological symptoms, polytrauma with craniocerebral trauma higher than grade I, preexisting primary and secondary osteoarthritis of the ankle joint and previously suffered injuries of the same anatomical region (e.g. ankle fractures), postoperative complications (infection, thrombosis, compartment syndrome, flap plastic, revision in external clinics, wound healing disorder, bleeding, necrosis or amputation), and patients who had already died.

The collective was differentiated according to the following parameters: Age, gender, BMI, concomitant diseases, profession, type of accident (private/work-related), fractured side, type of fracture (type B/C),
and concomitant injuries.

Furthermore, patients were retrospectively categorized into two groups regarding the reduction quality. The evaluation of the joint surface was carried out conducting a dynamic inspection of the complete 3D data set in all 3 planes. The first group was defined as reduction results with articular surface incongruencies (steps, gaps or defects) of less than or equal to 2 mm in the scan images. The second group included all patients whose incongruencies exceeded 2 mm in size of step, gap or defect. According to this classification, 15 patients were placed in Group I and 19 patients in Group II.

The postoperative results were then evaluated using the following parameters: Olerud and Molander (O & M) score, Short-Form–36 (SF–36) score, difference of leg circumference, movement deficit, Kellgren and Lawrence grade of osteoarthritis, and pain intensity using a visual analogue scale.

From the SF–36 score, several scores can be derived, which are assigned to specific categories. In this case, all four domains of the score (Physical Functioning, Role Physical, Bodily Pain and General Health) were used, which mainly cover physical aspects of health, as well as a final component (Physical Component Summary) summarizing them once again. In addition, the Mental Component Summary (MCS) was analyzed, a comprehensive domain that summarizes the mental areas of health. The two overarching scores serve as an overview.

**The severity of osteoarthritis of the ankle joint was determined using the radiographic classification by Kellgren and Lawrence.**

The range of motion of both ankle joints was measured with a goniometer applying the neutral-zero method and subsequently compared to the healthy contralateral side by forming differences to determine any deficit. This was calculated separately for flexion and extension, and these values were added together to give an overall value.

Furthermore, the circumferences of both legs of each patient were measured. This was also performed in a side-by-side comparison and differences were again formed. The circumference of the healthy leg was subtracted from the circumference of the injured leg in order to identify a possible atrophy of the lower leg muscles or a swelling of the ankle joint. Measurements were taken at three different locations: 15 cm below the medial knee joint gap, at the narrowest point of the lower leg, and at ankle level.

**Follow-up included the current intensity of the pain in the affected region was examined on the visual analogue scale (VAS).**

Finally, group-specific analyses, correlation analyses and multivariate linear regression analyses were performed using the data set collected. The statistical analysis was carried out using IBM SPSS Statistics 21 (IBM Corporation, Armonk) and Microsoft Excel 2010 (Microsoft Corporation, Redmond).
Results

A total of 34 patients with osteosynthetically treated tibial plafond fracture could be re-examined. The average age of the study group, consisting of 8 women and 26 men, was 44.6 years at the time of surgery (SD: 11.87, range: 21–64). Patients averaged 1.74 m in height (SD: 0.82, range: 1.57–1.89) and weighed 81.64 kg (SD: 12.32, range: 60–110). This resulted in an average BMI of 26.8 kg/m² (SD: 3.46, range: 20.96–36.51).

Among the follow-up subjects with at least one risk factor, 5 were obese, 9 consumed nicotine, 12 consumed alcohol, 3 were diagnosed with diabetes mellitus, 1 had gout and 1 had hyperthyroidism.

The professions of patients were divided into four categories, depending on the level of physical activity: 4 pensioners/students/unemployed, 11 with sedentary work, 11 with basic physical work and 8 with heavy physical work.

In the follow-up collective, referring to the AO/OTA Classification, 20 of the subjects had type B fractures and 14 suffered from type C fractures. In Group I there were 11 type B fractures and 4 type C fractures. In Group II there were 9 type B fractures and 10 type C fractures.

During the follow-up, patients completed two questionnaires (the Olerud and Molander score and the SF–36 score): On average, the patients surveyed scored 69.12 points (SD: 24.79, range: 10–100) in the Olerud and Molander score. The comparison of both groups according to the reduction quality is shown in Table 1 below. In the SF–36 survey, the Physical Component Summary (PCS) averaged 48.25 points (SD: 10.6, range: 25.22–60.77) and the Mental Component Summary 50.65 points (SD: 9.58, range: 27.22–64.83). The PCS score distribution in the two groups is shown in Table 2.

Figure 2 shows the categorization of the two patient groups according to their grade of osteoarthritis classified by Kellgren and Lawrence.

Figure 3 shows the number of patients with the deficit of range of motion depending on the group affiliation for the reduction result.

Descriptive statistics on the circumferential differences 15 cm below the medial knee joint gap, at the narrowest point of the lower leg and at ankle level within the two groups are summarized in Table 3.

The mean value for the intensity of pain, according to the visual analogue scale, was 2.88 and the median was 2.5 (SD: 2.57, range: 0–8, 25% percentiles: 0, 75% percentiles: 5). The illustration of the group-specific results for the visual analogue scale is shown in Table 4.
Group-specific analyses:

With the numbers available, no significant differences could be found with regard to age ($P = 0.836$), sex ($P = 0.231$), BMI ($P = 0.151$) or type of fracture ($P = 0.127$) in the groups differentiated according to reduction quality. Significant distribution differences were observed with regard to nicotine abuse ($P = 0.002$), profession with heavy physical work ($P = 0.014$) and concomitant injuries ($P = 0.004$), whereby these were predominantly found in the suboptimal reduction group (Group II).

Considering the number of patients available, the Olerud and Molander score could be significantly influenced by the reduction quality ($P = 0.000$): The mean difference was 33.79 points with a standard error difference of 6.32. The 95% confidence interval was 20.92 to 46.66 points.

Significant association of SF–36 score with reduction quality could also be observed ($P = 0.001$ to $P = 0.02$; without MCS domain): In the comparison of the PCS domain, the mean difference amounted to 10.24 points ($P = 0.003$). The standard error difference amounted to 3.25 points. The range of the 95% confidence interval was between 3.63 and 16.86 points. There were no significant differences with regard to the MCS domain of the SF–36 score ($P = 0.142$), when considering reduction quality.

Only the circumferential difference 15 cm below the knee joint gap showed a significant deviation within the two groups ($P = 0.012$): The mean difference was 1.29 cm with a standard error difference of 0.48 cm. The range of the 95% confidence interval was between 0.31 and 2.28 cm. The remaining circumferential differences were not significant ($P = 0.729$; $P = 0.278$).

Significant differences of movement deficit in comparison of reduction quality ($P = 0.001$): The mean ranks of the good reduction group were lower (11.50°) than the mean ranks of the suboptimal reduction group (22.24°).

Significant deviation in pain level, captured by visual analogue scale, depending on reduction quality ($P = 0.001$): The mean difference was 2.77 with a standard error difference of 0.76. The range of the 95% confidence interval was between –4.31 and –1.23.

A significantly different distribution between Goup I and Group II with regard to the grade of osteoarthritis ($P = 0.005$) could be seen (Figure 2).

In summary, the group with the favored reduction quality showed a better result in terms of clinical follow-up and quality of life except for the MCS domain of the SF–36. In this case comparable postoperative results were observed.

Analysis of variance (ANOVA):
Table 5 lists the descriptive statistics regarding the Olerud and Molander scores depending on the type of articular surface irregularity. It was found that only the group of patients with steps differed significantly from those with the combination of gaps and defects ($P = 0.034$). All other groups did not provide significant differences regarding the comparison of their mean values in the Olerud and Molander scores.

Furthermore, it was examined whether there was a significant difference between the groups regarding their mean value in the SF–36 score domains. However, none of the components of the SF–36 score showed a significant result with respect to the comparison of the mean values of the different articular surface irregularity groups.

Thereafter, it was analyzed whether there were significant differences between the specific groups of joint surface irregularities in terms of circumference differences. The ANOVA analysis showed no significant differences.

The mean values of the movement deficits did not differ significantly with respect to the joint surface irregularities. The individual groups with extension deficits showed a $P$-value of 0.234. A $P$-value of 0.134 was found for the flexion deficit and a $P$-value of 0.084 for the total deficit.

The Chi2 test did not yield a significant result with regard to the comparison of the distribution of the individual irregularity groups in the different osteoarthritis stages ($P = 0.232$).

The ANOVA analysis for the mean value comparison of the visual analogue scale with respect to the various irregularity groups showed no significant result ($P = 0.076$).

Correlation analyses:

The width of the gaps ranged from 0 to 8.3 mm (SD: 1.74), the range of defects was 0 to 9 mm (SD: 2.7) and the steps varied from 0 to 4.7 mm (1.27).

The correlations between the Olerud and Molander Score and the step, gap and defect sizes revealed the results listed in Table 6, whereby only the defect size correlated significantly ($P = 0.005; r = -0.470$) with the Olerud and Molander Score. The score decreased with increasing defect size.

The correlation analysis according to Pearson regarding the size of the specific joint surface irregularities and the six domains of the SF–
36 score did not yield any significant results.

The irregularity sizes correlated with the movement deficits. Only the defect size demonstrated significant results in the correlation analysis with the extension deficit ($P = 0.038; r = 0.358$), the flexion deficit ($P = 0.041; r = 0.353$) and the total deficit ($P = 0.013; r = 0.420$). The Spearman coefficients were positive.

The step size ($P = 0.807$) and defect size ($P = 0.084$) did not correlate significantly with the grade of osteoarthritis. However, the gap size correlated significantly ($P = 0.035$) and the Spearman coefficient was positive. A larger gap in the articular surface resulted in a higher grade of osteoarthritis.

Furthermore, it was examined whether there was a significant correlation between the circumferential differences and the step, gap and defect sizes. However, this could not be confirmed by the Pearson correlation analysis. No significant correlations were found here.

The visual analogue scale did not correlate significantly with either the step size or the gap size. The defect size, however, showed a significant result ($P = 0.012$). The Pearson coefficient was positive ($r = 0.425$). Thus, it could be concluded that larger defects were associated with higher values on the VAS.

**Multivariate linear regression analyses:**

In this study, the reduction quality had the greatest influence on the functional result after operatively treated tibial plafond fracture determined by the Olerud and Molander score ($P = 0.001$) and the PCS domain of the SF–36 score ($P = 0.018$).

**Discussion**

The operative treatment of intra-articular tibial plafond fractures remains difficult even for the experienced trauma surgeon, since the intraoperative assessment of the tibial joint surface and the implant placement using conventional fluoroscopy is limited.[26–29] The aim of this study was to evaluate the impact and benefit of reduction quality, using intraoperative 3D imaging criteria, in terms of postoperative outcome on the follow-up of 34 patients with tibial plafond fractures type B and C according to the AO classification.

Previous publications with a smaller number of cases showed that intraoperative 3D imaging may be beneficial for the operative treatment of tibial plafond fractures.[16, 18–20] Studies dealing with functional outcome and health-related quality of life after operations due to tibial plafond fractures have already been published. Cisneros et al. describe, depending on the chosen surgical procedure, persistent pain (Numerical Rating Scale 2.64–3.1) in the follow-up examination after 2 years in 31 patients with tibial plafond fractures and Stengel et al., in the context of a follow-up examination of 21 patients, showed that the functional prognosis in SF–36 and the associated quality of life of tibial plafond fractures remain unsatisfactory despite clear improvements in surgical management.[24, 25, 30] Similar
results could also be observed in our investigations using the visual analogue scale, as well as the clear deviation of the PCS in SF–36 from the normal population. Investigations evaluating the postoperative outcome of tibial plafond fractures in conjunction with anatomical reduction using intraoperative 3D imaging criteria have not yet been published.

Previous studies focused on whether an anatomically correct reduction of the distal tibial joint surface in tibial plafond fractures results in a prognostic difference in patient outcomes and concluded that remaining joint gaps or steps of more than 2 mm after the reduction and axial deviations in the frontal or sagittal plane of more than 5 degrees can lead to poorer clinical results and higher osteoarthritis rates.[5, 31–35] Resch et al. could even demonstrate that a postoperative incongruity of the articular surface is followed by heavier arthrosis than a comparable incongruity after conservative treatment.[33] De-las-Heras-Romero et al. analyzed the impact of intra-articular tibial plafond fractures and the predictive factors on patients’ quality of life. They already revealed that fracture severity, reduction quality and arthrosis were the main prognostic factors and showed that the SF–36 scores (PCS 54.8; MCS 63.3) and the Olerud and Molander score (60.1) are significantly lower than in the age-matched general population.[30] Our investigations also provided a similar result. Patients with poorer reduction results, in terms of gaps, steps, and articular surface irregularities of more than 2 mm, also showed significantly worse results in terms of quality of life and clinical-functional outcome. Even more, the correlation analysis between the size of the irregularity and the movement deficit showed positive Spearman coefficients, which is why it could be concluded that large defects were associated with large movement deficits. Secondly, regression analyses, regardless of group affiliation, confirmed that the reduction result is the most important factor affecting postoperative outcome. Therefore, a reduction and restoration of the joint surface as anatomically correct as possible is desirable. Intraoperative 3D imaging may provide additional information already during the initial operative procedure and thus may enable the surgeon to perform corrections of the reduction and implant placement intraoperatively.[18–20, 22, 23] This can potentially avoid revision surgery and decrease the associated perioperative risks for the patient and at the same time positively influence the outcome in the long term.

Smoking as a risk factor correlated significantly with the Olerud and Molander score. Nicotine consumption led to a lower score. The negative effect of nicotine consumption on osteogenesis and fracture healing has already been well demonstrated in vitro and in vivo test series.[36, 37] Furthermore, a recent study also shows that nicotine consumption has an influence on pain perception, so that smokers are dependent on significantly more analgesics postoperatively.[38] Other studies reported smoking as a predictive factor for musculoskeletal complaints, defined as having pain and/or stiffness in muscles and joints.[39]

The study had several limitations. The absolute number of 34 participants was quite low and therefore allows only a limited statement about the overall population. Furthermore, it was also disadvantageous in terms of the statistical evaluation of some results due to the resulting high range. Nevertheless, in view of the low incidence of the type of injury, the fact that type B and C fractures are very rare, and the long follow-up period, the number of patients examined compared to other studies is actually very high.
Two different devices have been used over the years to perform the 3D scans. However, the image quality of the two devices is comparable in terms of diagnostic evaluation and surgical analysis.

Conclusions

In conclusion, the established reduction criteria in intraoperative 3D imaging appear to have the highest impact on postoperative quality of life and functional outcome. This is despite other relevant factors such as nicotine consumption, concomitant injuries or gender, as well as the type of accident.

Furthermore, it is not always the type of joint surface irregularity that is decisive, but rather the size. This should be taken into account in the reduction analysis and corrected if necessary, especially if the surface irregularity is above 2 mm.

Abbreviations

Olerud and Molander (O & M); Short-Form–36 (SF–36); computed tomography (CT); Mental Component Summary (MCS); Physical Component Summary (PCS); visual analogue scale (VAS); Analysis of variance (ANOVA)

Declarations

Ethics approval and consent to participate: The Ethics Commission of the Rheinland-Pfalz Medical Association (Mainz, Germany) approved the proposal of this study under the reference number 837.251.12 (8352-F) in its meeting on the 4th of July 2012, and written informed consent was obtained from all patients.

Consent for publication: Not applicable.

Availability of data and materials: The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests: PG and JF are paid members of an advisory board for Siemens. MP, FE, HK, BS, NB, and SV declare that they have no competing interests.

Funding: The research group had grants/grants pending and technical support from Siemens (Erlangen, Germany). Siemens had no involvement in the study design, collection, analysis and interpretation of
data, the writing of the manuscript, and the decision to submit the manuscript for publication.

Authors’ contributions: MP wrote the manuscript. FE and NB did the measurements. SV, BS, and HK developed the concept and the modalities. SV carried out the statistical analysis. JF and PG supervised the study and assisted with the concept. All authors read and approved the final manuscript.

Acknowledgements: Not applicable.

References


Tables

Table 1: Descriptive statistics for the Olerud and Molander scores with comparison of the groups (Group I = good reduction; Group II = suboptimal reduction). The values correspond to the scores achieved.

<table>
<thead>
<tr>
<th>Reduction quality</th>
<th>Mean</th>
<th>Median</th>
<th>Standard deviation</th>
<th>Min.</th>
<th>Max.</th>
<th>25%-Percentile</th>
<th>75%-Percentile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I</td>
<td>88.00</td>
<td>95.00</td>
<td>15.09</td>
<td>60.00</td>
<td>100.00</td>
<td>82.50</td>
<td>100.00</td>
</tr>
<tr>
<td>Group II</td>
<td>54.21</td>
<td>55.00</td>
<td>20.43</td>
<td>10.00</td>
<td>100.00</td>
<td>45.00</td>
<td>65.00</td>
</tr>
</tbody>
</table>

Table 2: Descriptive statistics with score distribution for the Physical Component Summary (SF-36) in both groups (Group I = good reduction; Group II = suboptimal reduction). The values correspond to the scores achieved.

<table>
<thead>
<tr>
<th>Reduction quality</th>
<th>Mean</th>
<th>Median</th>
<th>Standard deviation</th>
<th>Min.</th>
<th>Max.</th>
<th>25%-Percentile</th>
<th>75%-Percentile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I</td>
<td>53.97</td>
<td>57.93</td>
<td>7.64</td>
<td>35.52</td>
<td>60.77</td>
<td>48.17</td>
<td>59.40</td>
</tr>
<tr>
<td>Group II</td>
<td>43.73</td>
<td>43.12</td>
<td>10.58</td>
<td>25.22</td>
<td>60.61</td>
<td>34.91</td>
<td>51.97</td>
</tr>
</tbody>
</table>

Table 3: Descriptive statistics for the measured circumference differences (circumference of injured leg - circumference of healthy leg) at three locations of the lower leg with a comparison of the two groups (Group I = good reduction; Group II = suboptimal reduction). The values are provided in [cm].
<table>
<thead>
<tr>
<th>Location of measurement</th>
<th>Reduction quality</th>
<th>Mean</th>
<th>Median</th>
<th>Standard deviation</th>
<th>Min.</th>
<th>Max.</th>
<th>25%-Percentile</th>
<th>75%-Percentile</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 cm below the medial knee joint gap</td>
<td>Group I</td>
<td>-0.23</td>
<td>0.00</td>
<td>0.42</td>
<td>-1.00</td>
<td>0.00</td>
<td>-0.25</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>Group II</td>
<td>-1.53</td>
<td>-1.00</td>
<td>1.83</td>
<td>-6.00</td>
<td>0.50</td>
<td>-2.75</td>
<td>0.00</td>
</tr>
<tr>
<td>narrowest point of the lower leg</td>
<td>Group I</td>
<td>0.73</td>
<td>0.50</td>
<td>0.78</td>
<td>0.00</td>
<td>2.00</td>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>Group II</td>
<td>0.84</td>
<td>1.00</td>
<td>0.99</td>
<td>-1.00</td>
<td>3.00</td>
<td>0.00</td>
<td>1.50</td>
</tr>
<tr>
<td>ankle level</td>
<td>Group I</td>
<td>0.63</td>
<td>0.50</td>
<td>0.69</td>
<td>0.00</td>
<td>2.00</td>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>Group II</td>
<td>0.97</td>
<td>1.00</td>
<td>1.02</td>
<td>-1.00</td>
<td>3.50</td>
<td>0.50</td>
<td>1.25</td>
</tr>
</tbody>
</table>

**Table 4:** Descriptive statistics for pain intensity using the visual analogue scale with a comparison of the two groups (Group I = good reduction; Group II = suboptimal reduction). The values of pain intensity are on a scale from 1 to 10.

<table>
<thead>
<tr>
<th>Reduction quality</th>
<th>Mean</th>
<th>Median</th>
<th>Standard deviation</th>
<th>Min.</th>
<th>Max.</th>
<th>25%-Percentile</th>
<th>75%-Percentile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I</td>
<td>1.33</td>
<td>1.00</td>
<td>1.88</td>
<td>0.00</td>
<td>7.00</td>
<td>0.00</td>
<td>2.00</td>
</tr>
<tr>
<td>Group II</td>
<td>4.11</td>
<td>5.00</td>
<td>2.40</td>
<td>0.00</td>
<td>8.00</td>
<td>3.00</td>
<td>5.50</td>
</tr>
</tbody>
</table>

**Table 5:** Descriptive statistics of the Olerud and Molander Score with distribution regarding the type of single and combined joint surface irregularities. The values correspond to the scores achieved.

<table>
<thead>
<tr>
<th>Type of joint surface irregularities</th>
<th>N</th>
<th>Mean</th>
<th>Standard deviation</th>
<th>Min.</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step</td>
<td>4</td>
<td>97.50</td>
<td>2.89</td>
<td>95.00</td>
<td>100.00</td>
</tr>
<tr>
<td>Gap</td>
<td>9</td>
<td>68.89</td>
<td>24.47</td>
<td>40.00</td>
<td>100.00</td>
</tr>
<tr>
<td>Defect</td>
<td>2</td>
<td>60.00</td>
<td>21.21</td>
<td>45.00</td>
<td>75.00</td>
</tr>
<tr>
<td>Step + gap</td>
<td>9</td>
<td>72.22</td>
<td>17.34</td>
<td>45.00</td>
<td>95.00</td>
</tr>
<tr>
<td>Step + defect</td>
<td>4</td>
<td>51.25</td>
<td>18.87</td>
<td>25.00</td>
<td>65.00</td>
</tr>
<tr>
<td>Gap + defect</td>
<td>4</td>
<td>41.25</td>
<td>24.28</td>
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<td>69.12</td>
<td>24.79</td>
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**Table 6:** Pearson correlation analysis between the Orelud and Molander Score and the size of the different joint surface irregularities.
Figures
**Figure 1**

Standardized workflow for the application of intraoperative 3D imaging for the assessment of reduction quality in trauma surgery visualized as flow chart.

![Flow chart diagram](image)

**Figure 2**

Distribution of patients in terms of grade of osteoarthritis according to Kellgren and Lawrence. Direct comparison of the number of patients in each group (Group I = good reduction; Group II = suboptimal reduction) using a bar chart.

![Bar chart diagram](image)
Figure 3

Distribution of patients in both groups for range of motion deficits. Number of patients from each group are assigned to the respective movement deficit in degrees [°] represented as bar chart.