Title

Guided versus Freehand acromioplasty during rotator cuff repair. A randomized prospective study.

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Abstract

Introduction: There is no consensus on how to perform acromioplasty, particularly regarding the level and extent of bone resection, which depend on scapular and humeral morphologies.

Hypothesis: We aimed to determine whether computer-assisted acromioplasty planning helps surgeons remove impinging bone, reduce unnecessary resections, and improve short-term outcomes of rotator cuff tears (RCR).

Patients and Methods: We randomized 64 patients undergoing RCR of full-thickness supraspinatus tears into two groups: 'guided acromioplasty' (GA) and 'freehand acromioplasty' (FA). The pre- and post-operative scapula models were reconstructed using computed-tomography scans to quantify impinging bone removal, unnecessary bone resections, and identify zones of acromial bone removal. All patients were evaluated preoperatively and at 6 months to assess their range of motion (ROM), functional scores and tendon integrity using ultrasound.

Results: The two groups did not differ in demographics, clinical or morphologic characteristics. Compared to FA, GA tended to lower impinging bone removal (55±26% vs 43±27%, p=0.087) and to increase unnecessary resection of the total bone removed (49±22% vs 57±27%, p=0.248). GA resulted in significant anterior under-resection, while FA resulted in significant medial over-resection. Clinical outcomes and ROM improved significantly for all patients, except for internal rotation in the GA group. There were no other significant differences between the two groups, neither in terms of post-operative scores nor in terms of clinical net improvements, nor tendon repair integrity.

Conclusions: This computer-assisted planning for acromioplasty during RCR proved no benefits in terms of bone removal, tendon healing, or clinical outcomes. Nonetheless such planning tools could help less experienced surgeons improve the efficacy of acromioplasty.

Type of study: Therapeutic study

Level of proof: Level I, Randomized controlled trial

Keywords: Shoulder; Subacromial impingement; Acromioplasty; 3D surgical planning; Rotator cuff repair; Guided versus freehand

Introduction

It is still controversial whether non-traumatic rotator cuff tears are caused by compression of tendons against the acromion, also called subacromial impingement (extrinsic mechanism) [1], or by overload of degenerative tendons (intrinsic mechanism) [2]. Subacromial impingement of the rotator cuff has been reported to be the most common shoulder disorder [3], and various surgical treatments have been proposed, including acromionectomy [4], and lateral [5] or anterior acromioplasty [6]. Nowadays, acromioplasty is commonly performed during rotator cuff repair (RCR), to prevent postoperative impingements and reduce risks of retears [7].

There is no evidence-based consensus on how to perform acromioplasty, particularly regarding the level and extent of bone resection, which depend on scapular and humeral morphologies. Moreover, several authors reported that acromioplasty, and notably coracoacromial ligament release, could alter the coracoacromial arch by causing significant anterosuperior translation or 'escape' of the humeral head [8], weakening the deltoid origin [9], and causing adhesions between the tendons on the resected bone [10]. While recent studies found that a laterally prominent acromion increases the risk of rotator cuff tears [11], emphasizing the benefits of acromioplasty, the efficacy of the procedure at preventing subacromial impingements is yet to be proven [12].

In the authors' experience, computer-assisted pre-operative planning helps understand individual patient morphology and motions, and hence identify impinging acromial zones that should be removed [13]. This study therefore aimed to determine whether computer-assisted acromioplasty planning helps surgeons remove impinging bone, reduce unnecessary resections, and improve short-term outcomes of RCR.

Material and methods

Patients

We prospectively enrolled 127 adult patients scheduled to undergo RCR of full-thickness supraspinatus tears (isolated or with posterior extensions to the infraspinatus) of small or medium size (<3 cm according to DeOrio and Cofield [14]). The indications for surgery were confirmation of full-thickness tendon tear on magnetic resonance arthrography, and persistence of pain and symptoms despite 6 months of conservative treatment, with correction of scapulothoracic dyskinesis confirmed with normalization of the scapular retraction test [15]. We excluded patients that had (i) previous shoulder surgery, (ii) acute trauma, (iii) chronic dislocation, (iv) rotator cuff arthropathy with glenohumeral osteoarthritis and superior migration of the humeral head, (v) medical conditions that precluded informed consent or inability to read or write, (vi) fatty infiltration of grades 3 or 4 [16], (vii) incomplete documentation, or (viii) concomitant subscapularis tears which usually result from anterior impingement with the coracoid [17]. The study protocol had been registered at ClinicalTrials.gov (NCT02725346) and approved by the Medical Ethics Committee of Geneva University Hospital (CCER #15-151). All patients provided written informed consent for their participation and for the use of their data and images for research and publishing purposes.

Eligible patients were randomized into 2 groups that differed only in the method used to perform adjuvant acromioplasty: RCR with ‘guided acromioplasty’ (GA) and RCR with ‘freehand acromioplasty’ (FA) (Figure 1). The patients were randomly allocated in a 1:1 ratio, with block sizes of 4 and 6 using a randomization sequence created using SAS 9.1 statistical software (SAS Institute Inc, Cary, North Carolina). All patients were operated by the same surgeon. The GA group was operated following computer-assisted preoperative acromioplasty planning identifying locations and amounts of impinging bone. Conversely, the FA group was operated without computer-assisted acromioplasty planning.

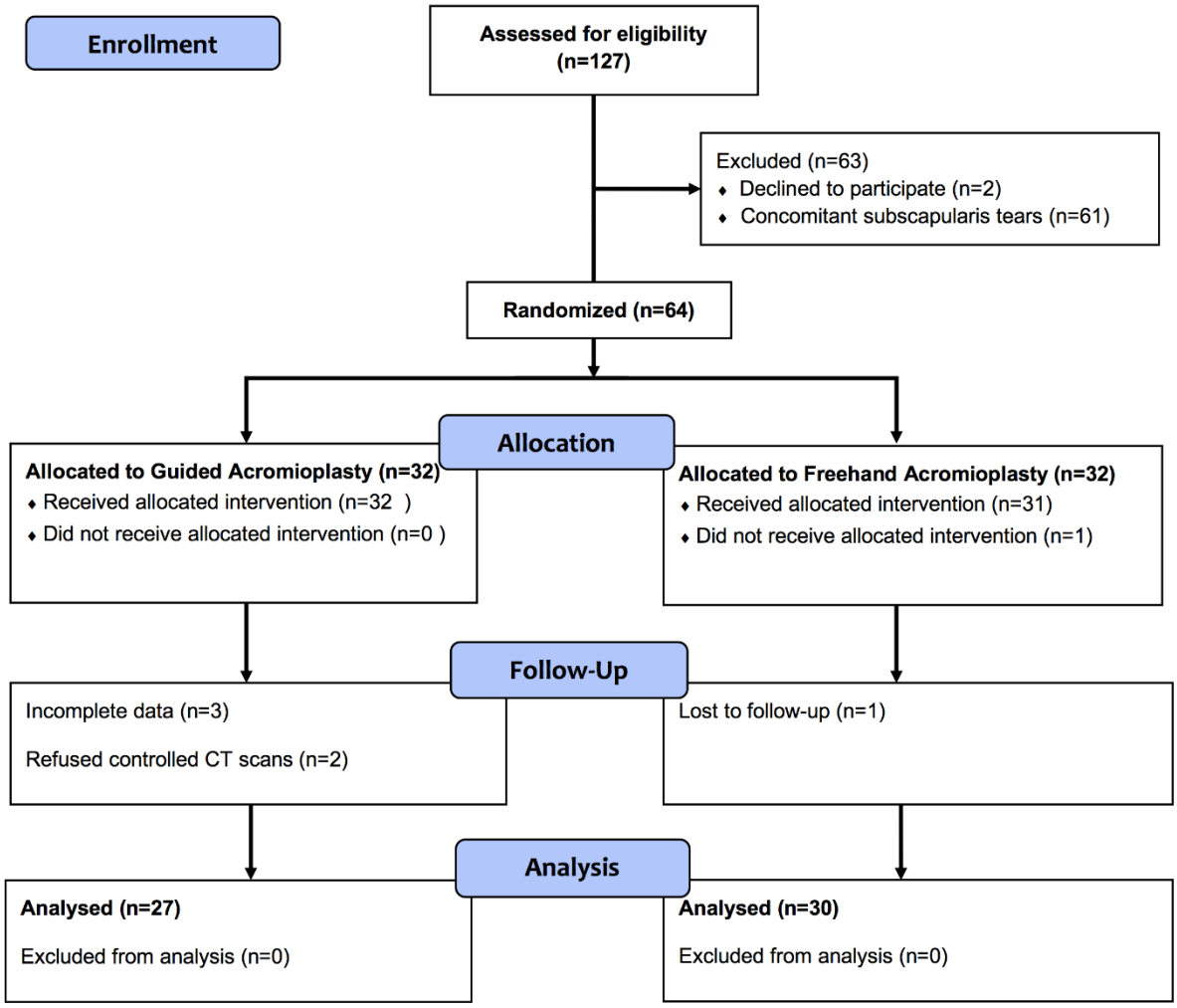

Figure 1: Study chart flow diagram.

Acromioplasty planning

All patients had computed tomography (CT) scans of the entire scapula and humerus using a Lightspeed VCT 64 rows system (General Electric, Milwaukee, WI, USA). Three-dimensional (3D) bone reconstructions were produced using Mimics (Materialise NV, Leuven, Belgium) before manipulating them using the preoperative planning software 'ArthroPlanner' (Artanim Foundation, Meyrin, Switzerland) validated by Charbonnier et al. [13].

First, generic bone models were produced using a template-fitting approach (WrapX, R3DS, Russia), and biomechanical parameters were computed to describe motions of the

glenohumeral joint. The articular center was automatically calculated by a 'sphere fitting' technique (Figure 2A). Second, bone coordinate systems were established for the scapula and humerus (Figure 2B) based on the definitions suggested by the International Society of Biomechanics [18]. Morphological parameters were then measured to analyze individual shoulder anatomy, and include the critical shoulder angle (CSA) [19] (Figure 2C). Third, motion was applied at the humerus with real-time evaluation of impingement, and the minimum humero-acromial distance was measured [20]. A color scale was also used to map the variations of humero-acromial distance on the scapular surface (Figure 2D). Given the thickness of the soft tissues, subacromial impingement was indicated when the computed humero-acromial distance was <6mm [21]. To test a variety of realistic movements, a motion database of daily activities (e.g., cross arm, comb hair, hand behind back) was used in addition to standard kinematic sequences (e.g., elevation, scaption). Finally, the acromial resection plan was defined based on the 3D simulation results, and simulation data were exported in a simple 3D viewer which allowed surgeons to replay all simulations, observe impingements dynamically and review the resection plan (Figure 3).

Surgery

The patients were operated between July 2015 and March 2016 at Hôpital de la Tour (Meyrin, Switzerland), by one experienced surgeon (AL). The size and location of tears were confirmed arthroscopically, after subacromial bursectomy, but before rotator cuff debridement. Single- or double-row techniques were used to repair the torn tendons based on their length and mobility [22], and biceps tenodesis or tenotomy were performed in all cases. All repairs were made with a double row of sutures using 2 anchors, of which 1 was implanted at the bone-cartilage junction and 1 was implanted at the lateral part of the greater tuberosity [22]. For patients in the GA group, the surgeon performed acromioplasty following the preoperative plan, while for

patients in the FA group, the surgeon was blinded to the preoperative plan. In both groups, acromioplasty was limited to the impingement site, preserving the coracoacromial ligament, and flattening a hooked or curved acromion whilst reducing the CSA.

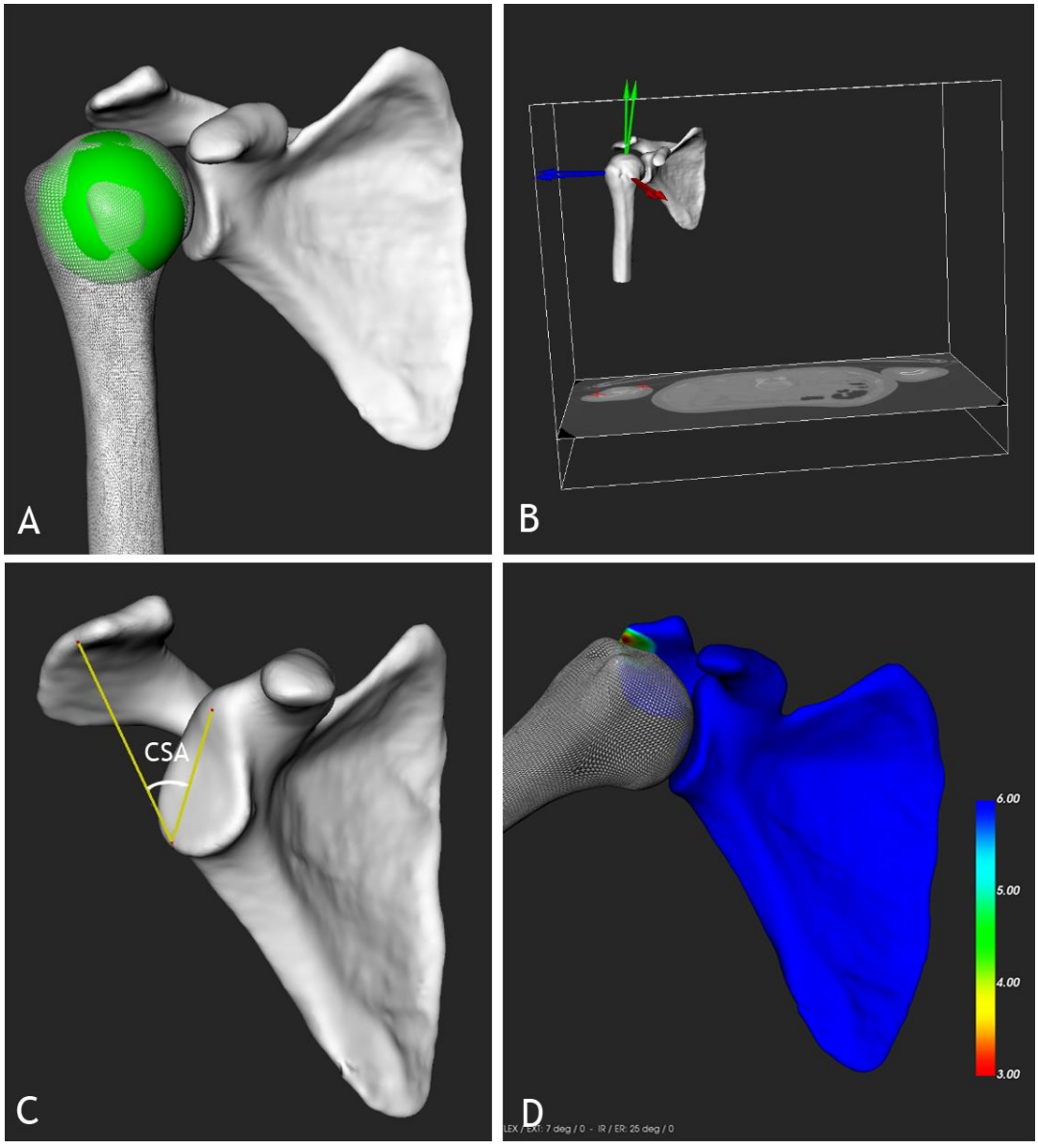

Figure 2: A) Glenohumeral center computation by fitting a sphere on the humeral head. B) Bone coordinates systems computation. C) CSA angle measurement. D) Visualization of the humero-acromial distance during motion (red color = minimum distance, other colors = areas of increased distance).

Postoperative rehabilitation

All patients followed a standard postoperative rehabilitation protocol [23] which required wearing abduction slings for the first four weeks. Immediately after surgery, patients were encouraged to perform shrugging, protraction, and retraction of the shoulder girdles, as well as intermittent exercises of the elbow, wrist, and hand; and external rotation of the arm to neutral position while wearing their slings. During the first four weeks, patients performed progressive passive overhead stretches and external rotation with the arm at the side. Active range of motion (ROM) started at four weeks and progressive strengthening started at three months [23].

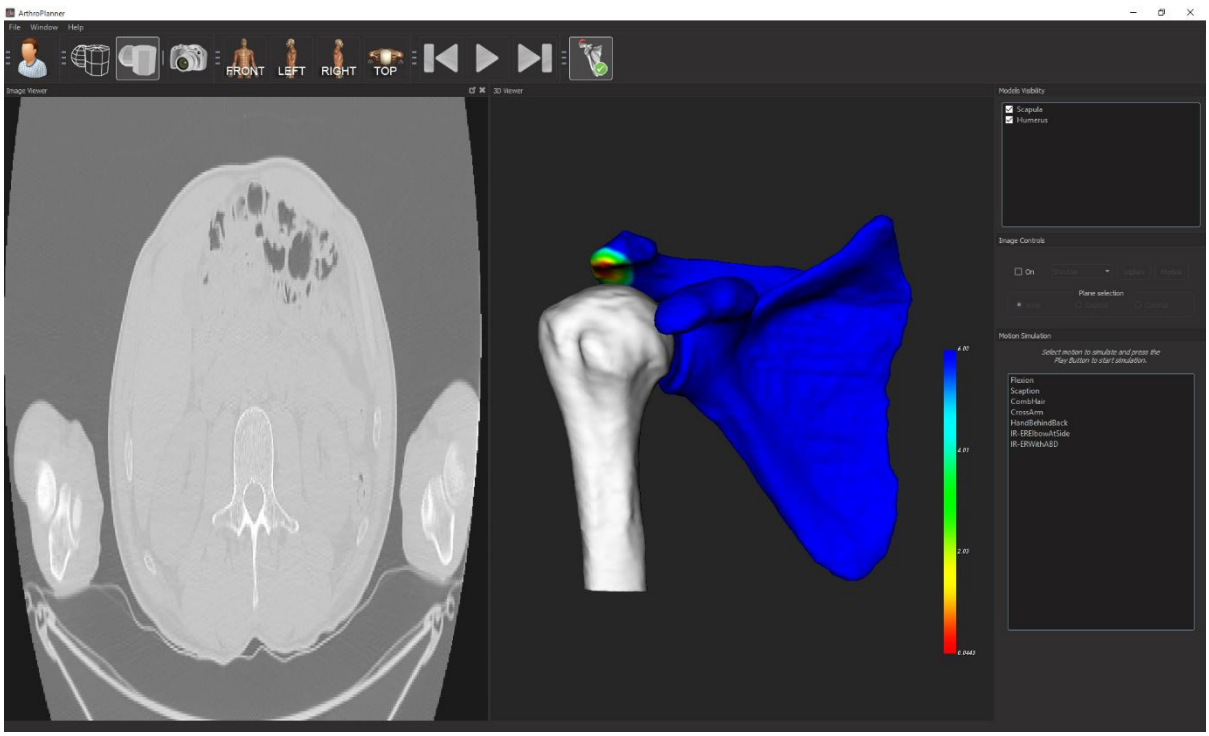

Figure 3: 3D viewer with the simulation and visualization tools. The window on the right shows the acromial resection plan.

Clinical assessment

All patients were clinically evaluated preoperatively and at a follow-up of 6 months to assess (i) shoulder forward flexion and rotations using a digital goniometer (Dartfish ©, Alpharetta,

GA, USA) on a video-recorded physical examination, (ii) active internal rotation to the nearest spinal level, (iii) pain on visual analogic scale (pVAS), (iv) Constant score [24], subjective shoulder value (SSV) [25], simple shoulder test (SST) [26] and the American Shoulder and Elbow Surgeons (ASES) score [27]. Data collection and measurements were performed by an independent observer (OR) blinded to the study design and purpose.

Radiographic assessment

Six months following surgery, a postoperative CT scan of the operated shoulder was acquired and reconstructed in 3D to assess the volume of residual impinging bone. The pre- and post-operative scapula models were compared to quantify acromial bone removal by calculating distances between the meshes of both models (Figure 4). An ultrasound assessment was also performed to evaluate repair integrity following the classification of Sugaya et al. [28] by an experienced musculoskeletal ultrasound specialist (KFC).

Statistical Analysis

Descriptive statistics are presented in terms of mean and standard deviation (SD). Shapiro–Wilk tests were used to assess the normality of distributions. For non-Gaussian continuous data, differences between groups were evaluated using Wilcoxon rank-sum tests (Mann–Whitney U test). For categorical data, differences between groups were evaluated using Fisher exact tests. Statistical analyses were performed using R version 3.3.2 (R Foundation for Statistical Computing, Vienna, Austria). P values < 0.05 were considered statistically significant. Multivariable linear regressions were conducted to detect associations between 4 outcomes (net improvements in ASES, Constant score, SSV and SST) with 8 independent variables (Type of Acromioplasty (FA/GA), sex, dominant arm, smokers, worker compensation status, age at index operation, critical shoulder angle, and type of rotator cuff tears).

A priori sample size calculation indicated that 52 patients (26 per group) were needed to detect a minimal clinically important difference in ASES scores of 12 points [29], with a SD of 15 points and a statistical power of 0.80.

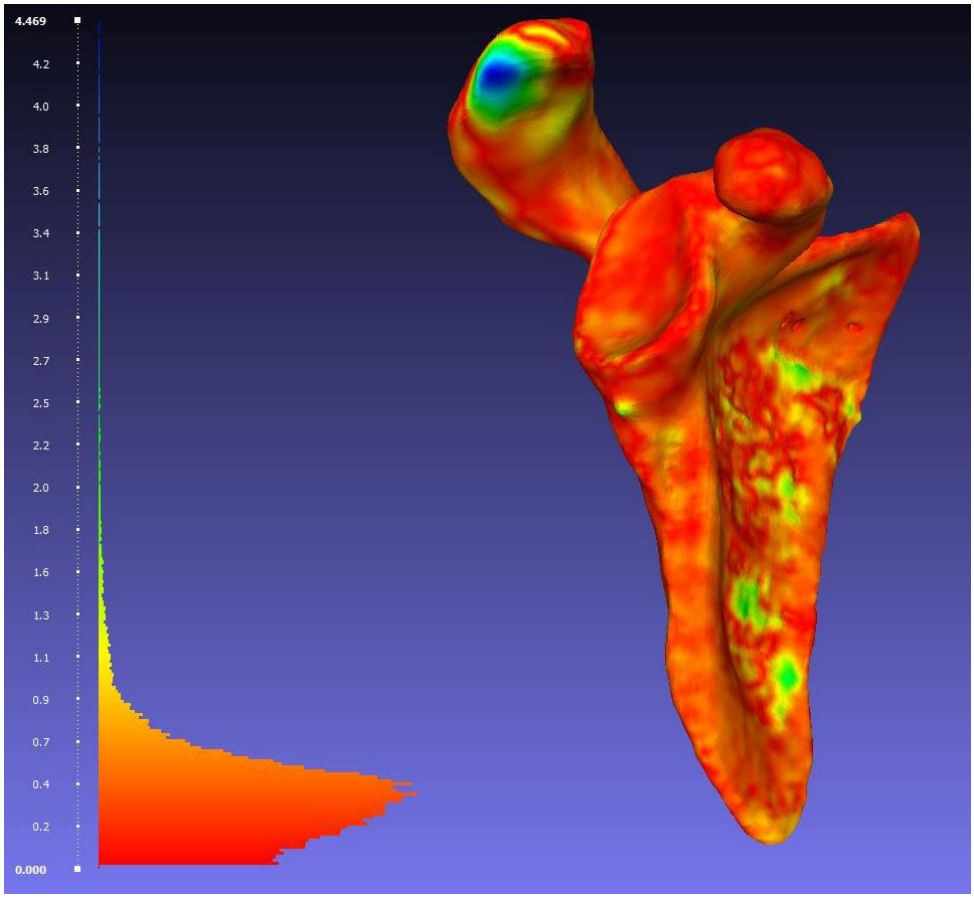

Figure 4: Visualization of the point-to-mesh distances on the preoperative model. The colors represent the variations of distance between the preoperative and postoperative models. The blue color denotes the zones of maximum distance (= maximum bone removal). Note: the postoperative model which is superposed on the preoperative model is not shown for clarity.

Results

Of the 127 patients screened for eligibility, 61 were excluded because they had concomitant subscapularis tears, and 2 declined to participate, leaving 64 patients for randomization (Figure 1). There were no significant differences between the two groups in terms of patient demographics nor clinical or morphologic characteristics (Table 1). In the GA group, 2 patients refused to undergo postoperative CT scans and 3 patients had incomplete clinical scores, leaving 27 patients for analysis. In the FA group, 1 patient was lost to follow-up, and 1 patient did not require acromioplasty, deemed unnecessary by the blinded surgeon during surgery, leaving 30 patients for analysis. There were also no significant differences in terms of surgical procedures, suture techniques, distal clavicle resections, nor prevalence of biceps tenodesis or tenotomy (Table 2).

The volume of impinging bone identified was 3.3±2.3 cm^3 (range, 0.5–9.3) in the GA group, and 3.7±2.2cm^3 (range, 0.5–9.4) in the FA group. The proportion of impinging bone removed was lower in the GA group (43±27%) than in the FA group (55±26%), though the difference was not statistically significant (p=0.087). The unnecessary resections represented a slightly greater proportion of the total bone removed in the GA group (57±27%) than in the FA group (49±22%) (p=0.248). The preoperative plans indicated similar extents and zones of bone removal for both groups, but the postoperative images suggested that GA results in significant anterior under-resection, while FA results in significant medial over-resection (Figure 5).

Clinical outcomes and ROM improved significantly for all patients, except for internal rotation with arm at 90° of abduction, which improved in the FA group but not in the GA group (p=0.063). There were no other significant differences between the two groups, neither in terms of post-operative scores nor in terms of clinical net improvements. Multivariable linear regressions confirmed that net improvements in ASES, Constant score, SSV and SST did not

significantly differ between the FA and GA groups, even after adjusting for cofounding factors (Tables 3 and 4) Repair integrity was of Sugaya type I in 17 (63%) and type II in 10 shoulders (37%) in the GA group, and of Sugaya type I in 18 shoulders (60%), type II in 11 (37%), and type V in 1 shoulder (3%) in the FA group (p=1.000).

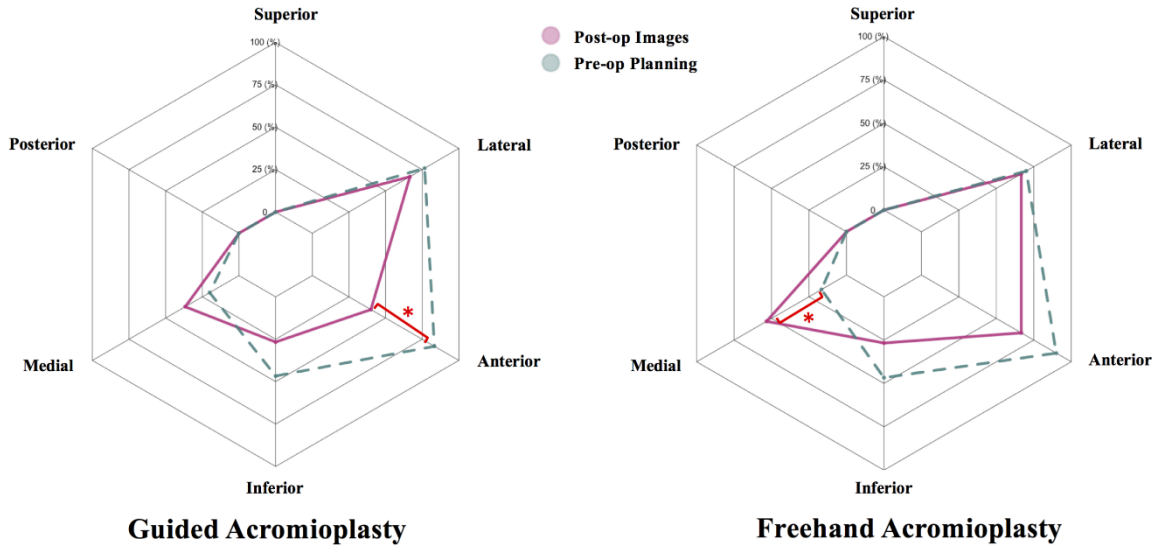

Figure 5: Radar charts illustrating differences of bone removal locations on the acromion between post-operative reconstructions and pre-operative planning. * indicated significant differences.

Discussion

The purpose of the present study was to determine whether computer-assisted acromioplasty planning helps surgeons remove impinging bone, reduce unnecessary resections, and improve short-term outcomes of RCR. Since subacromial impingement results from a dynamic mechanism, and as the location and extent of acromial bone to be removed are determined subjectively by the surgeon, the authors hypothesized that computer-assisted acromioplasty (GA) could improve surgical outcomes when compared to conventional acromioplasty (FA). Our results did not confirm this hypothesis, as there were no significant differences between GA and FA in terms of volume of impinging bone removed, unnecessary bone resections, clinical outcomes or tendon healing. These preliminary findings should not deter surgeons and engineers, however, from developing and enhancing computer-assisted planning tools and surgical guides to help less experienced surgeons improve the accuracy and the efficacy of acromioplasty.

It has been previously theorized that the anterior and lateral aspects of the acromion contribute considerably to subacromial impingement and shear stresses within the supraspinatus tendon [30]. Nyffeler et al. [30] also showed that shoulders with prominent lateral acromial extensions are more likely to develop full-thickness RCTs. There is little evidence, however, regarding the protective role of anterior acromioplasty in the long term [31]. Several recent studies therefore questioned the efficacy of acromioplasty [32-33] and explored alternative treatments [34], albeit with small series and short follow-up [35-36], which may not be sufficient to detect tendon degeneration over decades of impingement [31]. It is still unknown if postoperative clinical improvement is only related to relief of impingement [6], decrease of stress on the supraspinatus tendon [37], or improvement of shoulder kinematics after repair [38].

The benefits of acromioplasty planning include detailed analysis of patient anatomy, notably the proximal humerus, CSA [11], as well as the dynamic mechanisms of subacromical impingement, all of which could help manage patients expectations depending on their sports and activities. Interestingly, conservation of the coracoacromial ligament was always possible in the GA group, which may be preferable in the long-term, to avoid alteration of the coracoacromial arch [39]. Although GA allows surgeons to analyze subacromial impingement three-dimensionally and identify impinging bone, we could not demonstrate its benefits over FA, at optimizing bone removal or improving short-term outcomes. Further studies with resection guides based on the preoperative planning need to be performed to help surgeons reproducing their planning intraoperatively and thereby better analyze and understand the benefits/drawbacks of such surgical software.

Strengths and limitations

The main strengths of this study are its prospective randomized design, the strict selection of patients, the unique technique used to plan acromioplasty, and the analysis of postoperative bone removal. Furthermore, only one surgeon and one independent examiner were involved in the evaluations, which ensured consistency of surgical techniques and subjective assessments. However, this study has several limitations. First, clinical and radiographic outcomes were limited to six months and remain insufficient to compare outcomes in mid or long terms, though it is unlikely that repair integrity changes thereafter [40]. Although we used several clinical outcomes, we did not use specific scores for rotator cuff problems (e.g. Western Ontario Rotator Cuff Index). Second, it would be of great interest to study a cohort without RCTs as it is uncertain whether the observed improvements in shoulder motion can be attributed to removal of impinging bone or to tendon repair and physiotherapy [38], though all patients had conservative treatment preoperatively, including correction of scapulothoracic dyskinesia. Furthermore, our study cohort may differ from others as there was a very low number of

worker's compensation patients which could be explained by the private activity of the surgeon, but also by the particularity of the social and health care systems in Switzerland. Third, the surgeon, already aware of potential deleterious effects of excessive anterior acromioplasty, may have operated the FA group less invasively based on prior experience, thereby attenuating differences between groups. Fourth, acromioplasty planning required pre- and post-operative CT acquisitions, even though magnetic resonance imaging would avoid exposing patients to radiations but would be less accurate for 3D bone reconstructions. Finally, the analyses were limited to posterosuperior rotator cuff lesions. However, we did not observe during planning retrocoracoid impingement [17] and we thus believe that the technique of planning could be extended to lesions of the anterior rotator cuff.

Conclusions

The present computer-assisted technology for planning adjuvant acromioplasty during rotator cuff repair proved no benefits of guided acromioplasty over freehand acromioplasty in terms of removal of impinging bone, tendon healing, or clinical outcomes. These preliminary findings should not deter surgeons and engineers, however, from developing and enhancing computer-assisted planning tools and surgical guides to help less experienced surgeons improve the accuracy and the efficacy of acromioplasty.

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Conflict of interest, disclosure statement, funding sources, contribution of authors

We have no conflict of interest.

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AL participated in study design, data collection, literature review, manuscript writing and manuscript editing. SC participated in study design, data collection. DP participated in study design, data collection. FCK participated in study design, data collection. OR participated in study design, data collection. BK participated in study design, data collection. HB participated in statistical analysis, literature review, manuscript writing and figures and tables preparation. CC participated in study design, data collection, manuscript editing. All authors approved the final manuscript.

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Table 1: Preoperative demographics, and morphological data.

	Guided Acromioplasty (n= 32 shoulders)		**Freehand Acromioplasty** (n= 32 shoulders)		*p-value*
	Mean ±SD	Range	Mean ±SD	Range	
Male gender	18 (56%)		16 (50%)		0.802
Operation on dominant side	23 (72%)		23 (72%)		1.000
Smokers	3 (9%)		2 (6%)		1.000
Worker compensation status	3 (9%)		4 (13%)		1.000
Type of RCT					0.430
Isolated supraspinatus	13 (41%)		9 (28%)		
Supraspinatus and Infraspinatus	19 (59%)		23 (72%)		
Age at index operation	55.9 ± 9.8	(33.0 - 74.0)	57.6 ± 7.4	(44.0 - 72.0)	0.798
Critical Shoulder Angle (CSA)	40.7 ± 6.7	(29.0 - 52.5)	39.6 ± 4.3	(31.4 - 48.3)	0.559

RCT, Rotator Cuff Tear;

Table 2: Intraoperative data.

	Guided Acromioplasty (n= 27 shoulders)		**Freehand Acromioplasty** (n= 30 shoulders)		*p-value*
	Mean ±SD	Range	Mean ±SD	Range	
Suture technique					0.793
single-row	14 (52%)		17 (57%)		
double-row	13 (48%)		13 (43%)		
Biceps procedures					0.429
Tenodesis	16 (59%)		14 (47%)		
Tenotomy	11 (41%)		16 (53%)		
Distal clavicle resection	11 (41%)		13 (43%)		1.000
Surgical duration (min)	58.1 ± 16.4	(35.0 - 95.0)	65.0 ± 18.1	(40.0 - 110.0)	0.160

LHB, Long Head of the Biceps;

Table 3: Multi-variable regression analysis of clinical scores

	ASES Improvement			CS Improvement			SSV Improvement			SST Improvement		
Variable	**β**	**95% C.I.**	**p-value**	**β**	**95% C.I.**	**p-value**	**β**	**95% C.I.**	**p-value**	**β**	**95% C.I.**	**p-value**
Type of Acromioplasty												
Freehand (FA)	REF			REF			REF			REF		
Guided (GA)	0.9	(-10.7 – 12.5)	0.881	-3.6	(-16.5 – 9.3)	0.574	0.2	(-13.2 – 13.7)	0.976	-0.7	(-2.5 – 1.0)	0.403
Male sex	0.5	(-11.1 – 12.1)	0.933	5.3	(-7.6 – 18.3)	0.411	1.6	(-11.8 – 15.1)	0.808	1.0	(-0.8 – 2.7)	0.285
Dominant Arm	-11.6	(-26.4 – 3.3)	0.123	-16.8	(-33.3 – -0.3)	**0.046**	-7.9	(-25.0 – 9.3)	0.363	-0.7	(-3.0 – 1.6)	0.544
Smokers	17.4	(-5.9 – 40.8)	0.140	21.8	(-4.2 – 47.7)	0.098	4.3	(-22.7 – 31.4)	0.748	2.3	(-1.2 – 5.9)	0.197
Worker compensation status	-7.7	(-25.7 – 10.2)	0.391	-5.1	(-25.0 – 14.9)	0.612	3.3	(-17.6 – 24.1)	0.755	-0.9	(-3.6 – 1.8)	0.514
Age at index operation (yrs)	-0.1	(-0.9 – 0.6)	0.771	-0.1	(-0.9 – 0.7)	0.840	0.2	(-0.7 – 1.0)	0.698	0.0	(-0.1 – 0.1)	0.650
Critical Shoulder Angle (CSA)	0.3	(-0.9 – 1.4)	0.651	0.3	(-1.0 – 1.7)	0.598	0.4	(-0.9 – 1.8)	0.531	0.0	(-0.2 – 0.1)	0.742
Type of RCT												
Isolated supraspinatus	REF			REF			REF			REF		
Supraspinatus and Infraspinatus	0.1	(-12.6 – 12.8)	0.991	-0.4	(-14.5 – 13.7)	0.953	10.4	(-4.3 – 25.1)	0.162	-0.1	(-2.1 – 1.8)	0.885

ASES, American shoulder and elbow surgeons; CS, Constant score; SSV, Subjective shoulder value; FA, Free-hand acromioplasty; GA, Guided acromioplasty; Simple shoulder test; CSA, Critical shoulder angle (°); RCT, Rotator cuff tear; REF, reference

Table 4: Pre- and post-operative clinical data.

	Guided Acromioplasty (n= 27 shoulders)		*p-value*	Freehand Acromioplasty (n= 30 shoulders)		*p-value*	*p-value*
	Mean ±SD	Range	Pre vs Post	Mean ±SD	Range	Pre vs Post	Guided *vs* Freehand
Foward Flexion			<0.001			<0.001	
Pre-operative	92.0 ± 35.9	(-35 – 162)		106.2 ± 47.7	(-15 – 170)		0.129
Post-operative	141.5 ± 23.8	(-56 – 170)		145.4 ± 26.1	(-65 – 176)		0.179
Net improvement	49.5 ± 43.3	(-21 – 120)		40.6 ± 53.3	(-70 – 139)		0.603
External Rotation (elbow at side)			<0.001			0.010	
Pre-operative	26.2 ± 13.7	(-5 – 50)		25.5 ± 16.4	(-0 – 75)		0.749
Post-operative	42.6 ± 18.8	(-12 – 80)		37.7 ± 14.0	(-15 – 64)		0.218
Net improvement	16.4 ± 18.0	(-29 – 52)		12.2 ± 21.9	(-35 – 50)		0.333
External Rotation (with arm at 90° abduction)			0.005			0.031	
Pre-operative	33.7 ± 16.7	(-2 – 70)		42.8 ± 25.4	(-10 – 90)		0.195
Post-operative	54.4 ± 23.5	(-0 – 90)		54.7 ± 21.9	(-10 – 90)		0.980
Net improvement	16.7 ± 30.0	(-65 – 60)		15.1 ± 31.7	(-59 – 80)		0.749
Internal Rotation (with arm at 90° abduction)			0.063			0.001	
Pre-operative	18.4 ± 20.8	(-5 – 85)		16.9 ± 16.2	(-7 – 60)		0.958
Post-operative	27.8 ± 21.6	(-0 – 90)		33.9 ± 20.3	(-0 – 75)		0.256
Net improvement	7.4 ± 24.6	(-37 – 78)		18.3 ± 22.7	(-20 – 72)		0.108
Internal Rotation (spinal level)			0.010			<0.001	
Pre-operative	7 ± 4	(-1 – 14)		7 ± 5	(-2 – 14)		0.808
Post-operative	10 ± 4	(-2 – 14)		10 ± 5	(-2 – 16)		0.366
Net improvement	2.8 ± 4.9	(-8 – 11)		4 ± 4	(-5 – 12)		0.668
Pain on VAS			<0.001			<0.001	
Pre-operative	6.4 ± 2.3	(-2 – 10)		6.9 ± 1.5	(-3 – 9)		0.474
Post-operative	2.2 ± 2.4	(-0 – 9)		2.3 ± 2.0	(-0 – 8)		0.724
Net improvement	-4.2 ± 2.8	(-9 – 4)		-4.6 ± 2.4	(-9 – 1)		0.705
Constant score			<0.001			<0.001	
Pre-operative	42.1 ± 18.3	(-6 – 74)		37.8 ± 19.0	(-7 – 79)		0.325
Post-operative	67.6 ± 21.2	(-15 – 100)		66.9 ± 19.8	(-17 – 100)		0.842
Net improvement	25.5 ± 23.7	(-27 – 82)		28.9 ± 23.5	(-13 – 81)		0.956
ASES			<0.001			<0.001	
Pre-operative	43.6 ± 18.9	(-8 – 80)		38.6 ± 16.3	(-10 – 70)		0.314
Post-operative	79.8 ± 19.2	(-32 – 100)		73.5 ± 18.3	(-30 – 98)		0.207
Net improvement	36.6 ± 21.2	(-0 – 79)		35.7 ± 20.3	(-13 – 73)		0.415
SSV			<0.001			<0.001	
Pre-operative	50.9 ± 20.7	(-20 – 80)		45.5 ± 22.3	(-9 – 80)		0.434
Post-operative	80.1 ± 16.7	(-30 – 100)		75.3 ± 15.4	(-30 – 99)		0.210
Net improvement	29.2 ± 27.2	(-20 – 75)		30.0 ± 20.4	(-10 – 81)		0.949
SST			<0.001			<0.001	
Pre-operative	5.0 ± 2.3	(-2 – 9)		4.2 ± 2.1	(-0 – 8)		0.177
Post-operative	8.9 ± 2.6	(-1 – 12)		8.7 ± 2.2	(-1 – 11)		0.569
Net improvement	3.9 ± 3.2	(-3 – 9)		4.6 ± 3.1	(-3 – 9)		0.394

VAS, Visual Analogic Scale; ASES, American Shoulder and Elbow Surgeons; SSV, Subjective Score Value; SST, Simple Shoulder Test;