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Is bone grafting always necessary in revision reverse total shoulder arthroplasty with uncontained glenoid bone defects?

Running Title: treating uncontained glenoid defects in RTSA

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This study was executed with approval of the Ethical Committee of the University of Ghent (2019/1931).

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ABSTRACT

Background

Patients with an uncontained glenoid bone defect can still successfully undergo a reverse total shoulder arthroplasty (RTSA). Currently there is a tendency towards reconstruction of the premorbid glenoid plane with bone grafts which is technically demanding. We investigated if central peg positioning in the spine pillar (CPPSP) is a more feasible alternative to the use of bone grafts.

Methods

60 revisions to a RTSA with uncontained glenoid bone defects were included in this study. Patients were treated with bone grafts in 29 cases and with the CPPSP technique in 31 cases. We assessed clinical results using the Constant score and assessed the complication ratio.

Results

In the CPPSP group the Constant score changed from 42 to 69 points. In the bone graft group it changed from 47 to 60 points. This difference in increase in Constant score was significant (p=0.031), due to a significant difference in strength, in favor of the CPPSP group. The overall complication rate was 37,7% (20/53) with a reoperation rate of 18,9% (10/53). Dislocations occurred only in the CPPSP group (n=3) and loosening of the glenoid occurred only in the bone graft group (n=3).

Conclusion

Patients with uncontained glenoid bone defects undergoing a revision to a RTSP obtain similar clinical results with the CPPSP technique compared to the use of bone grafts. The CPPSP technique is a valid alternative but has different complications.

Level of evidence: Level III; Retrospective Cohort Comparison; Treatment Study

Keywords revision/RTSA/glenoid bone loss/spine pillar

Complication rates after revision reverse total shoulder arthroplasty (RTSA) are approximately twice as high compared to primary RTSA [18]. One important reason for this higher rate is bone loss at the glenoid side [18]. Antuna *et al* found large combined glenoid defects during revision arthroplasty in 30 percent of cases [1].

To date, there is no agreement on how to treat these glenoid bone defects. Different surgical options include augmented glenoid baseplates [15], prosthetic lateralization [7], bony increased offset reversed shoulder arthroplasty [5], patient-specific instrumentation and custom-made implants [8 27]. In all these previously described techniques, the aim is to restore the native joint line and to obtain an adequate baseplate fixation. To obtain this primary stable fixation, it is important to have the central plot of the baseplate fixed into the remaining glenoid bone. However, when reconstructing the native glenoid plane, this means in the anatomic version, it is sometimes difficult/impossible to prepare the central plot with the cannulated stop drill ø 7.5 mm (+10 or +15mm) without causing a fracture or blowout of the anterior wall. Resulting in a weaker screw dependent fixation (Figure 1) [2].

Instead of restoring the premorbid glenoid plane and jeopardizing the primary fixation of the baseplate, another possibility is to primarily focus on a strong fixation of the base plate in the remaining bone. The spine pillar of the scapula can provide a strong bony fixation of the baseplate, since it has a greater bone density and longer pegs and screws can be used [16]. As

Lung *et al* mentioned: the initial fixation depends on bone density, a longer central peg and longer screws, not the number nor the angulation of the screws [19]. To obtain this fixation in the spine pillar the baseplate needs to be oriented with a downward (+/-24°) and anterior tilt (+/-15°) to the premorbid glenoid plane [16].

The aim of this study is to evaluate the short-term outcome of two different surgical techniques in treating uncontained glenoid bone defects in revision to a reverse shoulder arthroplasty. The two different techniques are central peg positioning in the spine pillar (CPPSP) and reconstruction of the premorbid glenoid plane using tricortical iliac crest autografts and femoral allografts (Figure 2).

MATERIAL AND METHODS

Patient selection.

In this monocentric, retrospective study a total of 216 patients undergoing revision reverse shoulder arthroplasty between January 2010 and December 2018 were screened for eligibility. Inclusion criteria were a previously anatomic or reverse total shoulder replacement with uncontained glenoid bone defects. Central or superior defects were categorized as contained and combined central and peripheral defects as uncontained [21]. The type of glenoid bone defect was decided peroperatively. Hence, scattering on Computed Tomography (CT) and the removal of glenoid baseplate, which can lead to new bone defects, make the preoperatively determination of these defects difficult. Patients undergoing a primary reverse shoulder arthroplasty with uncontained glenoid bone defects were not included in this study. We were able to withhold 60 cases.

Surgical technique.

All surgeries were performed by the same senior surgeon. The deltopectoral approach was used in all cases, with a Redfern-Wallace approach to be able to visualize the glenoid perfectly for removing the glenoid baseplate and evaluating the amount of bone loss [26]. The humeral osteotomy according to Gohlke was used in case the stem could not be removed with a vertical osteotomy [11].

All patients underwent a revision surgery with the Delta XTEND baseplate and glenosphere (Delta Xtend prosthesis (DePuy Synthes, Warsaw, IN, USA)). This prosthesis has a fixed humeral inclination of 155°. Different central peg lengths at the baseplate are available (13,5 mm, +10, +15 mm with ø 7.5 mm). In this study different peg lengths were used, according to the amount of medialization of the glenoid due to the uncontained bone defect. The screws can be inserted with a locking mechanism in a variable angle. Glenospheres of 42 and 38 mm were used, centric or eccentric. In eccentric glenospheres an extra prosthetic offset of 2 mm is offered. The prosthetic center of rotation in situated at the subchondral plate to overcome prosthetic stress rising.

The bone grafts were introduced according to the technique of Gohlke *et al* and according to the recommendation of Wagner *et al* and to Gupta *et al* [12,13,29]. An example of a case treated with bone grafts is illustrated in Figure 3.

We always used iliac crest autografts or allografts from a femoral head, delivered by our bone bank. We tailored the grafts to optimize the area of contact with the native glenoid bone and to restore at least the original native glenoid plane. A few millimeters of lateralization was accepted according to the bio-RSA technique [5]. All grafts were initially fixed with K-wires to allow for classic glenoid reaming over the centrally positioned K-wire that was positioned in native glenoid bone. We always perforated the medial cortical glenoid bone to ensure that the central plot was always fixed into the natural glenoid bone. The glenoid graft was compressed by hammering and compressing the central plot in the original glenoid. It was fixed with at least two compressive and angulated stable screws. The initial k-wires were removed after the baseplate was considered mechanically stable.

For the CPPSP technique, the K-wire was used to find the longest bony pillar of the spine (the direction is always downward tilted and in anteversion to the native glenoid). Once the pillar was identified, the proximal cortex was perforated with this K-wire. Next, reaming of the glenoid surface was performed with the Glenoid Resurfacing Reamer Diameter 27 mm until a minimum of 50% of contact area with the baseplate could be reached. This in an effort to minimize the medialization of the prosthetic center of rotation. Afterwards the K-wire was subsequently over drilled with the cannulated drill of ø 7.5 mm. The proximal cortex was always drilled to ensure a bicortical fixation of the baseplate. The length of this spine pillar was measured with the cannulated drill (+ 10 mm or + 15 mm). Then, the baseplate was introduced and if possible, cancellous bone was squeezed between the premorbid glenoid and the baseplate. At last, a reinforcement of the baseplate fixation was accomplished by means of minimal 2 and maximal 4 angulated screws. Figure 4 illustrates a case treated with the CPPSP technique with a reverse total shoulder arthroplasty angle of minus 16 degrees, and postoperatively an adjusted Constant score of 86 points.

Shoulder function and outcome.

The Constant score was determined by the surgeon himself or by the resident and was subdivided in total Constant score, total strength, total mobility, total pain, total activities of daily living (ADL). Next, the adjusted Constant score was calculated according to Katolik *et al* [17,24]. The difference between the pre- and postop adjusted Constant score was determined.

Radiographic measurements.

On a standard anteroposterior x-ray of the shoulder we have calculated the reverse shoulder arthroplasty angle [3]. Signs of loosening were evaluated by looking for radiolucency around the peg, screws and the humeral stem. Notching was evaluated according to the Nerot-Sirveaux classification. We have used the Suter-Henninger system to determine the quality of the anteroposterior x-rays to minimize defaults in measurement [28].

Statistics.

For the statistical analysis we have divided the patients in two different groups according to the applied surgical technique. Statistical analysis was processed using SPSS (Statistical Package for the Social Sciences, IBM Corp., Armonk, NY, USA). To evaluate if differences between the patient groups were significant, we have used the non-parametric Mann Whitney U test. The null hypothesis tested was that there is no significant difference between the adjusted Constant scores in the different patient groups. Statistical significance was set at $P<0{,}05$.

RESULTS

Patient population.

The mean age was 66 years (37-90 years, standard deviation 12) at the time of revision surgery. The mean time postoperative was 12 months, with a standard deviation of 158 days. The difference in age and time postoperative was not statistically significant (p= 0,830 and p= 0,431 respectively) between the defined groups. We have treated 27 males and 33 females. The right shoulder was involved in 38 cases, the left shoulder in 22 shoulders.

Indications.

The most encountered indications for revision include failed anatomic shoulder prothesis (23%) (aseptic loosening glenoid and rotator cuff lesions), loosening of the glenoid in RTSP (17%) and infections (13%). All indications for revision are listed in Table 1.

Shoulder function and outcome.

The postoperative adjusted Constant score (aCS) and the difference in pre- and postoperative aCS were statistically significant between the CPPSP group and the bone graft group (p= 0,031). Probably due to the difference in strength which differs significantly between the groups, in favor of the CPPSP group (p= 0,005). The elevation has a mean of 7 points in each group (105-120°), the abduction was 7 points (105-120°) in the CPPSP group and 6 points (91-105°) in the bone graft group. The mean endorotation was 4 in both groups. The mean exorotation was 7 in the CPPSP group and 6 in the bone graft group. Results are listed in table 2.

Radiographic measurements.

The reverse shoulder arthroplasty angle was minus 6,3 (±10,4) in the CPPSP technique group and 3,1 (±8,7) in the graft group. This difference was statistically significant (p = 0,001). Signs of loosening and notching are discussed in the complication section.

Complications.

Complications are listed in Table 3. The complication rate is 37,7% (20/53). The reoperation rate is 18,9% (10/53). It is noteworthy that dislocations occur in the CPPSP technique group, while loosening of the glenoid occurs in the graft group. Symptomatic loosening of the glenoid was always treated with a tricortical iliac crest autograft and a baseplate with a long peg. Dislocations were treated with revision and introduction either a bigger glenosphere with offset (42mm – n = 1) or a lengthener (+9mm – n = 2). All dislocations healed uneventfully.

Stress fractures around the scapula occurred in both groups. All of these fractures were treated by bracing and watchful waiting. All stress fractures have healed with time or became asymptomatic. We encountered two periprosthetic fractures: one was treated with plate screw osteosynthesis and one was revised with a long stem bypassing the fracture.

DISCUSSION

We investigated if the CPPSP technique without reconstruction of the premorbid glenoid plane, is a safe and good technique in terms of clinical results in case of revision surgery to a RTSA for uncontained glenoid bone defects.

Overall, we have seen a mean improvement in adjusted Constant score of 22 points. This was an improvement of 31 points for the CPPSP technique and 14 points for the bone graft group.

This difference was statistically significant, due to the difference in strength. The difference in mobility was not statistically significant. However, we have seen a mean improvement of 3 points (which equals 45°) of elevation in the CPPSP group, and 1 point (which equals 15°) in the bone graft group. However, the mean postoperative elevation was 7 points in both groups. Boileau *et al* discussed indications, complications and results of patients undergoing revision of reverse shoulder arthroplasty [4]. Compared to this article we see a similar improvement in elevation. Boileau *et al* mention a postoperative elevation of 111°, we have seen a similar postoperative result of 7 points, which equals 105°-120°. Furthermore, we noticed a similar increase in Constant score in the article of Boileau compared to the CPPSP technique group (36 points and 31 points respectively) but not in the graft group (14 points). However, preoperative Constant scores were much lower in Boileau's group (26 compared to 44).

The complication ratio of this type of revision surgery is as high as 37,7% (20/53) with a reoperation rate of 18,9% (10/53). The most frequent encountered complications include stress fractures of the scapula (3/20), instability (3/20; only in the CPPSP group), glenoid loosening (3/20; only in the bone graft group) and complications related to the clavicle osteotomy (5/20). According to the review article of Chalmers *et al* and the article of Boileau *et al* the complication rate was between 12 and 50 percent in revision reverse shoulder arthroplasty [4,6]. Melis *et al* mention a 30% complication rate and 22% reoperations in their cohort with revisions of anatomical total shoulder arthroplasty to a RTSA [24]. Wagner *et al* mention 24% of reoperations in revision RTSA [30].

Dislocations occurred in the CPPSP group, probably due to the more medial situated center of rotation and to an insufficient lateralization of the humerus. The dislocations always occurred in the first weeks postoperative. This problem could be solved with the use of lengtheners in order to retention the deltoid muscle with permanent success. The rate of dislocation is similar to what is seen in the literature: 9,4% versus 5,7% (3/53) in our series [18].

Loosening of the glenoid occurred only in the bone graft group (11%; 3/27). Similar to the 18% of reoperations described by Wagner *et al* [30]. Loosening was seen before the extended (long) peg glenoid baseplates were commercially available. All patients were revised with a new structural autograft (tricortical iliac crest autograft) and a glenoid with a long peg, without re-occurrence of new complications.

The relative high occurrence of clavicle related complications is due to the used Redfern-Wallace approach (clavicle osteotomy) [26]. Before the year 2018 we only used only Nice knots for osteo-suturing the osteotomy [25]. Since the year 2018 we started using an intramedullary K-wire of 2,5 mm to reinforce this osteosynthesis after which we have seen no clavicle related complications anymore.

Our radiological results demonstrate clearly the non-anatomical positioning of the baseplate. In the CPPSP group the reverse shoulder arthroplasty angle is negative (-6,3°), whereas in the graft group this angle is positive (3,1°) similar to the results described by Boileau [3]. Unfortunately, we were not able to include radiographical confirmation of the non-anatomical anteversion of the baseplate. As previously described, the anteversion would be about 15° according to the article of Karelse *et al*.

We used the spine pillar as a primary fixation point for the peg of the baseplate, and reinforced this fixation with screws. However, Frankle *et al* mentioned that the pillar can be affected in 17.6% of the cases with severe cuff tear arthropathy [10]. In contrast, a recent systematic review on bone grafting in primary and revision RTSA stated that the glenoid bone defect was only graded in six out of the thirteen studies (46.2%) [20]. And more importantly, none of these studies mentioned damage at the spine pillar. It is our personal experience that the spine pillar can almost always be found and provides a strong bony fixation for the glenoid peg. This primary stable fixation is offered at the medial side by the cortex of the end of the spine pillar and at the glenoid side by a surface of native bone of the glenoid. In accordance with the principles of Formaini *et al* we guaranteed at least 50% of native bone contact with the baseplate [9].

These results suggest that the CPPSP technique is a valid method for treating uncontained bone defects at the glenoid side in revision to a reverse shoulder arthroplasty. Postoperative results are at least comparable to the results of bone grafting. We consider the technique of downward tilting and a more inferior placement of the baseplate especially useful in revision surgery. An advantage is that no extra surgical skills are needed to perform this technique which also benefits the duration of the surgery.

Another advantage of this technique is that it can be used in case of (suspected) infected total shoulder arthroplasty as a one stage revision technique. It eliminates the problem of graft subsidence, which is known to occur in case of infection [14]. Furthermore, the postoperative shoulder function is better in case of one stage revision surgery compared to two stage revision surgery in periprosthetic infected cases [22]. Our results are in accordance with Wagner *et al* who concluded that revision RTSA's that were treated with bone grafts had higher rates of glenoid loosening and implant failure than procedures in which bone graft [30].

A disadvantage of this technique is that the bone stock has not been rebuilt. Nevertheless, bone grafting can still be performed if needed in case of a second revision [20].
An additional drawback is that with the CPPSP technique the prosthetic center of rotation medialized which might result in a higher dislocation rate due to the loss of the stabilizing wrapping force. This tendency was confirmed by three early dislocations. Nevertheless, in the majority of cases the medialization did not interfere with the clinical results. These findings are in accordance with the experience of McFarland [23].

Finally, limitations of this study include the heterogenous patient population in terms of indication to revision. There might also be a selection bias in treating patients with one technique over the other. Since it is a retrospective study, patients were not treated according to randomization.
This is a single center study which results in insufficient power for most comparisons. However, we were able to show some trends and provide an alternative technique to treat an insufficient glenoid bone stock without grafts. This technique has comparable results in terms of clinical results to the use of bone grafts.
The follow-up was short, however the aim of this article was evaluating the non-anatomic reconstruction of the baseplate in revision to a RTSA for uncontained glenoid bone loss, and not the long-term results. Larger series and a longer follow-up are needed to confirm the specific complications in each group and the validity of this technique.

CONCLUSION

Our experience with the CPPSP technique is that it is a safe and straightforward technique in treating uncontained glenoid bone defects for revision reverse shoulder arthroplasty. Results are comparable to the results of bony lateralization with bone grafts. The use of bone grafts is complicated by glenoid loosening and the CPPSP technique is complicated by early dislocations. Early dislocations can be treated with lengtheners in order to retention the deltoid. We believe that the CPPSP technique is a valid technique in treating uncontained glenoid bone defects in case of revision surgery.

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TABLES AND FIGURES

Figure 1: When reconstructing the native glenoid plane, this means in the anatomic version, there is a risk of fracture or blowout of the anterior or posterior wall [2].

Figure 2: illustration of the bone graft technique (left) and the CPPSP technique (right). Center of rotation (COR) indicated with a red dot, showing a medialization of the COR in the CPPSP technique.

Figure 3: Example of a case treated with a tricortical bone graft and a long glenoid peg. Figure 3A preoperative x-ray, figure 3B postoperative x-ray.

Figure 4: Example of a case treated by the CPPSP technique. Figure 4A preoperative x-ray, figure 4B postoperative x-ray. The reverse shoulder arthroplasty angle is minus 16 degrees in this case.

Table 1: Indication for revision surgery – count in the different patient groups. ATSA: anatomic total shoulder arthroplasty; RTSA: reverse total shoulder arthroplasty; CPPSP: central peg positioning in the spine pillar.

Table 2: Clinical outcome of the two different surgical techniques. aCS: adjusted Constant score; CPPSP: central peg positioning in the spine pillar.

Table 3: Complications according to the different surgical techniques. CPPSP: central peg positioning in the spine pillar.

Table 1: Indication for revision surgery – count in the different patient groups. ATSA: anatomic total shoulder arthroplasty; RTSA: reverse total shoulder arthroplasty; CPPSP: central peg positioning in the spine pillar

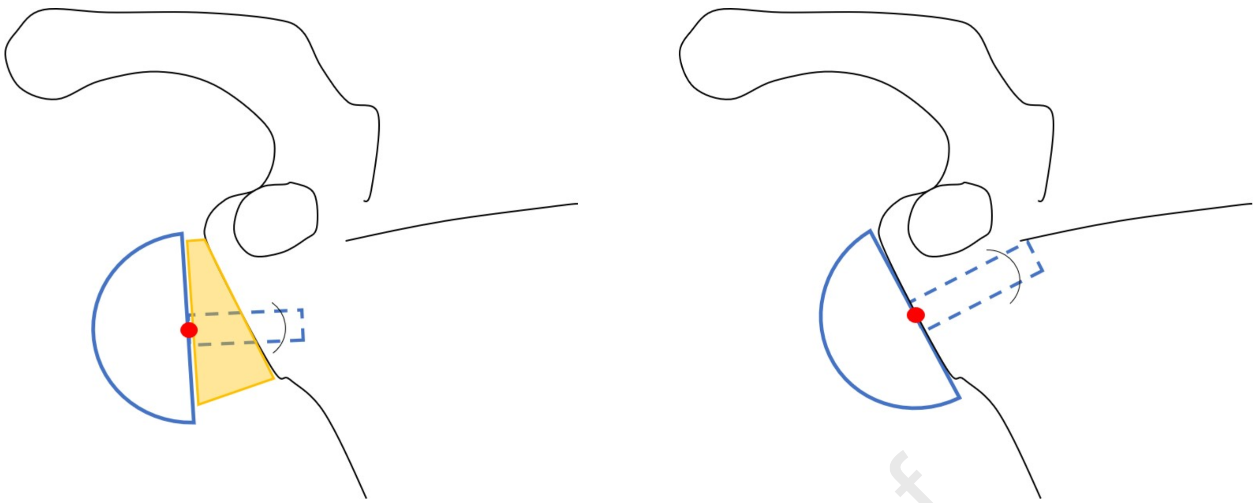
	CPPSP	*Bone graft*	*Total*	*Percentage*
Failed ATSA	6	8	14	23
loosening glenoid RTSA	1	9	10	17
Infection	7	1	8	13
Luxation RTSA	5	2	7	12
Painful RTSA	5	1	6	10
Failed hemi	1	4	5	8
Spacer (2 stage for infection)	1	3	4	7
Periprosthetic fracture	4	0	4	7
loosening humerus RTSA	1	1	2	3
Total	31	29	60	100

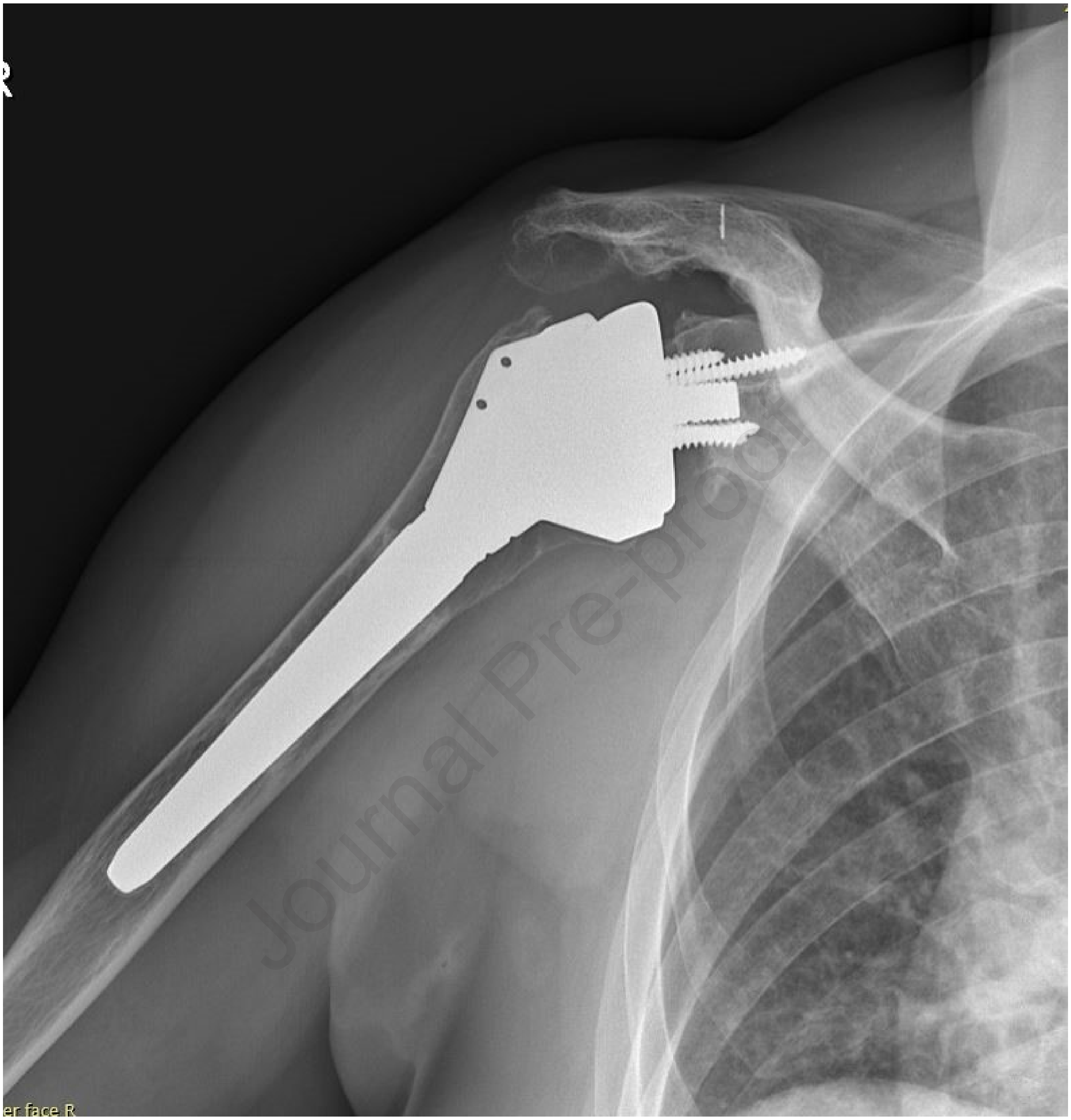
Table 2: Clinical outcome in terms of the Constant score of the two different surgical techniques. aCS: adjusted Constant score; CPPSP: central peg positioning in the spine pillar; SD: standard deviation.

			CPPSP		**bone graft**		**total**		**p-value**
			mean	SD	mean	SD	mean	SD	
adjusted CS preop			42	(±24)	47	(±21)	44	(±22)	0,395
	pain		7	(±4)	9	(±4)	8	(±4)	
	ADL		11	(±5)	11	(±4)	11	(±4)	
	mobility		15	(±11)	18	(±12)	16	(±11)	
		elevation	5	(±3)	5	(±3)	5	(±3)	
		abduction	5	(±3)	5	(±3)	5	(±3)	
		endorotation	2	(±2)	3	(±3)	3	(±3)	
		exorotation	3	(±4)	5	(±4)	4	(±4)	
	strength (kg)		3	(±5)	2	(±3)	3	(±4)	
adjusted CS postop			69	(±18)	60	(±20)	64	(±20)	0,110
	pain		12	(±3)	12	(±4)	12	(±4)	
	ADL		15	(±3)	15	(±4)	15	(±4)	
	mobility		25	(±10)	23	(±11)	24	(±10)	
		elevation	7	(±2)	7	(±3)	7	(±3)	
		abduction	7	(±3)	6	(±3)	6	(±3)	
		endorotation	4	(±2)	4	(±3)	4	(±3)	
		exorotation	7	(±4)	6	(±4)	7	(±4)	
	strength (kg)		6	(±4)	3	(±3)	5	(±4)	
difference in adjusted CS			31	(±24)	14	(±29)	22	(±28)	0,031
	pain		6	(±5)	3	(±6)	4	(±5)	0,091
	ADL		5	(±6)	3	(±5)	4	(±6)	0,302
	mobility		12	(±13)	5	(±14)	8	(±14)	0,103
		elevation	3	(±4)	1	(±4)	2	(±4)	0,161
		abduction	3	(±4)	1	(±4)	2	(±4)	0,095
		endorotation	2	(±4)	1	(±3)	2	(±4)	0,547
		exorotation	4	(±4)	2	(±5)	3	(±5)	0,111
	strength (kg)		5	(±5)	1	(±4)	3	(±5)	0,005

Table 3: Complications according to the different surgical techniques. CPPSP: central peg positioning in the spine pillar

Complication	*CPPSP*	*Bone graft*	*Total*
Clavicule fracture	2	2	4
non union clavicula	1	0	1
notching	0	2	2
Hematoma	0	1	1
loosening glenoid	0	3	3
glenoid graft resorption	0	1	1
Dislocation	3	0	3
Periprosthetic fracture	1	1	2
Stress fractures around the scapula	2	1	3
None	17	16	33
No follow up	5	2	7
Total	31	29	60

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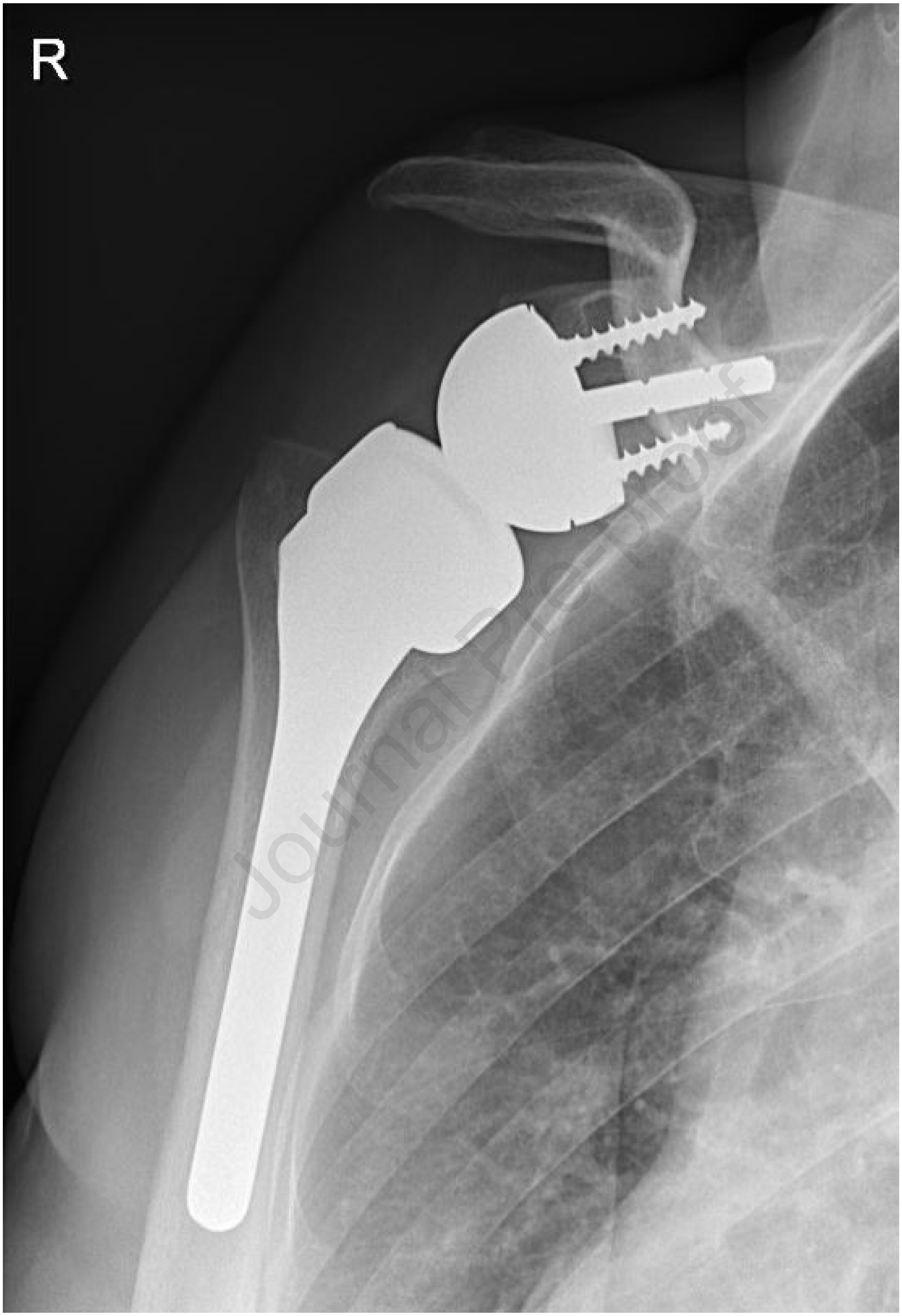
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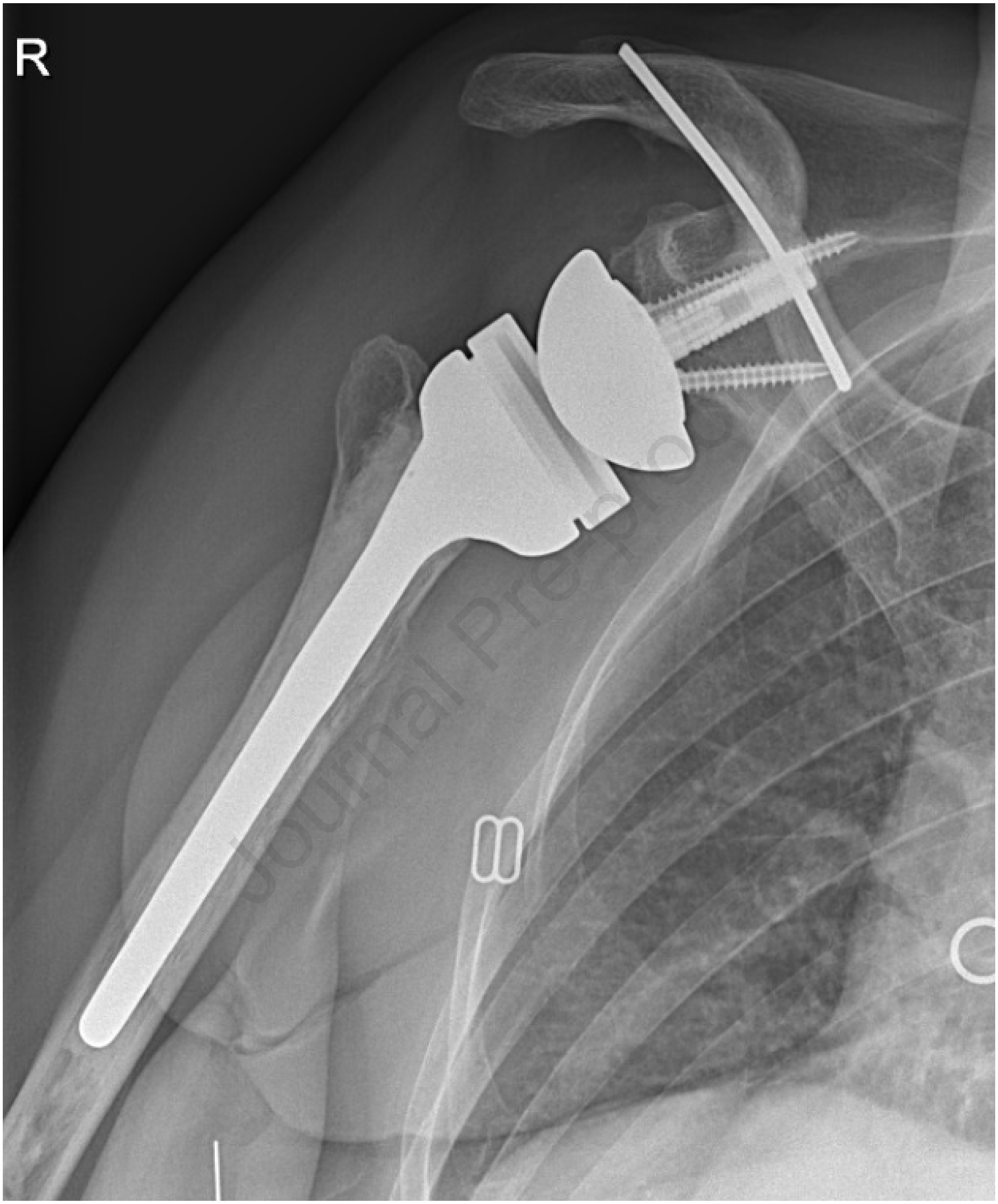
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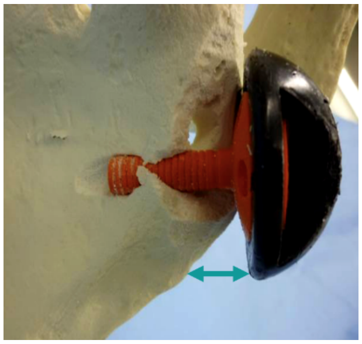


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