Effectiveness of Reverse Total Shoulder Arthroplasty for Primary and Salvage Fracture Care - Clinical and Radiological Outcome in Mid-term Follow-up in a Single-Center Experience

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Abstract

Background

The introduction of reverse total shoulder arthroplasty (RSA) as a treatment option in complex proximal humeral fractures, including patients with poor bone quality, has significantly extended the surgical armamentarium.

The aim of this study was to investigate the mid-term outcome following fracture RSA (FRSA) in acute or sequelae, as well as salvage procedures. It was hypothesized that revision FRSA (SRSA) leads to similar mid-term results as primary fracture treatment by RSA (PRSA).

Methods

This retrospective case-series study describes the radiological and clinical mid-term outcome in a standardized single-center and one-material Inlay design. Patients who underwent FRSA between 2008 and 2017 were matched (minimum follow-up: two years, minimum age at the time of operation: 60 years).

The assessment tools used for functional findings were range of motion (ROM), Visual Analogue Scale, absolute (CS) plus normative Constant Score, Quick DASH, and Subjective Shoulder Value. All adverse events and the radiological results and their clinical correlations were analyzed statistically (using α = 5% and 95% confidence intervals).

Results

Following FRSA, 68 patients were included (mean age: 72.5 years, mean FU: 46 months). Forty-two underwent primary RSA (PRSA), 26 revision RSA (SRSA). Adverse advents were observed in 13% (n = 9/68).

No statistically significant results were found in PRSA and SRSA in effect sizes by scores, whereby the failed osteosynthesis SRSA subgroup obtained significantly negative values in ROM subzones (flexion: p = .046, abduction: p = .037). Decreased tubercle healings in PRSA relative to SRSA were observed (p = .006). A missing bony healing of the tubercles was related to significant negative clinical outcome (all scores: p < .05, external rotation: p = .019). In SRSA, significant postoperative improvements could be stated (CS: 23 to 56 at mean, p = .001), the time from index surgery to operative revision revealed no associations in functional findings.

Conclusions

RSA is an effective option in severe shoulder fracture management with predictable results as salvage as well as first-line treatment. Promising mid-term functional results, reasonable implant survival rates, and a high patient satisfaction could be achieved.

Trial Registration

Not applicable, level of evidence III.

Background

Proximal humeral fractures (PHFs) represent the third most common fracture type in the elderly population (1,2). Due to demographic changes, the simultaneous incidence of osteoporosis, and various other comorbidities, the management of these injuries remains challenging (1). The spectrum of surgical treatment modalities include closed reduction and percutaneous pin fixation (1), open reduction and internal fixation (ORIF) by locking or non-locking plates (3–7) and intramedullary nails (8,9). Further primary non-joint-preserving treatment options for PHFs include anatomical total shoulder arthroplasty (ASA) (10–13), hemiarthroplasty (HA) (14), and reverse shoulder arthroplasty (RSA) (13,15–18). However, due to rotator cuff deficits or unsuccessful tubercle fixation, functional results tend to be inferior in ASA and HA (10,19,20).

Meanwhile, recent trends show that RSA has become the treatment of choice for complex proximal humeral fractures, especially in patients with poor bone quality (21). The RSA was primarily designed to treat patients with massive rotator cuff defects (22–25). Thus, indications have been extended to further pathologies, such as cuff tear arthropathy (26,27), and proximal humeral fractures (PHFs) (17,28) or revision arthroplasty (29). Moreover, RSA is used as a salvage procedure in cases of symptomatic mal- or non-unions following (failed) primary osteosynthesis or HA of PHFs (1,13,29).

The keypoint in clinical practice is to perform a stable osteosynthesis after meticulous, gentle reduction without denudation of fracture fragments in complex fracture situations. Various treatment options and expectations for acute PHFs lead to vivid discussions among surgeons and patients. To address this focus, we hypothesized that a failed joint preserving strategy treated by revision RSA might achieve similar clinical results as the primary joint replacement approach. Therefore, the aim of the study was to evaluate the functional outcome following primary RSA (PRSA) for PHFs compared to secondary RSA (SRSA) performed as a salvage procedure.

Methods

Study design and patient recruitment

This retrospective case-series study characterizes a single-center evaluation in a standardized setting following reverse total shoulder arthroplasty in primary (PRSA) or secondary / sequelae (SRSA) fracture care.

All consecutive patients older than 60 years at the time of surgery were included after the treatment by either PRSA or SRSA between January 2008 and December 2017 at a level-III trauma center (AUVA – Trauma Hospital Styria | Graz). The time-line was chosen based on data accessibility. Only patients with

the Inlay (Grammont) design (155° humeral neck-shaft angle) were included; two different implants were involved {Delta Xtend, DePuy Synthes; Warsaw, USA | Anatomical Reverse, Zimmer; Warsaw, USA}.

The PRSA group included patients that received RSA implantation as primary treatment for three- or four-part and articular segment fractures according to Neer's classification (30,31). In this group, all cases have been treated with a reverse shoulder arthroplasty within ten days after trauma. For the SRSA group, a minimum time interval from index to revision surgery of three months has been defined. This group comprised subgroups of patients that underwent RSA implantation in cases of humeral head necrosis following angular stable plate osteosynthesis (HHN), as following failed open reduction and internal fixation (fORIF) and after trauma hemiarthroplasty (THA). For detailed study design, see Figure 1.

Patient characteristics

Data were collected prospectively in the respective hospital database. Patient characteristics and pathological as well as course of treatment data were summed up and analyzed retrospectively. All postoperative adverse events were evaluated via the hospital database and their medical history in the final patient investigation. Major complications were specified by requiring an unplanned revision, all others were classified as minor complications. The follow-up (FU) time was defined as an interval between surgery and last assessment. The minimum FU was fixed by two years.

Specific details in operative and postoperative procedure

The operative procedure and rehab protocol were equivalent in the entire sample according to the standardized work-up at our center. A deltopectoral approach was performed in the beach-chair position in every case. Further, all humeral monobloc components were cemented. For glenoid preparation, a full 360° release was accomplished under axillary nerve visualization. If necessary, an additive arthrolysis and scar release was performed.

All tubercles were fixed via non-resorbable transosseous and cerclage sutures and circular sutures around the prosthesis neck. If a detachment of the subscapularis tendon was necessary, a double-row transosseous refixation was realized. Passive physiotherapy with a free range of motion (ROM) in a pain-free interval was started two days postoperatively. The active-assistive motion was initiated five weeks postoperatively, deltoid muscle mass improvement was fostered at the beginning of the seventh week.

Clinical outcome assessment

Patients were assessed to determine their current clinical level via the following scores: Visual Analog Scale (VAS), absolute Constant Score (CS) (32), normative Constant Score (nCS) (33), Subjective Shoulder Value (SSV) (34), and Quick DASH (QD) (35). ROM was evaluated in degrees for flexion, abduction, and external rotation (ER). The internal rotation (IR) was characterized in points based on the functional shoulder-specific CS (32). Patient-specific assessment was carried out via the modified valuation of the CS, which is based on age- and gender-related characteristics (nCS) (33).

The SSV symbolizes a Single Assessment Numeric Evaluation (SANE) of the shoulder, representing a shoulder self-assessment by the patient him- / herself. The score is expressed as a percentage of an entirely healthy shoulder, which would score 100% (34). The QD is a self-assessment instrument and includes eleven questions concerning complaints regarding the upper extremity and activities of daily living (35). The preoperative CS, which was available in their prospective documentation in the hospital database, was compared to their respective postoperative values. Further analysis in the SRSA group was performed by differentiation in early (<12 months) and late (>12 months) time intervals from index surgery to revision RSA implantation regarding their mid-term outcome in CS.

Radiological outcome assessment

During follow-up, X-rays in three planes (anterior-posterior, axial, and supraspinatus outlet view) were performed. The final X-rays were analyzed under comparison to index and interim radiological data. They were evaluated by three trauma and orthopedic surgeons (AS, GH, and MN) regarding implant dislocation, grade of notching according to Sirveaux (36), resorption of the major and/or minor tubercles, and radiological signs of loosening of the prosthesis.

To assess clinical correlations and the radiological outcome, the CS and nCS were chosen for evaluation in the following focuses: tubercle bone stock healing and scapular notching.

Statistical analysis

Statistical analysis was performed using the SPSS software {IBM SPSS Statistics version 26, Armonk, USA}. Continuous parameters are presented as mean, standard deviation (SD), and categorical or quantitative data.

In order to compare findings between the PRSA and SRSA group a t-test was utilized. Kruskal-Wallis and post-hoc Dunn-Bonferroni tests were performed to compare the data between each group and their respective subgroups (PRSA and SRSA [HHN, fORIF, THA]). The Spearman's Rho correlation coefficient (ρ*)* was additionally used for the final relationship analyses. A Fisher's exact test was utilized to compare the rates of adverse events. P-values (*p*) below .05 were considered as statistically significant, confidence intervals of 95% were computed.

Results

Demographics

In total, 68 patients met the inclusion criteria. The PRSA group consisted of 42 patients, the SRSA group of 26 patients. The SRSA collective comprised twelve cases (46%, n = 12/26) treated after HHN, ten patients (38.5%, n = 10/26) treated following fORIF, and four patients (15.5%, n = 4/26) undergoing THA.

The mean age of the entire collective was 72.5 years (SD: 6.8, range: 60–89) at the time of surgery; 73.6 years (SD: 6.8) in PRSA and 70.5 years (SD: 6.7) in SRSA patients. The average follow-up time for all

patients was 46 months (SD: 25.1, range: 24-134); 41 months (SD: 21.3) in PRSA, 54 months (SD: 26.5) in SRSA collective. Mean surgery time duration was 160 minutes (SD: 44.1) in PRSA, 207 minutes (SD: 38.2) in SRSA, and 178 minutes (SD: 47.6, range 86-352) in all patients. Surgical revision was performed at an average of 45.5 months (SD: 54.1, range: 3.4–180) following index surgery in the SRSA group.

ROM

All average ROM values were comparable in each of the groups. No statistically significant relevancies were revealed comparing PRSA versus SRSA (all P-values ≥ .05). Comparing the SRSA subgroups to the PRSA group, a statistically significant negative average flexion (p = .046) and abduction (p = .037) were evaluated of those previously treated following fORIF. Further data of SRSA subgroup analysis explored no significant associations. All ROM values are discussed in Tables 1 and 2.

Analyzing the ROM results, the strongest relationship was found for flexion and abduction with a correlation coefficient of ρ = .901 (p < .001).

Scores

The outcome values of PRSA and SRSA did not reveal any statistically significant differences, as displayed in Table 3. Thus, no significant differences were observed in CS (p = .204) and nCS (p = .211), for details see Figure 2. Similarly, no significant associations were evaluated in both scores when comparing the PRSA values with individual subgroups within the SRSA (see Table 4).

When comparing the VAS and QD score amongst primary and secondary care, homogeneous results were observed in PRSA and SRSA (p = .573 and .291), as cited in Table 3 and Figure 3 (QD). Regarding the SRSA subgroups, no statistical significance could be evaluated concerning VAS and QD scores (p ≥ .05, see Table 4). Assessing the patient satisfaction, equivalent SSV results in PRSA and SRSA were observed, which was statistically not significant (p = .558), see Figure 4. For specific details, see Table 3 plus 4.

Of the score data analyzed, the most substantial relationship was found for the CS and QD with a correlation coefficient of ρ = -.785 (p < .001).

A significant improvement in CS could be validated in the SRSA group; the preoperative mean CS was 23 (SD: 9.7), whereby a postoperative average CS of 56 (SD: 13.9) resulted in final FU (p = .001), see Figure 5. Additional SRSA differentiation in early (<12 months) and late (>12 months) time of operative revision did not reveal a statistical significance; all scores were comparable (p ≥ .05) – see Table 5.

Radiological findings and their functional correlations

No implant dislocations, as well as no glenoid loosenings, were observed. In one patient, who suffered from rheumatoid arthritis, a humeral component's loosening had to be noticed.

Radiographic changes of the tubercles, like resorption and/or dislocation, were observed in total in 28% (n = 19/68). A significant increasing in the PRSA group in comparison to the SRSA group (40% {n= 17/42}

vs. 8% {n= 2/26}; p = .006, ρ = -.329) could be observed. For listed details, see Table 6.

When comparing the healed with unhealed tubercles like resorption zones or dislocations, statistically significant values were documented in all scores. (all: p = <0.05). The ROM analysis verified a significant negative ER in unhealed situations (p = .019); see Table 7 for details.

A total rate of scapular notching of 23% (n = 16/68) without any correlation regarding PRSA or SRSA was evaluated (p = .687, ρ = .70; see Table 8). Only one case was classified with a higher grade of notching (grade 3 / PRSA group). No influence in postoperative CS was observed in the overall collective. A mean CS of 55 was evaluated in the notching group. Patients without notching revealed a CS of 60 on average (p = .352). Similar respective values were shown in mean nCS, notching versus non-notching: 69 versus 73 (p = .268)

Complications

The overall rate of adverse events was 13% (n = 9/68). Six percent (n = 4/68) were classified as major, seven percent (n = 5/68) as minor complications. There were fewer complications in the SRSA group when compared to the PRSA group without any statistically significance (p = .196). The seven complications (in 6 patients) in the PRSA group included two patients requiring revision surgery. This represents a rate of adverse events of 17% in PRSA (n = 7/42). The two complications in the SRSA group were a single major and minor complication, which led into one revision surgery. Hence, a rate of 8% (n = 2/26) was observed in SRSA group. Listed details of all adverse events are depicted in Table 9.

Discussion

The aim of the study was to analyze the effectiveness of FRSA via a standardized setting in mid-term outcome. While RSA significantly improved the treatment of patients with rotator cuff disorders, we focused on the value and better understanding of RSA in fracture management.

The PRSA and SRSA groups did not show statistically significant differences in the range of motion and functional scores, which confirms our hypothesis. Only the subgroup following fORIF showed significantly decreased values regarding flexion and abduction compared to the PRSA.

Significant improvements between pre- and postoperative CS could be proven in SRSA. Furthermore, the time from index to revision surgery demonstrated no influence on the functional outcome, which indicates that RSA implantation represents a successful treatment strategy in salvage care. However, radiographic changes regarding the tubercles and the overall complication rate were increased in the PRSA compared to the SRSA sample.

Grubhofer et al. (37) evaluated 51 patients that had undergone RSA for complex proximal humeral fractures with an average follow-up of 35 months. At the final follow-up check, the absolute CS was at a mean of 62 points, which is well comparable to the PRSA group of our sample (at mean: 60 points).

The French Society of Orthopaedic and Traumatology Surgery (38) performed a pro- and retrospective multicenter study involving nine institutions to investigate RSA's outcome in patients with four-part PHF. The retrospective part of the study included 41 patients with a mean follow-up of 39 months, and the prospective part involved 32 patients with an average follow-up of eleven months. The mean absolute CS was 57 (retrospective) and 50 (prospective) points, respectively. Both values are comparable to our PRSA group (average CS: 60).

Grubhofer and colleagues (39) evaluated 44 shoulders that had undergone revision RSA following unsatisfactory outcome following proximal humeral ORIF at a mean follow-up of 46 months. The authors reported a statistically significant improvement regarding the CS (pre-RSA: 26 [4-54] points; post-RSA: 55 [19-80] points). Their outcome is similar to our fORIF-SRSA subgroup (mean CS: 52 points). Further, the significant increase of CS in our results, from preoperative at mean 23 to postoperative 56, represents an equivalent effect.

Dezfuli et al. (40) evaluated a sample of 49 patients receiving RSA for either acute proximal humeral fracture, mal- or non-union, failed ORIF or trauma hemiarthroplasty. As in our sample, the authors found no statistically significant differences between the subgroups.

Cicak et al. (41) evaluated 37 patients treated with RSA for either acute proximal humeral fractures or sequelae of these. For 21 of these patients, RSA was the primary surgical treatment (14 of these had chronic and seven acute humeral fractures). The further 16 patients had undergone previous surgical therapy, including ORIF or percutaneous fracture fixation. The group of patients that received RSA for acute fractures had a mean ER of 28° and an average IR up to the level of L4. In comparison, our PRSA sample had an average ER of 17° and a mean IR of four points (CS – the level of L5/S1) (32). Regarding the subgroup that had undergone previous surgery, the authors reported a mean ER of 19° and an average IR to L4. Our SRSA subgroup showed an ER of 14° on average and a mean IR of three points (CS – the level between buttock and iliosacral joint) (32).

Regarding the SSV, Grubhofer et al. (39) evaluated 44 shoulders that had received RSA due to unsatisfactory ORIF and reported an improvement of the preoperative SSV from 29% (range: 0-90%) to 67% (range: 5-95%) at the final control examination. We found almost equal values for PRSA and SRSA (76 and 75%). The same authors (37) re-evaluated 51 patients (52 shoulders) treated with RSA for acute proximal humeral fractures. Authors reported a mean SSV of 83% (range: 0-100%). The French Society of Orthopaedic and Traumatology Surgery (38) reported a mean SSV of 75% for their retrospective study group and 69% for their prospective collective. These data are well comparable to our PRSA group, which showed an average SSV of 76%.

Complication rates for RSA are reported to range from 19 to 68% (22,42–44), including a high percentage of scapular notching and impairment of external rotation as the main problems (18). Furthermore, RSA may involve periprosthetic fractures, fractures of the glenoid, acromion or humeral shaft, neurological lesions, infection, dislocation, mechanical failures or loosening of the glenosphere (2,22). Lehtimäki et al. (2) identified all RSAs utilized for proximal humeral fractures from the Nordic Arthroplasty Register

Association registry data from the interval between 2004 and 2016, whereby 1523 implantations could be included in the study. Only two percent of these (33/1523) required revision surgery with instability as the most common reason (11/1523). The nine adverse effects (13%) and six percent major complication rate of the present study have to be re-evaluated regarding their incidence. Implant-related major complications concern in only one solely case of instability and dislocation. A shaft loosening had to be attributed to an underlying disease. All other adverse events were not implant-related or fateful events. These facts lead to a major complication rate of three percent in total collective, comparable to Lehtimäki et al. (2). Moreover, the rate of adverse events was similar in primary and secondary care.

Common agreements exist regarding decreasing notching rates in modern prosthesis designs (45). The clinical impact of scapular notching appears controversial in the literature. Some authors report a significant decrease in outcome by notching; others declare no important influences (46–48). A recent systematic review (49), including 2,222 shoulder arthroplasties, found that 155° implants had a total notching rate of 16.8%. The authors reported that the notching rate is significantly higher at the 155° as in the 135° design. These values are comparable to our results of a 23% notching rate.

Jain et al. (50) identified a tubercle healing rate of 70.5%, which is equivalent to our results of 72% in a meta-analysis of 382 shoulder arthroplasties and a similar FU period. Acceptable functional results in non-healed or (partial) resorption tubercle patients (28% of the total collective) substantiate that a fracture RSA implantation allows predictable postoperative results. Nevertheless, statistically significant correlations by healed tubercles were shown in all functional scores and patient satisfaction characteristics, as well as in ER – an essential aspect for the daily processes. Based on these data in mid-term clinical outcome, we recommend that surgeons make a strict effort on tubercle refixation.

Strengths and limitations

This study investigated the combined effect of radiological events and tubercle bone stock associated with clinical outcome in primary and secondary fracture care and may allow preoperative assessments in order to estimate the postoperative processes. Due to changes in patient requirements and the increasing demand for salvage procedures, this study reinforces our understanding with mid-term results in an assimilable patient number. The clinical significance is fortified by continuously increasing implantation rates of RSA in fracture care in a modern material design. Future research is needed to establish potential superiorities and the best surgical option in younger patients.

However, there are several limitations to this study. First, the study design was retrospective, and our preoperative documentation (except SRSA) did not collect all the tests and scores used in our follow-up study. Therefore, we argue with the term amelioration only in the SRSA group with CS and nCS.

Second, the follow-up period is mid-term, and the complication rate might increase with time. Next, group sizes regarding patient numbers and FU were inconstant; this aspect is well comparable to literature data in this patient sample. Furthermore, the study was conducted only using reverse total shoulder systems with cemented humeral components, and direct comparisons to its contemporaries the cementless RSA

systems cannot be drawn. Lastly, multiple surgeons (four experienced trauma and orthopedic surgeons) were involved, and no comparisons regarding their personal experiences and outcome were performed.

Conclusions

The similar mid-scale/-term findings of both strategies confirm the value of RSA in complex shoulder fracture management as a primary or secondary / salvage care to maintain autonomy. Predictable, promising mid-term functional results, a high patient satisfaction, and excellent pain reliefs could be demonstrated.

In SRSA, significant postoperative improvements could be stated. The time from index surgery to operative revision represented no statistically significant factor for clinical outcome.

A satisfactory total tubercle healing rate was proven, whereby a significant increase of radiographic changes was revealed in PRSA. Statistically significant improvements in functional findings by healed tubercles were shown. Further, no statistically significant correlations of notching regarding PRSA or SRSA differentiation were observable in a modern material design.

In our setting, RSA has become a successful and effective option for complex proximal humeral situations with inadequate bone stock. FRSA burdened by a low complication rate requiring further surgery and a reasonable implant survival rate, whereby a specific patient selection should occur due to the few available options in the case of RSA failure.

Abbreviations

ASA anatomical shoulder arthroplasty, AUVA Austrian Social Insurance for Occupational Risks, CS absolute Constant Score, ER external rotation, fORIF failed open reduction and internal fixation, FRSA fracture reverse total shoulder arthroplasty, FU follow-up, HA hemiarthroplasty, HHN humeral head necrosis, IR internal rotation, nCS normative Constant Score, ORIF open reduction and internal fixation, QD Quick DASH, *p* *p*-value, po points, PHF proximal humeral fractures, ρ Spearman's Rho correlation coefficient, ROM range of motion, RSA reverse total shoulder arthroplasty, PRSA primary reverse total shoulder arthroplasty, SANE Single Assessment Numeric Evaluation, SD standard deviation, SRSA secondary reverse total shoulder arthroplasty, SSV Subjective Shoulder Value, THA trauma hemiarthroplasty, VAS Visual Analog Scale.

Declarations

Ethics approval and consent to participate

The study protocol was approved by the local ethics committee (Votum EK 32/2017) of the Austrian Social Insurance for Occupational Risks (AUVA), and was performed in agreement with the protocol. The

study was performed in accordance with the principles of the Declaration of Helsinki and the ICH-GCP Guidelines. Informed consent was written obtained from all individual participants included in the study.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author at a reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors contributions

AS was responsible for the initiation of the study, analysis of the data, the first draft of the manuscript and contributed significantly with the input from MP to the final draft of the manuscript. MP had the original idea of the study, initiated the study, participated in critical revision of the article for important intellectual content and supervision. AS and MP worked out the study design, all authors conceived the study protocol.

All authors were involved in drafting of the manuscript and approved the final version to be submitted for publication.

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Tables

Table 1: ROM of PRSA versus SRSA

ROM	PRSA	SRSA	P-value
Flexion	125° (SD: 39.6)	122° (SD: 35.3)	.598
Abduction	118° (SD: 38.2)	107° (SD: 32.3)	.184
ER	17° (SD: 18.7)	14° (SD: 17.8)	.552
IR	4 po (SD: 2.6)	3 po (SD: 1.9)	.169

No statistical relevancies were observed by differentiation in PRSA and PRSA; good functional results could be shown in both groups. Flexion, abduction, and ER are depicted in degrees, IR in points according to a subitem of Constant Score. The values are presented on average.

(ER – external rotation, IR – internal rotation, po - points ROM – range of motion, FRSA – fracture reversed total shoulder arthroplasty, PRSA – primary reversed total shoulder arthroplasty, SRSA – secondary reversed total shoulder arthroplasty, SD – standard deviation)

Table 2: ROM of SRSA

ROM	HHN SRSA	fORIF SRSA	THA SRSA
Flexion	137° (SD: 27.1)	**96° (SD: 34.6)**	142° (SD: 22.2)
Abduction	117° (SD: 29.6)	**85° (SD: 23.6)**	137° (SD: 25.0)
ER	13° (SD: 17.0)	7° (SD: 6.3)	27° (SD: 21.3)
IR	3 po (SD: 1.3)	3 po (SD: 1.4)	5 po (SD: 3.5)

A statistically relevant decrease of flexion (p = .046) and abduction (p = .037) was revealed in the SRSA subgroup following fORIF; all other values were similar. Flexion, abduction, and ER are depicted in degrees, IR in points according to a subitem of Constant score. Significant results are bold-marked. The values are presented on average.

(ER – external rotation, fORIF SRSA – reversed total shoulder arthroplasty following failed open reduction and internal fixation, HHN RSA – reversed total shoulder arthroplasty following humeral head, IR – internal rotation, po – points, ROM – range of motion, SD – standard deviation, THA - SRSA – reversed total shoulder arthroplasty following trauma hemiarthroplasty)

Table 3: Scores of PRSA versus SRSA

SCORES	PRSA	SRSA	P-value
VAS	1.1 (SD: 2.0)	0.9 (SD: 1.3)	.573
CS	60 (SD: 16.7)	56 (SD: 15.1)	.204
nCS	74 (SD: 19.7)	69 (SD: 18.1)	.211
QD	23 (SD: 20.7)	25 (SD: 16.7)	.291
SSV	76% (SD: 18.7)	75% (SD: 15.1)	.558

Similar results without statistical significance were evaluated in all scores. The SSV is displayed in percent, all other scores in points. The values are presented on average.

(CS – absolute Constant Score, nCS – normative Constant Score, FRSA – fracture reversed total shoulder arthroplasty, PRSA – primary reversed total shoulder arthroplasty, QD – Quick DASH, SD – standard deviation, SRSA – secondary reversed total shoulder arthroplasty, SSV – Subjective Shoulder Value, VAS – Visual Analog Scale)

Table 4: Scores of SRSA

SCORES	HHN SRSA	fORIF SRSA	THA SRSA
VAS	0.7 (SD: 1.3)	1.3 (SD: 1.5)	0.5 (SD: 1.0)
CS	58 (SD: 13.1)	52 (SD: 16.9)	69 (SD: 9.1)
nCS	70 (SD: 15.7)	62 (SD: 20.5)	83 (SD: 11.0)
QD	19 (SD: 9.2)	34 (SD: 22.2)	18 (SD: 7.6)
SSV	78% (SD: 15.5)	72% (SD: 16.2)	78% (SD: 12.6)

The subgroup differentiation revealed no statistical significance and comparable results in all groups (all scores $p \geq 0.05$). The SSV is displayed in percent, all other scores in points. The values are presented on average.

(CS – Constant Score, fORIF SRSA – reversed total shoulder arthroplasty following failed open reduction and internal fixation, HHN SRSA – reversed total shoulder arthroplasty following humeral head necrosis, nCS – normative Constant score, PRSA – primary reversed total shoulder arthroplasty, QD – Quick DASH, SD – standard deviation, SRSA – secondary reversed total shoulder arthroplasty, SSV – Subjective Shoulder Value, THA SRSA – reversed total shoulder arthroplasty following trauma hemiarthroplasty, VAS – Visual Analog Scale)

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Table 5: Clinical outcome of early versus late time from index to SRSA surgery

SCORES	<12 MONTHS	>12 MONTHS	P-value
VAS	0.95 (SD: 1.2)	0.875 (SD: 1.4)	.885
CS	55 (SD: 14.1)	57 (SD: 16.1)	.831
nCS	68 (SD: 16.8)	69 (SD: 19.4)	.883
QD	27 (SD: 21.7)	23 (SD: 13.1)	.533
SSV	75% (SD: 16.0)	76% (SD: 14.5)	.882

No statistical relevancies were observed; good functional results could be shown in both groups. The SSV is displayed in percent, all other scores in points. The values are presented on average.

(CS – Constant Score, nCS – normative Constant Score, QD – Quick DASH, RSA – reversed total shoulder arthroplasty, SD – standard deviation, SRSA – secondary reversed total shoulder arthroplasty, SSV – Subjective Shoulder Value, VAS – Visual Analog Scale)

Table 6 - Radiographic tubercle changes of PRSA and SRSA

LOCALISATION	PRSA	SRSA	P-value
Major tubercle	31% (n = 13/42)	11% (n = 2/26)	
Minor tubercle			
Both tubercles	9% (n = 4/42)		
TOTAL	***40% (n = 17/42)***	***8% (n = 2/26)***	***.006***

Statistically, significant positive tubercle changes were evaluated in the PRSA group; radiological changes contained dislocations and (partial) resorptions in this group. In the SRSA group, only postoperative partial resorptions were detected. Significant values are bold-marked.

(PRSA – primary reversed total shoulder arthroplasty, SD – standard deviation, SRSA – secondary reversed total shoulder arthroplasty)

Table 7 – Clinical outcome of healed versus non-healed tubercles

SCORES and ROM	HEALED	NON-HEALED	P-value
VAS	0.7 (SD: 1.3)	1.6 (SD: 2.5)	.162
CS	**62 (SD: 14.1)**	**52 (SD: 19.5)**	**.029**
nCS	**75 (SD: 17.3)**	**64 (SD: 22.7)**	**.021**
QD	**19 (SD: 13.4)**	**34 (SD: 25.4)**	**.002**
SSV	**79% (SD: 14.4)**	**68% (SD: 21.0)**	**.017**
Flexion	129° (SD: 36.4)	114° (SD: 39.6)	.125
Abduction	118° (SD: 37.7)	107° (SD: 35.3)	.245
ER	**19.79° (SD: 19.1)**	**8° (SD: 15.8)**	**.019**
IR	4 po (SD: 2.2)	3 po (SD: 2.6)	.355

Significant positive values were observed via healed tubercles. Flexion, abduction, and ER are displayed in degrees, IR in points according to a subitem of Constant Score. The SSV is displayed in percent, all other scores in points. Significant results are bold-marked. The values are presented on average.

(CS – Constant Score, ER – external rotation, IR – internal rotation, nCS – normative Constant Score, po – points, QD – Quick DASH, ROM – range of motion, SD – standard deviation, SSV – Subjective Shoulder Value, VAS – Visual Analog Scale)

Table 8 - Grade of scapular notching of PRSA and SRSA

NOTCHING	PRSA	SRSA	P-value
Grade 1	14% (n = 6/42)	12% (n = 3/26)	.598
Grade 2	5% (n = 2/42)	15% (n = 4/26)	.684
Grade 3	2% (n = 1/42)		
Grade 4			
In total	*21% (n = 9/42)*	*27% (n = 7/26)*	.687

Similar notching rates without statistical relevance were observed in both groups.

(PRSA – primary reversed total shoulder arthroplasty, SD – standard deviation, SRSA – secondary reversed total shoulder arthroplasty)

Table 9 - Adverse events

	EVENT	MONTHS	INTERVENTION	CLASSIFICATION
1	spontaneous muscle hematoma (OAC)	60	conservative	**minor**
2	spontaneous muscle hematoma (OAC)	35	conservative	**minor**
3	instability with dislocation	10	inlay change	**major**
4	major tubercle impingement	7	conservative	**minor**
5	traumatic periprosthetic fracture (accident)	131	ORIF	**major**
6	scapular spine fracture	116	conservative	**minor**
7	shaft loosening	70	conservative (non vult)	**major**
8	traumatic periprosthetic fracture (fall)	25	ORIF	**major**
9	plexus neuropraxia	perioperative	conservative	**minor**

Displayed are major and minor complications of total FU in all patients. Their several time- and event-specifications are depicted. The time from RSA implantation to each adverse event is presented in

months. The numbers from 1 to 7 involve PRSA patients, from 8 to 9 SRSA patients. Multiple events are possible in one patient.

(FU – follow-up, OAC - oral anticoagulants, ORIF – open reduction and internal fixation, PRSA – primary reversed total shoulder arthroplasty, RSA – reversed total shoulder arthroplasty, SRSA – secondary reversed total shoulder arthroplasty)

Figures

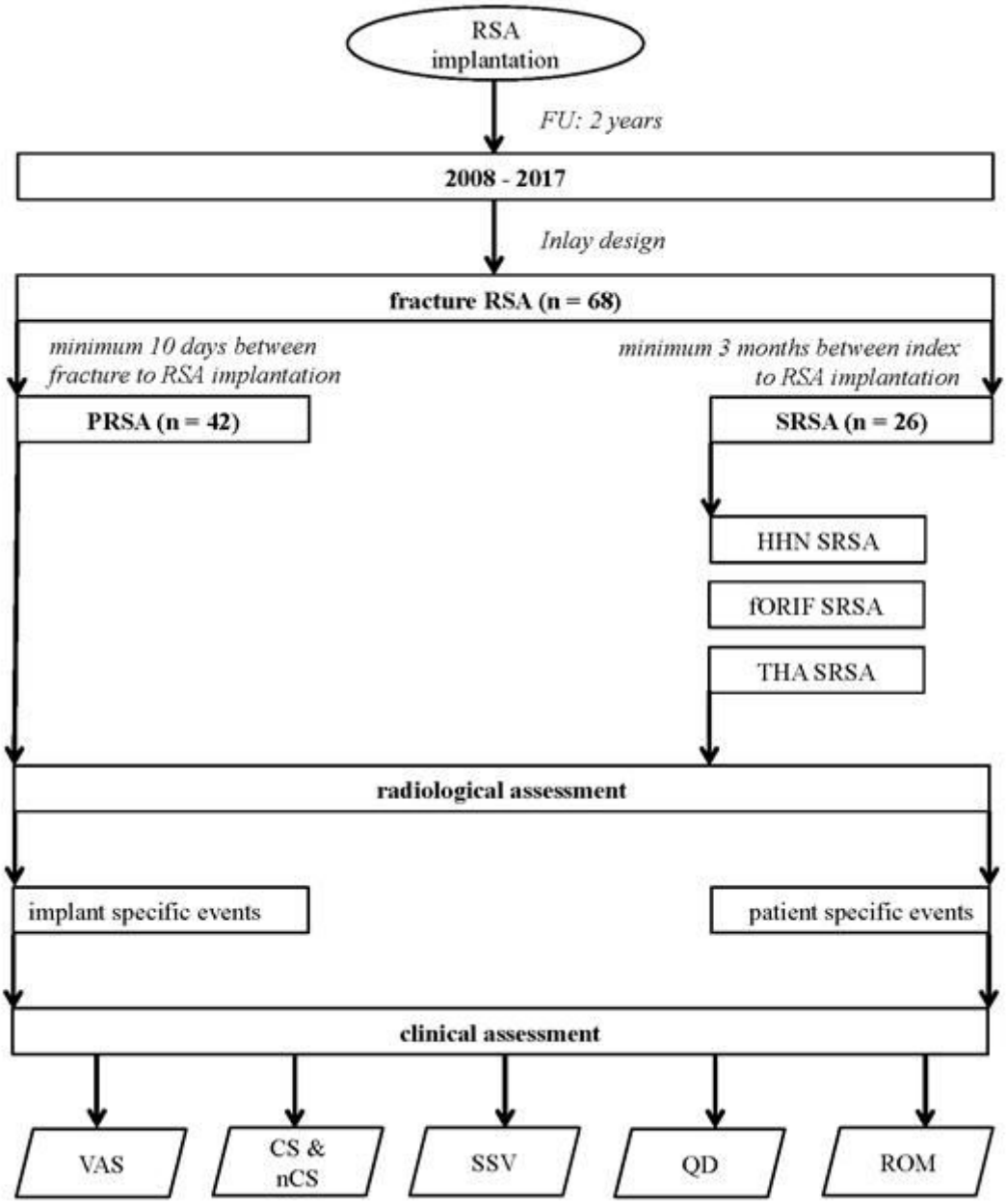

Figure 1

Study design: A flowchart regarding group and subgroup assessments illustrates the study focuses. (CS – Constant score, fORIF SRSA – reversed total shoulder arthroplasty following failed open reduction and internal fixation, FU – follow-up, HHN SRSA – reversed total shoulder arthroplasty following humeral head necrosis, nCS – normative Constant score, QD – Quick Dash, PRSA – primary reversed total shoulder arthroplasty, ROM – Range of motion, RSA – reversed total shoulder arthroplasty, SRSA – secondary reversed total shoulder arthroplasty, SSV – Subjective shoulder value, THA SRSA – reversed total shoulder arthroplasty following trauma hemiarthroplasty, VAS – visual analog scale)

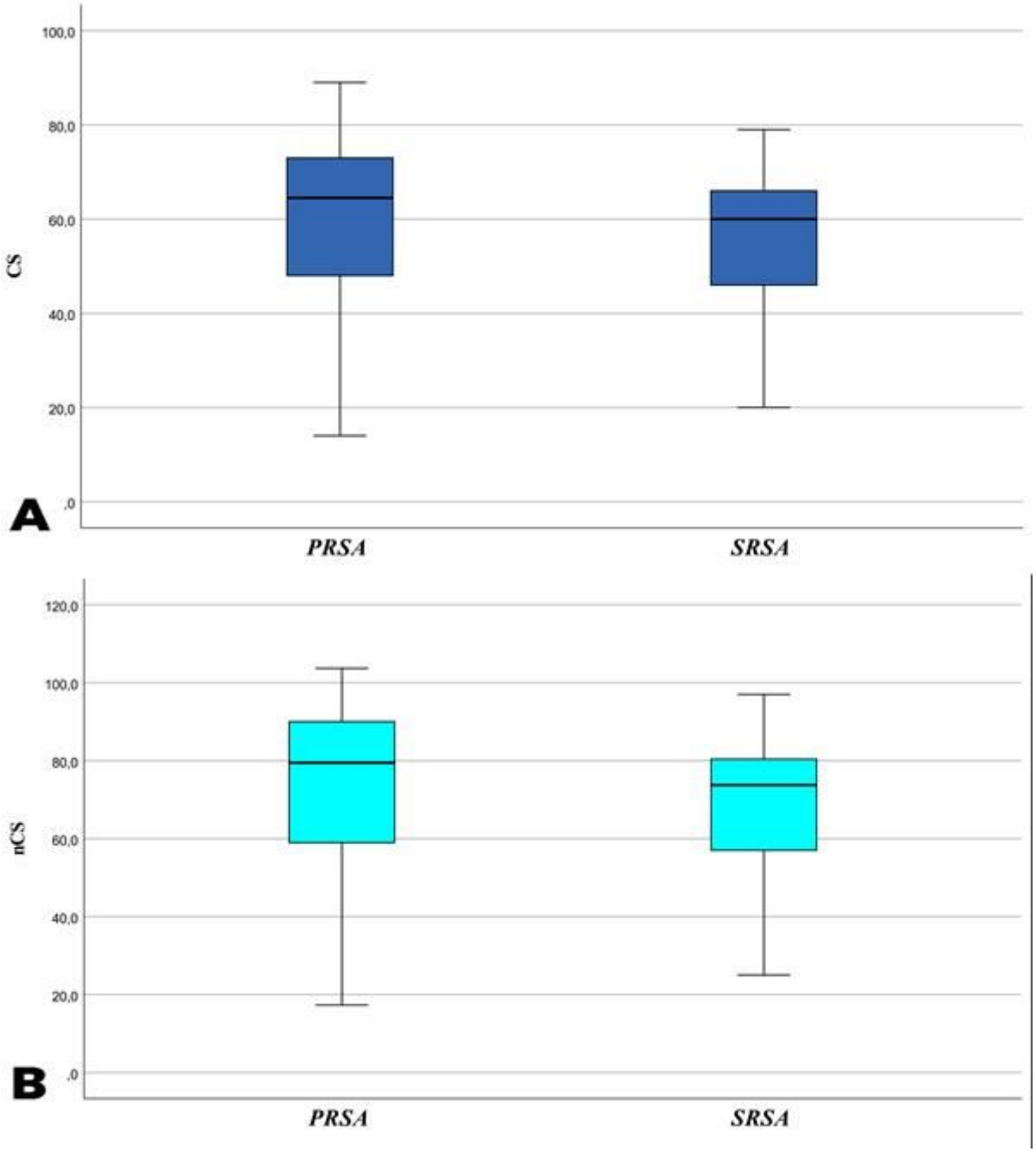

Figure 2

CS and nCS outcome of PRSA versus SRSA: No statistical significance was interpreted in CS (A - dark blue) as well as nCS (B - light blue). The range of data is similar, whereby a broader outlier spectrum was

to observe in the PRSA group. (CS – absolute Constant score, nCS – normative Constant score, PRSA – primary reversed total shoulder arthroplasty, SRSA – secondary reversed total shoulder arthroplasty)

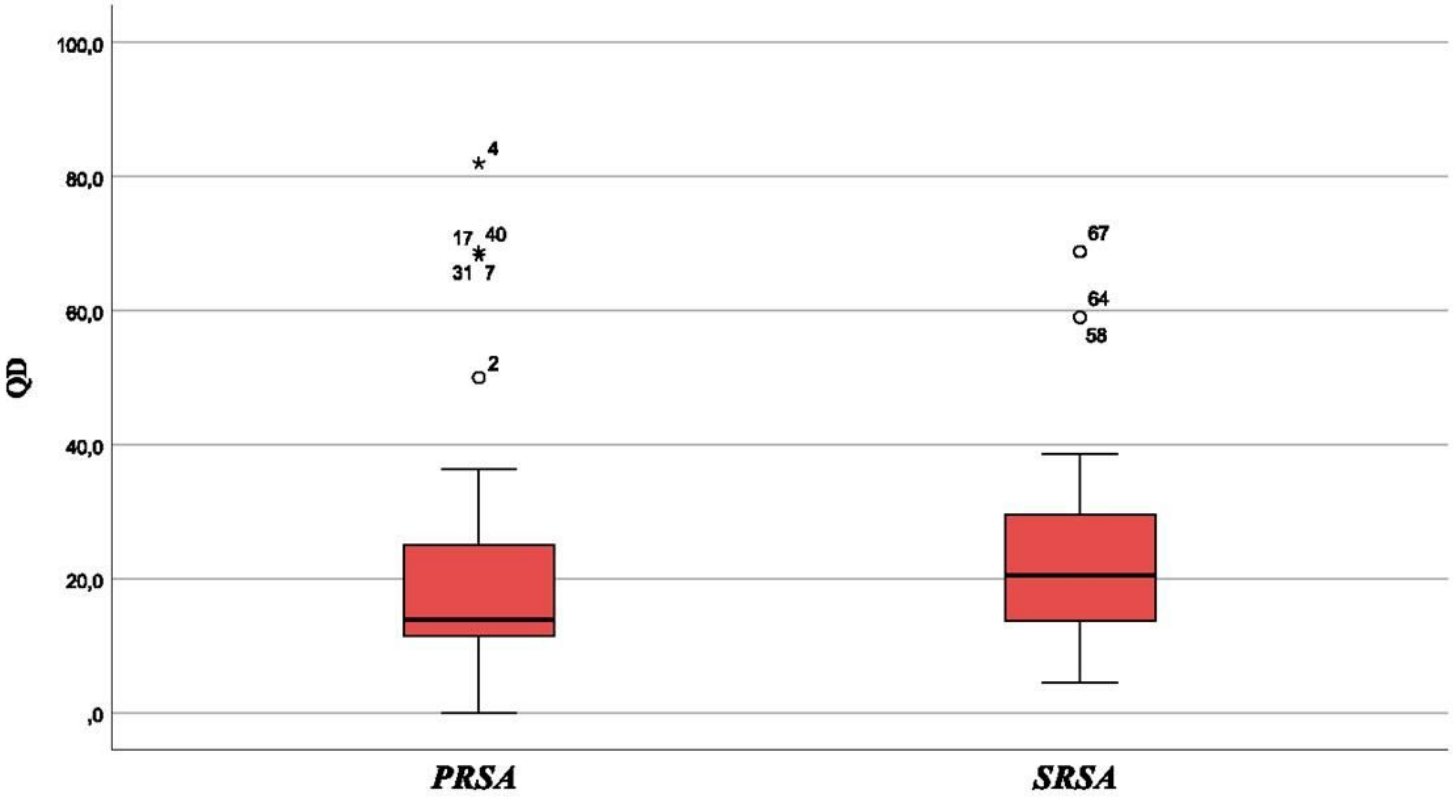

Figure 3

QD outcome of PRSA versus SRSA: No statistical significance was to reveal in QD. A broader outlier spectrum was observed in the PRSA group; the strongest outliers are displayed via a star. (QD – Quick Dash, PRSA – primary reversed total shoulder arthroplasty, SRSA – secondary reversed total shoulder arthroplasty)

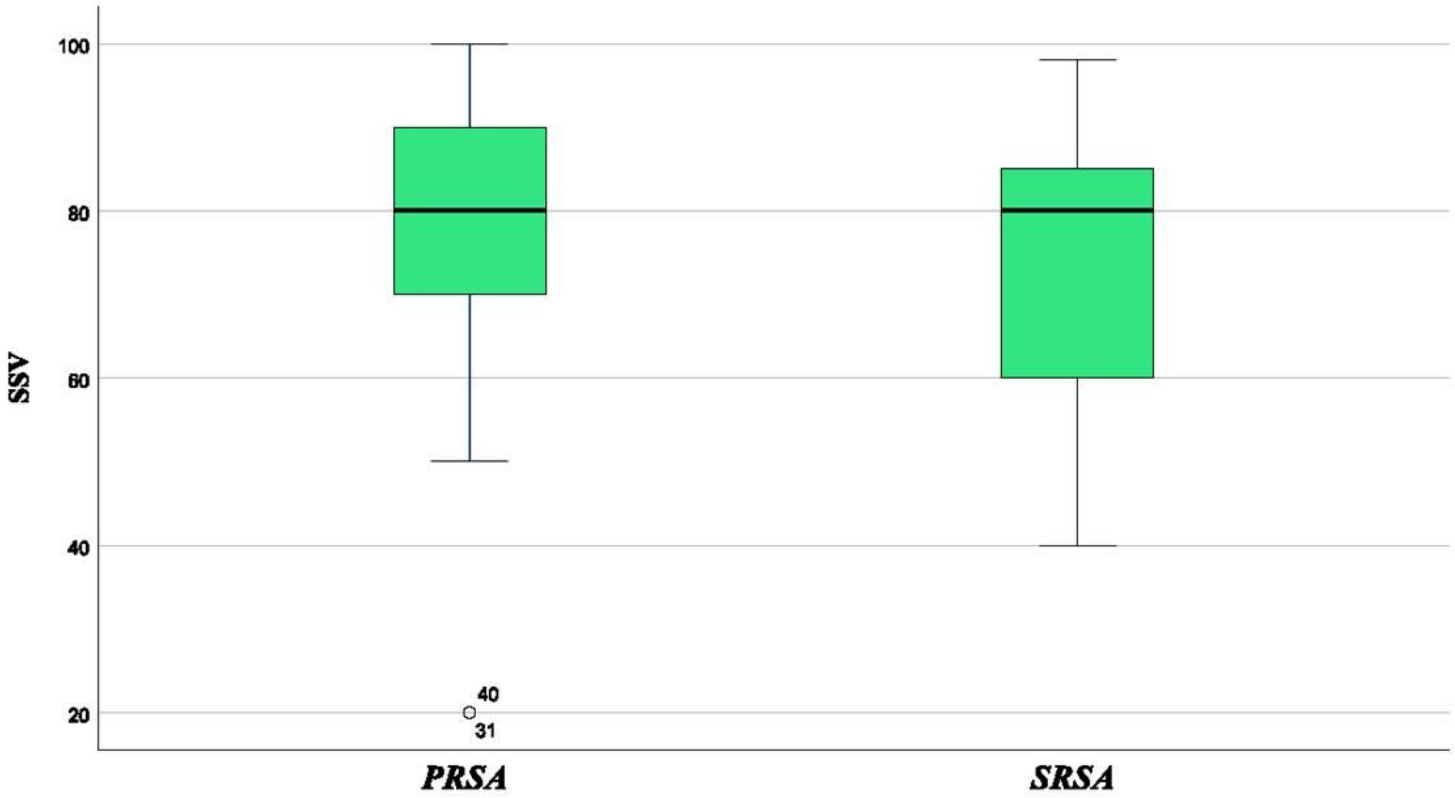

Figure 4

SSV outcome of PRSA versus SRSA: A well-balanced patient satisfaction was to reveal in SSV in both groups without any statistical significance. (PRSA – primary reversed total shoulder arthroplasty, SRSA – secondary reversed total shoulder arthroplasty, SSV – Subjective Shoulder Value)

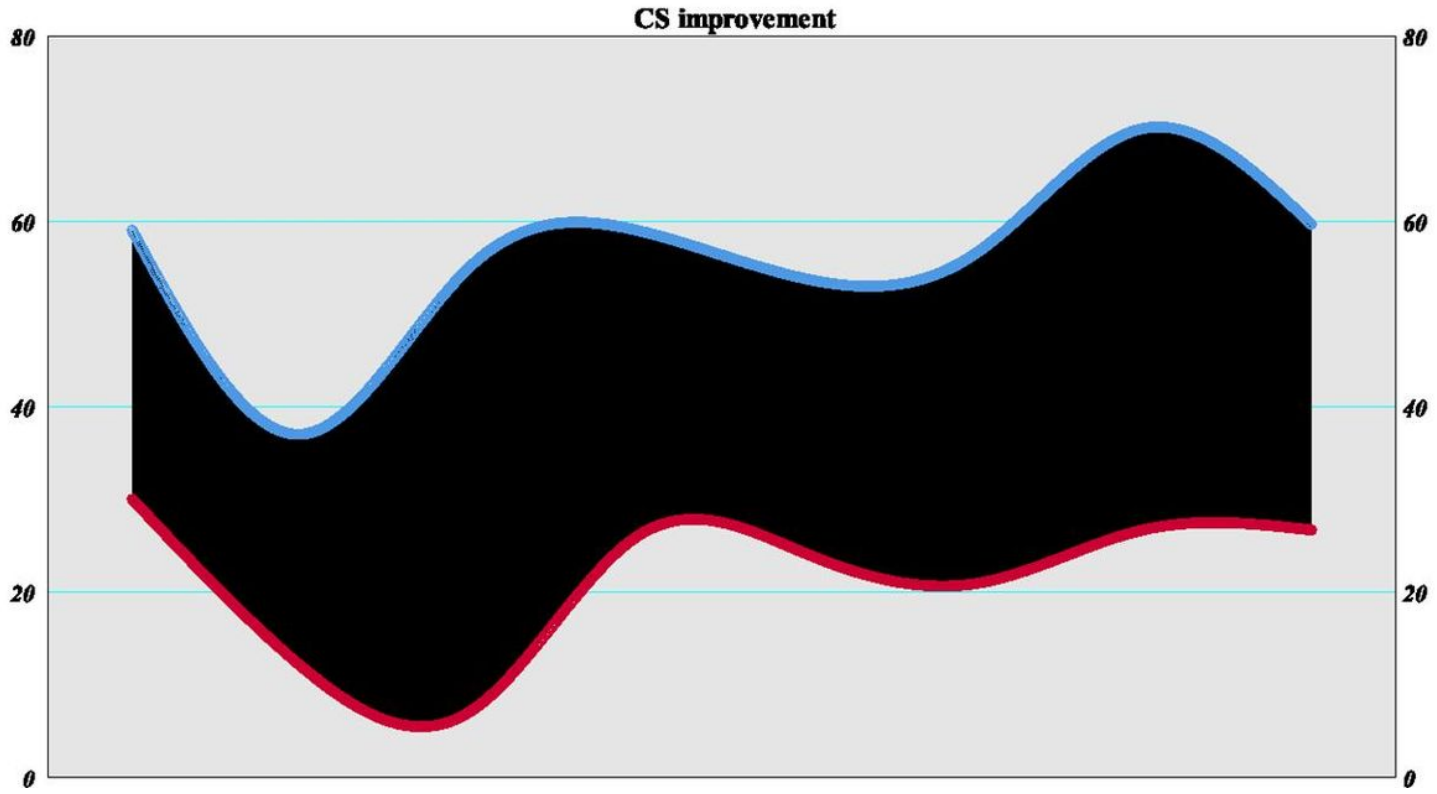

Figure 5

CS improvement of SRSA: The values from preoperative to final FU results are displayed in an area graph plot. The red line represents the preoperative, the blue line the postoperative values of final control examination. A significant improvement could be shown, p = .001. (CS – absolute Constant Score, FU – follow-up, P = P-value, SRSA – secondary reversed total shoulder arthroplasty)