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The Delta III and Delta Xtend reverse shoulder arthroplasty—risk of revision and failure mechanisms: a report on 3650 cases from the Norwegian Arthroplasty Register 1994-2021

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Background: The Delta reverse shoulder arthroplasty (RSA) is commonly used worldwide and is the most frequently used RSA in Norway. The aim of this registry-based study was to report 10- and 20-year implant survival, risk of revision, and reasons for revision in 2 consecutive time periods for Delta III (1994-2010) and Delta Xtend (2007-2021) prostheses.

Methods: We included 3650 primary RSAs reported to the Norwegian Arthroplasty Register: 315 Delta III (42% cemented stems) and 3335 Delta Xtend (88% cemented stems). We used Kaplan-Meier analyses to investigate implant survival. The reasons for revision were compared for the 2 designs and fixation technique. Factors that could influence the risk of revision, such as implant design, fixation technique, and patient factors, were investigated using Cox regression analyses with adjustments for age, sex, and diagnosis.

Results: Patients operated with Delta III were more likely to be diagnosed with inflammatory disease or fracture sequela, whereas acute fracture, osteoarthritis, and cuff arthropathy were the most frequent indications for Delta Xtend. Ten-year survival was 93.0% (95% confidence interval [CI]: 87.0-99.0) (cemented stem) and 81.6% (95% CI: 75.3-87.9) (uncemented stem) for Delta III and 94.7% (95% CI: 93.3-96.1) (cemented stem) and 95.7% (95% CI: 88.3-100) (uncemented stem) for Delta Xtend. Twenty-year survival for Delta III (uncemented stem) was 68.2% (95% CI: 58.8-77.6). Compared with DeltaXtend (cemented stem) at 10-year follow-up, we found a higher risk of revision for Delta III (uncemented stem) (hazard ratio [HR]: 2.9, 95% CI: 1.7-5.0), whereas no significant difference was found for Delta III (cemented stem) and Delta Xtend (uncemented stem). The most common reason for revision of Delta III (uncemented stem) was glenoid loosening followed by deep infection and instability. Instability was the most frequent revision cause for Delta Xtend (both cemented and uncemented stem). Men had an overall higher revision risk than women (HR: 2.8 [95% CI: 2.0-3.9]), and patients with fracture sequela had increased risk for revision (HR: 2.8, 95% CI: 1.7-4.7) compared with patients with osteoarthritis.

Discussion: We found that Delta III (uncemented stem) had a higher risk of revision compared with Delta Xtend (cemented stem). The risk of revision for glenoid component loosening was lower for Delta Xtend, but revisions due to instability/dislocation are still a concern. This register study cannot determine whether the differences found were caused by differences in implant design or other factors that changed during the study period. Risk of revision may have been affected by the indication for primary operation.

The Norwegian Arthroplasty Register has permission from the Norwegian Data Inspectorate to collect patient data based on written consent from the patients (ref: 24.1.2017: 16/01622-3/CDG) and comply by the Norwegian and EU data-protection laws.

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In 1985, Grammont introduced his concept for reverse shoulder arthroplasty (RSA) with a medialized and distalized center of rotation, as well as a nonanatomic neck-shaft angle of 155°.[5,17,18] In the second generation of the Grammont (Delta III; DePuy Synthes Warsaw, IN, USA), introduced in 1991, the center of rotation was further medialized to the native glenoid face, and the back of the glenoid baseplate was coated with hydroxyapatite (HA) to improve fixation.

By lengthening the arm and increasing deltoid tension, Delta III was successful in restoring the range of motion in cuff-deficient patients, but still rotation often remained limited, and failure to restore sufficient tension in the deltoid could result in instability.[6] Scapular notching was also a concern because it leads to progressive bone loss of the scapular neck and subsequent loosening of the glenoid component.[22]

Delta Xtend (DePuy Synthes) was introduced in 2006 as a successor to Delta III. The implant had less congruent humeral inserts to prevent polyethylene wear and improve range of motion (Fig. 1). The glenoid component was modified to a smaller baseplate with a curved back surface and the possibility of an eccentric glenosphere to allow inferior overhang.[42,30] The HA coating on the stem intended for uncemented fixation is the same on Delta III and Delta Xtend, but Delta Xtend has higher roughness underneath the coating. Delta III had a modular stainless steel polished stem with (intended for uncemented fixation) or without HA coating (intended for cemented fixation). Delta Xtend has 2 different stem options; the modular Delta Xtend stem is TiA6V grit blasted with HA coating, and the monobloc Delta Xtend stem is polished CoCr intended for cemented fixation. Glenoid components were also changed from stainless steel in Delta III to TiA6V + HA for the metaglene (baseplate) and CoCr for the glenosphere in Delta Xtend. Glenoid components are intended for uncemented fixation in both Delta III and Delta Xtend.

Delta Xtend is widely used globally.[3,26,25] Precise knowledge of the probability and implications of the various complications is imperative for the best choice of implant for RSA patients.

Two papers have reported improved short-term clinical outcomes and survival for Delta Xtend compared with Delta III.[1,21] In addition, some retrospective case series with long-term outcomes have been reported,[4,11] but to our knowledge, this is the first registry-based study to report on 20-year follow-up for RSAs.

Based on data in the Norwegian Arthroplasty Register (NAR), the aim of this study was to report 10- and 20-year implant survival, risk of revision, and reasons for revision in 2 consecutive time periods for Delta III (1994-2010) and Delta Xtend (2007-2021) prostheses.

Patients and methods

The NAR has collected data on shoulder arthroplasties on a national level since 1994.[19]

The completeness of primary shoulder arthroplasty data in the NAR was 90.8% in 2019-2020 and 84.6% for revisions.[15] The NAR collects surgical data reported on a 1-page paper form filled in by the surgeon immediately after the surgery. Data collected include the name of the operating hospital, date of operation, indication for surgery, type of surgery, implant details on product number level, type of fixation, laterality, and intraoperative complications, as well as patient-related factors such as age, sex, ASA score, and information on any former surgery in the shoulder.[12,19] Several diagnoses could be given for each operation, and in cases with more than 1 diagnosis, we used the hierarchy developed by the Nordic Arthroplasty Register Association (NARA).[32] The NAR uses the unique personal ID given to each inhabitant in Norway to link the primary shoulder arthroplasty to any subsequent implant revisions or other reoperations. A revision is defined as the insertion, exchange, or removal of any of the prosthesis components, whereas a procedure without insertion, exchange, or removal of components is registered as a reoperation. Reoperations have been reported since 2011, and these procedures (n = 5) were excluded in the survival analyses in the present study. Reasons for revision are reported. More than 1 reason for revision can be given in each case, and the hierarchy developed by the NARA was used in the analyses for revision causes where more than 1 reason was given.[32]

Information regarding deaths and emigrations was obtained from the Norwegian National Population Register.

Between 1994 and 2021, 11,287 primary shoulder arthroplasties were reported to the NAR, including 5079 RSAs. Delta III and Delta Xtend were used in 3650 of these procedures (Fig. 2). Delta III (n = 315) was used from 1994 until 2010 and was gradually replaced by Delta Xtend (n = 3335) from 2007 (Fig. 3). All primary Delta RSAs were included in the study. We compared the following 4 implant groups, all with uncemented glenoid components:

(1) Delta III, cemented stem (n = 133)
(2) Delta III, uncemented stem (n = 182)
(3) Delta Xtend, cemented stem (n = 2947)
(4) Delta Xtend, uncemented stem (n = 388)

Statistical analysis

Descriptive statistics were used to give an overview of the patient demographics. The median time of follow-up in the groups was

Figure 1 From left to right: Delta III (cemented stem), Delta III (uncemented stem), Delta III glenoid components, Delta Xtend (cemented stem), Delta Xtend (uncemented stem), and Delta Xtend glenoid components. Reprinted with permission from Ortomedic/DePuy Synthes.

estimated by the reverse Kaplan-Meier method. Results are presented with 95% confidence intervals (CIs).

Implant survival with an endpoint of all revisions were estimated by a Kaplan-Meier analysis with 10 years of follow-up in each group and, in addition, 20 years of follow-up for Delta III with censoring at the time of revision, death, emigration, or end of study (December 31, 2021). If a patient had sequential revisions, only the time to the first implant revision was included in the analyses.

To investigate the risk of revision, we compared Delta III and Delta Xtend, with cemented and uncemented stem using Cox multiple regression analyses for each revision cause according to the NARA hierarchy adjusted for age, sex, and diagnosis. We also compared cemented and uncemented stems within each implant. The proportional hazards assumption was evaluated graphically and fulfilled for follow-up of 0-2 years and 2-10 years, respectively.[31] The results are presented for the entire period. In addition, competing risk analyses were performed by calculating the subhazard ratios (SHRs)[14,23] for each cause of revision. The Fine and Gray method is a regression model expressed as SHRs with the possibility to adjust for relevant covariates. The reason to present the SHRs was to calculate correct estimates for revision for each cause separately. The SHRs describe the relative effect of potential covariates on the subdistribution hazard function. The endpoint was revision due to a specific cause, with revision due to all other causes as the competing factor. If the patient died or emigrated, the follow-up time was censored.[2]

All tests were 2-sided, and P values below .05 were considered statistically significant.

All statistical analyses were performed using SPSS Statistics (version 26.0.1.0; IBM Corp., Armonk, NY, USA), R version 4.0.2 (R Centre for Statistical Computing), and Stata/SE 17.0.

Results

The mean age of the study population was 73 years, and 75% were women. Female patients were more frequent in all study groups, but there were more men in the Delta Xtend (uncemented stem) group (42%) compared with the other implant groups (13%-24%). Baseline data for each of the 4 implant groups are shown in Table I. Inflammatory arthritis was the most common indication for the Delta III prostheses especially in the uncemented stem group, whereas acute fracture, primary osteoarthritis, and rotator cuff arthropathy were the most frequent indications for the Delta Xtend prostheses.

Risk of revision

In total, 159 arthroplasties were revised. To ensure as equal basis for comparison as possible between the arthroplasties, we censored the follow-up at 10 years when comparing Delta III and Delta Xtend. Revisions occurring after more than 10 years of follow-up (n = 12) were excluded from the SHR analyses. These revisions were all Delta III prostheses and were performed for either deep infection (n = 4), glenoid component loosening (n = 7), or polyethylene wear (n = 1).

Kaplan-Meier survival rates for the 4 implant groups are shown in Table II and Fig. 4.

Delta III (uncemented stem) had poorer survival than the other implant groups at 10 years (82% vs. 93%-96%) and 68% survival at 20 years.

Adjusted for age, sex, and diagnosis, Delta III (uncemented stem) had an almost 3 times higher risk of revision at 10 years compared with Delta Xtend (cemented stem) (HR: 2.9, 95% CI: 1.7-5.0, $P < .001$). No statistically significant difference was found for Delta III (cemented stem) or Delta Xtend (uncemented stem) compared with Delta Xtend (cemented stem) (Table III). When comparing uncemented and cemented stems for each implant separately, there was a tendency toward increased risk for revision for Delta III (uncemented stem) compared with Delta III (cemented stem), but the difference was not

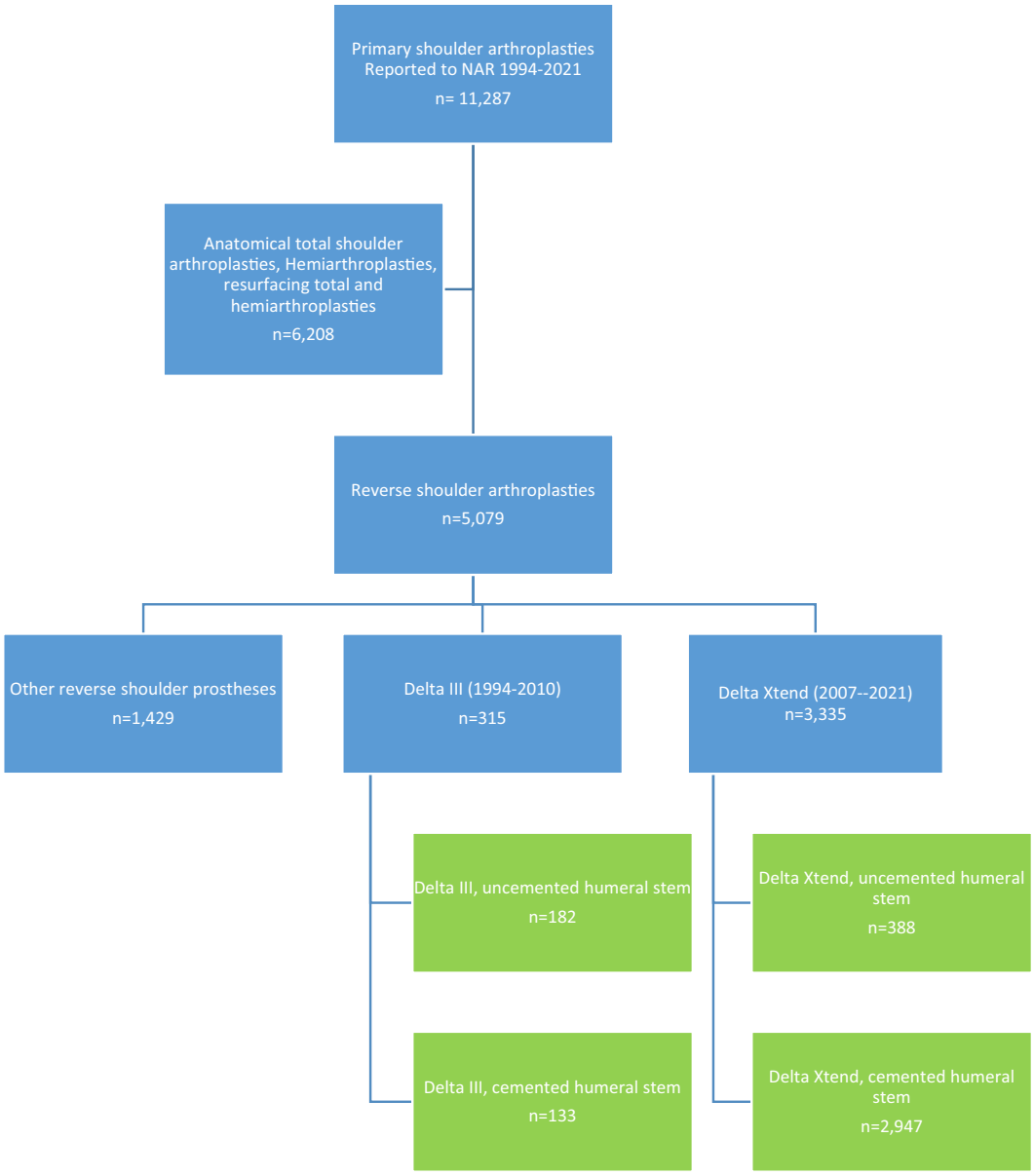

Figure 2 Inclusion and exclusion of shoulder arthroplasty patients from the Norwegian Arthroplasty Register (NAR) from 1994 to 2021. The 4 patient groups are highlighted by green boxes.

statistically significant (HR: 2.3, 95% CI: 0.95-5.30, $P = .064$) (Table IV). There was no statistically significant difference in risk for revision between Delta Xtend (uncemented stem) and Delta Xtend (cemented stem) (HR: 1.0, 95% CI: 0.59-1.95, $P = .808$) (Table V).

Men had almost 3 times increased risk of revision compared with women. This increased risk was mostly due to infection and dislocation. Arthroplasties for fracture sequelae had almost 3 times increased risk of revision compared with arthroplasties for osteoarthritis (Table III).

When used for patients with osteoarthritis, Delta III prostheses with both uncemented and cemented stems had a higher risk of revision compared with Delta Xtend with cemented stem (HR: 6.5, 95% CI: 2.2-19, $P = .001$, and HR: 6.0, 95% CI: 1.2-29, $P = .03$, respectively) (data not shown in the tables). When used for fracture sequelae, inflammatory arthritis, and rotator cuff arthropathy, no statistically significant differences in survival were found. There were too few patients with acute fracture operated with the Delta III prostheses to compare revision risk for this group of patients.

Reasons for revision are given in Table VI. The most frequent reasons for revision with 10-year follow-up were dislocation/instability (n = 51), deep infection (n = 40),

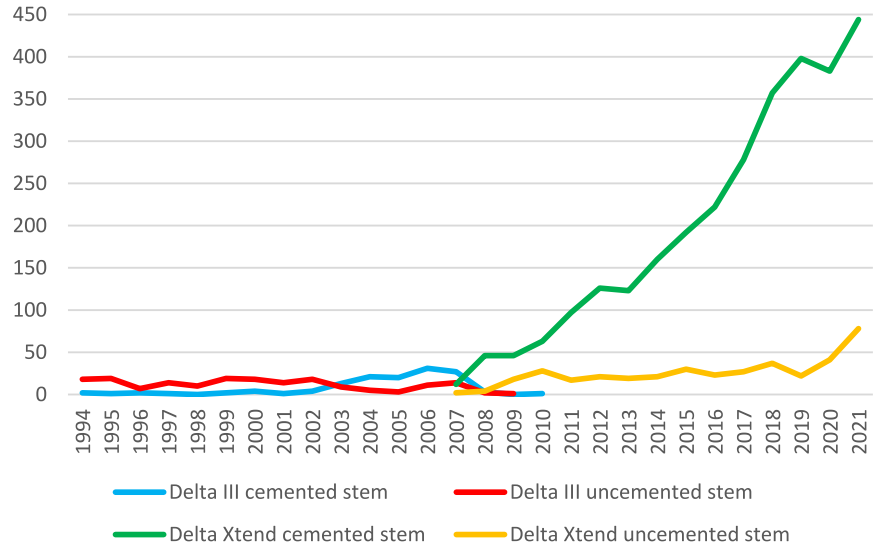

Figure 3 Primary operations with Delta reverse shoulder arthroplasties in the Norwegian Arthroplasty Register, 1994-2021.

Table I Demographics of the study population of 3650 Delta reverse shoulder arthroplasties from the Norwegian Arthroplasty register, 1994-2021; all glenoid components uncemented

	Delta III		Delta Xtend	
	Cemented stem (n = 133)	Uncemented stem (n = 182)	Cemented stem (n = 2947)	Uncemented stem (n = 388)
Women, n (%)	115 (87)	153 (84)	2247 (76)	225 (58)
Age at surgery (yr), mean ± SD	72 ± 10	69 ± 11	74 ± 8.9	72 ± 8.8
Age group (yr), n (%)				
<55	10 (8)	20 (11)	92 (3)	19 (5)
55-64	22 (17)	39 (21)	341 (12)	47 (12)
65-74	42 (32)	60 (33)	1078 (37)	169 (44)
75+	59 (44)	63 (35)	1436 (49)	153 (39)
Diagnosis, n (%)				
Inflammatory arthritis	42 (32)	104 (58)	112 (4)	43 (11)
Fracture sequelae	38 (29)	26 (14)	560 (19)	24 (6)
Primary osteoarthritis	26 (20)	33 (18)	550 (19)	155 (40)
Rotator cuff arthropathy	11 (8)	11 (6)	542 (18)	139 (36)
Acute fracture	2 (2)	5 (3)	1034 (35)	9 (2)
Instability sequelae	1 (1)	1 (1)	73 (3)	12 (3)
Other	13 (11)	1 (1)	67 (2)	7 (2)
Duration of surgery (min), mean ± SD	112 ± 41	94 ± 37	125 ± 39	120 ± 34
Follow-up years, median (IQR)	11.7 (7.9)	11.9 (5.6)	3.2 (4.0)	3.8 (5.5)

SD, standard deviation; *IQR*, interquartile range.

loosening of the glenoid component (n = 20), and loosening of the humeral stem (n = 12). SHRs were calculated at 10-year follow-up with all other revision causes merged as one competing risk in the analyses. Delta III with uncemented stem had significantly increased risk of revision due to glenoid loosening, humeral loosening, and deep infection compared with Delta Xtend with cemented stem. The change in reasons for revisions is also illustrated in Fig. 5, with loosening and infection more frequently observed early in the study period.

Time from surgery to revision

The median time from primary surgery to revision was 5 months (0-292 months). Dislocations and instability were

Table II Kaplan-Meier survival table for reverse shoulder arthroplasties in the Norwegian Arthroplasty Register, 1994-2021 revision due to all causes

	1 yr	2 yr	5 yr	10 yr	20 yr
Delta III					
Cemented stem	94.7 (91.0-98.4)	94.7 (91.0-98.4)	93.0 (88.5-97.5)*	93.0 (87.0-99.0)*	n = 4
Uncemented stem	97.2 (94.8-99.6)	93.3 (89.6-97.0)	89.6 (85.1-94.1)	81.6 (75.3-87.9)†	68.2 (58.8-77.6)†
Delta Xtend					
Cemented stem	97.7 (97.1-98.3)	97.2 (96.6-97.8)	96.1 (95.3-96.9)	94.7 (93.3-96.1)‡	n = 0
Uncemented stem	96.5 (94.7-98.3)	96.2 (94.2-98.2)	95.7 (93.5.2-97.9)§	95.7 (88.3-100)§	n = 0

Data are presented as Kaplan-Meier% (95% confidence interval).
* Last revision at 5.0 years, n = 75 at 10 years.
† n = 88 at 10 years, n = 27 at 20 years.
‡ Last revision at 8.7 years, maximum follow-up = 14.1 years, n = 145 at 10 years.
§ Last revision at 2.8 years, maximum follow-up = 13.1 years, n = 33 at 10 years.

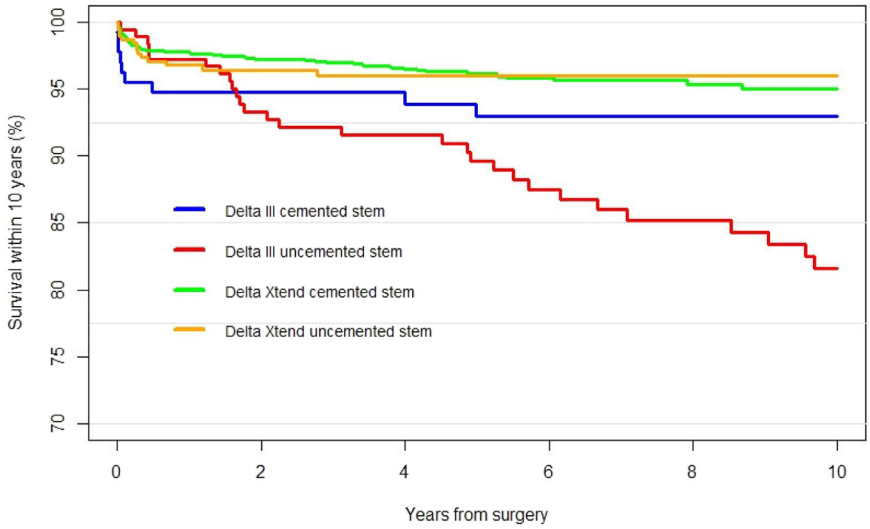

Figure 4 Kaplan-Meier survival with 10 years of follow-up for Delta III cemented stem (*blue*), Delta III uncemented stem (*red*), Delta Xtend cemented stem (*green*), and Delta Xtend uncemented stem (*yellow*).

early reasons for revision with a median time to revision of 2 months (0-102 months), whereas deep infection (19 months, 0-161 months), loosening of components (25 months, 0-292 months), and periprosthetic fracture (22 months, 0-115 months) occurred later (Fig. 6).

Intraoperative complications

Intraoperative complications were registered in 101 procedures (2.8%). Of these, 4 (3.0%) occurred in Delta III (cemented stem), 9 (4.9%) in Delta III (uncemented stem), 79 (2.7%) in Delta Xtend (cemented) stem, and 9 (2.3%) in Delta Xtend (uncemented stem) (Table VII). Bleeding, fracture of proximal or distal bone, and problems because of the patient's anatomy were the most common intraoperative complications.

Discussion

We found that Delta III with uncemented stem was associated with a higher risk of revision compared with Delta Xtend with cemented stem and a tendency toward a higher risk of revision compared with Delta III with cemented stem. Glenoid loosening was the most frequent cause of revision for the earlier design (Delta III uncemented stem). Instability was the most frequent revision cause with the modern design (Delta Xtend), but the rate of revision due to instability was not changed from Delta III to Delta Xtend. Male sex and sequelae after fracture as an indication for surgery were associated with a higher risk of revision.

The improvement in results may be partly due to the early learning curve in both patient selection and the technical procedure for RSA, as described by Walch et al,[41]

Table III Cox model with endpoint all-cause revision at 10-year follow-up, adjusted for sex, age, and diagnosis

	HR (95% CI)	*P* value
Prosthesis type		
Delta III, cemented stem	1.1 (0.54-2.4)	.738
Delta III, uncemented stem	**2.9** (1.7-5.0)	**<.001**
Delta Xtend, cemented stem	1	
Delta Xtend, uncemented stem	1.0 (0.57-1.8)	.945
Sex		
Female	1	
Male	**2.8** (2.0-3.9)	**<.001**
Age group (yr)		
<55	1.5 (0.86-2.7)	.153
55-64	1.0 (0.61-1.6)	.916
65-74	1	
75+	0.8 (0.53-1.6)	.242
Diagnosis		
Acute fracture	0.9 (0.46-1.7)	.665
Fracture sequelae	**2.8** (1.7-4.7)	**<.001**
Inflammatory arthritis	1.5 (0.78-2.9)	.226
Rotar cuff arthropathy	0.9 (0.51-1.7)	.833
Osteoarthritis	1	
Others	1.6 (0.77-3.5)	.203

HR, hazard ratio; *CI*, confidence interval.
Significant values are highlighted in bold figures.

Table IV Cox model with endpoint all-cause revision at 10-year follow-up for Delta III, adjusted for sex, age, and diagnosis

	HR (95% CI)	*P* value
Prosthesis type		
Delta III, cemented stem	1	
Delta III, uncemented stem	2.3 (0.95-5.3)	.064
Sex		
Female	1	
Male	**3.9** (1.9-8.0)	**<.001**
Age group (yr)		
<55	1.2 (0.41-3.4)	.765
55-64	1.3 (0.52-3.1)	.602
65-74	1	
75+	1.0 (0.36-2.5)	.914
Diagnosis		
Acute fracture	1.0 (0.11-8.1)	.969
Fracture sequelae	1.2 (0.37-3.8)	.775
Inflammatory arthritis	1.0 (0.36-2.8)	.993
Rotar cuff arthropathy	0.4 (0.04-3.0)	.347
Osteoarthritis	1	
Others	0.7 (0.08-6.4)	.750

HR, hazard ratio; *CI*, confidence interval.
Significant values are highlighted in bold figures.

Table V Cox model with endpoint all-cause revision at 10-year follow-up for Delta Xtend, adjusted for sex, age, and diagnosis

	HR* (95% CI)	*P* value
Prosthesis type		
Delta Xtend, cemented stem	1	
Delta Xtend, uncemented stem	1.0 (0.59-2.0)	.808
Sex		
Female	1	
Male	**2.6** (1.7-3.4)	**<.001**
Age group (yr)		
<55	1.7 (0.84-3.4)	.142
55-64	0.9 (0.50-1.6)	.686
65-74	1	
75+	0.8 (0.48-1.2)	.190
Diagnosis		
Acute fracture	1.0 (0.47-1.9)	.905
Fracture sequelae	**3.5** (1.9-6.3)	**<.001**
Inflammatory arthritis	1.6 (0.63-4.2)	.319
Rotar cuff arthropathy	1.1 (0.57-2.2)	.758
Osteoarthritis	1	
Others	2.0 (0.87-4.5)	.104

HR, hazard ratio; *CI*, confidence interval.
Significant values are highlighted in bold figures.

but also due to the development in the prosthesis design and surgical techniques.

The use of RSA has increased steadily in the study period, and the indications for RSA have changed from mostly inflammatory arthritis and fracture sequelae toward acute fracture, osteoarthritis, and rotator cuff deficiency and arthropathy. The decreased risk of revision with increased surgeons' experience and due to a change in indication for surgery has also been reported earlier.[41] We found a decreasing risk of revision due to infection during the study period, as opposed to the results from hip arthroplasty, where the risk seems to increase.[9,10] Changes in patient demographics, surgeons' skills, indications for revision, and better reporting probably influence the risk for infection more than the implant design. Although Cho et al's[7] meta-analysis from 2017 showed no increased risk of infection with RSA in inflammatory arthritis, patients with inflammatory arthritis have earlier been shown to have increased risk of revision due to infection.[27,35] The Delta III prosthesis, in particular with uncemented stem, was frequently used in patients with inflammatory arthritis, and this may explain some of the increased risk of revision due to infections and loosening.[7] Even if the risk of revision due to infection is lower for Delta Xtend, our reported rate of infection is still higher than earlier reported for anatomic total shoulder arthroplasties.[13,21,33]

We found increased risk of revision after fracture sequelae. This increased risk has also been described in earlier studies,[39,40] and these patients have also been reported to have poorer clinical results.[8]

Instability and dislocation were the most frequent reasons for revision in our study. The incidence of revision due to instability did not change from Delta III to Delta Xtend. In our study, the incidence was 1.4%, which was lower than

Table VI Reasons for revision by incidence and subhazard ratios (SHRs) for 3650 Delta reverse shoulder arthroplasties reported to the Norwegian Arthroplasty Register between 1994 and 2021

Prosthesis type and fixation of stem*	Deep infection (n = 40)	Instability/dislocation (n = 51)	Glenoid* loosening (n = 20)	Humeral* loosening (n = 12)	Periprosthetic fracture (n = 8)	Other (n = 20)	Total† (n = 151)
Delta III cemented stem, n = 133 (% revised)	1 (0.8)	6 (4.5)	1 (0.8)	0	0	1 (0.8)	9 (6.8)
SHR (95% CI)	0.5 (0.1-4.4)	2.0 (0.7-7.8)	1.9 (0.2-17.0)	–	–	1.0 (0.1-8.8)	1.2 (0.5-2.5)
Delta III uncemented stem, n = 182 (% revised)	9 (4.9)	2 (1.1)	12 (6.6)	5 (2.7)	2 (1.1)	3 (1.6)	40 (22.0)
SHR (95% CI)	**3.0 (1.1-8.5)**	0.6 (0.2-2.5)	**16.6 (5.3-52.0)**	**11.2 (3.4-36.3)**	3.2 (0.2-54.0)	0.8 (0.2-4.0)	**2.9 (1.8-4.8)**
Delta Xtend cemented stem n = 2947 (% revised)	27 (0.9)	36 (1.2)	5 (0.2)	7 (0.2)	6 (0.2)	16 (0.5)	96 (3.3)
SHR (95% CI)	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)	1 (ref)
Delta Xtend uncemented stem, n = 388 (% revised)	3 (0.8)	7 (1.8)	2 (0.5)	0	0	2 (0.5)	14 (3.6)
SHR (95% CI)	0.8 (0.2-2.6)	1.4 (0.6-3.4)	1.8 (0.3-10.2)	–	–	0.8 (0.2-3.6)	1.0 (0.6-1.9)

SHR, subhazard ratio*; CI*, confidence interval.

All other revision causes were merged and hence treated as one competing risk in the analyses. Results presented with 10 years of follow-up adjusted for age, sex, and primary diagnosis. Arthroplasties revised after 10 years (n = 12) were not included in the analyses. Delta Xtend (cemented stem) was used as reference comparing the 3 other Delta types. Statistically significant results are in bold (*P* value <.05, 2-sided test).

* All glenoid components are uncemented.

† The surgeons reported 147 revisions. Revisions where both glenoid and humeral loosening were registered are counted for in both groups (n = 4). A total of 151 revisions were included in the analyses.

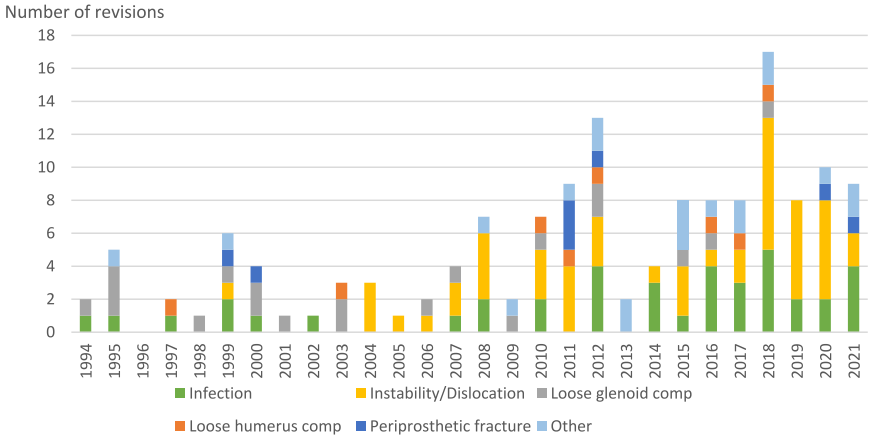

Figure 5 Reasons for revision by year of primary operation of Delta reverse shoulder arthroplasties with primary surgery from 1994 to 2021. Patients with loosening of both humerus and glenoid components are registered in both groups (n = 6): Delta III 1994-2010 and Delta Xtend 2007-2021.

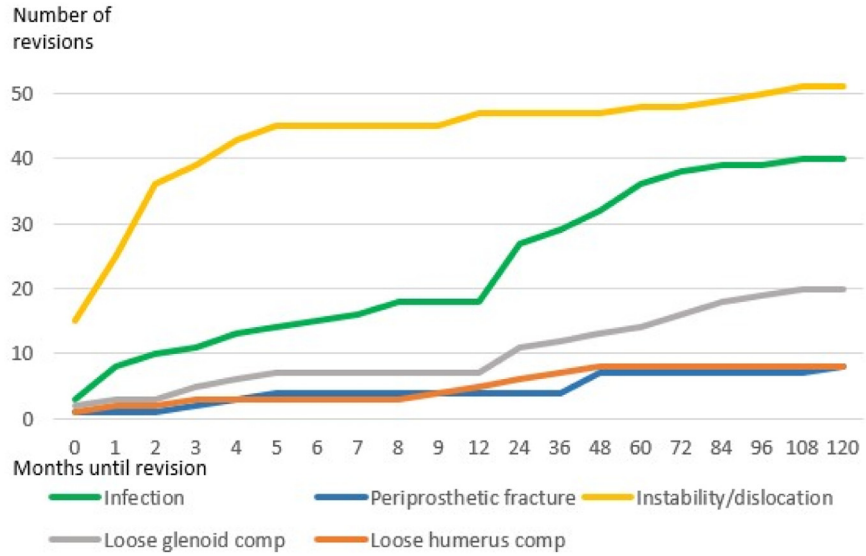

Figure 6 Time from primary surgery to revision (months) according to the cumulative frequency of the different reasons for revision. Note that the first year is given in 1-month intervals; thereafter 12-month intervals are given.

in earlier publications where high incidence (4.7%) of instability with the Grammont designs and the 155° neck-shaft angle have been reported.[43] Most revisions due to instability in our study occurred within the first 6 months after surgery. Delta Xtend was used more frequently with fractures in our population, and a higher rate of instability is expected.[29] The low rate of revision due to instability despite increased use in fracture patients may reflect increased awareness of the challenges with fracture patients.

Notching and glenoid loosening was one of the common complications with the early RSAs.[1,28,34,37,38] The focus on inferior positioning of the glenoid component and the possibility of choosing an eccentric glenosphere are measures taken to prevent loosening. The change to a curved back and HA coating on titanium on the glenoid baseplate may also contribute to less glenoid component loosening with Delta Xtend. Concurrently, we found that glenoid loosening was less common with Delta Xtend than with Delta III (uncemented stem).

We found an almost 3 times higher risk of revision for Delta III with uncemented stem compared with Delta Xtend with cemented stem. Further, even if not statistically significant due to the reduced number of patients, Delta III with uncemented stem had a tendency toward a doubled risk of revision compared with the Delta III cemented stem. On the other hand, no difference was found between Delta Xtend with uncemented and cemented stems. Uncemented

Table VII Intraoperative complications according to humerus fixation in Delta reverse shoulder arthroplasties reported to the Norwegian Arthroplasty register, 1994-2021

	Delta III		Delta Xtend		Total (n = 3650)
	Cemented stem (n = 133)	Uncemented stem (n = 182)	Cemented stem (n = 2947)	Uncemented stem (n = 388)	
Glenoid fracture, n (%)	–	5 (2.7)	12 (0.4)	1 (0.3)	18 (0.5)
Humerus fracture, n (%)	–	–	13 (0.4)	1 (0.3)	14 (0.4)
Extensive bleeding, n (%)	1 (0.8)	–	13 (0.4)	1 (0.3)	15 (0.4)
Anatomic problem*, n (%)	–	2 (1.1)	19 (0.6)	1 (0.3)	22 (0.6)
Technical problem†, n (%)	–	1 (0.5)	6 (0.2)	1 (0.3)	8 (0.2)
Administrative‡, n (%)	3 (2.3)	1 (0.5)	5 (0.2)	1 (0.3)	10 (0.3)
Soft tissue injury§, n (%)	–	–	4 (0.1)	2 (0.5)	6 (0.2)
Other, n (%)	–	–	7 (0.2)	1 (0.3)	8 (0.2)
Total complications, n (%)	4 (3.0)	9 (4.9)	79 (2.7)	9 (2.3)	101 (2.8)

* Includes change of components due to notching/impingement, failed attempt on ostheosynthesis, cementing an uncemented component because of poor bone quality, etc.
† Includes technical problems with components, cement, and instruments.
‡ Includes missing components, breaks in sterile technique, etc.
§ Includes injury of nerve, vessel, or tendon.

stems can lead to proximal bone resorption and signs of stress shielding with stem diameter being related to the degree of bone resorption.[24] In our study, the uncemented stem was used more frequently in Delta III as opposed to the study by Alberio et al[1] where mostly cemented stems were used in Delta III and uncemented stems in Delta Xtend. The Delta III uncemented stem had a smooth surface underneath the HA coating, and this can contribute to the observed increased risk of humeral loosening. The combination of a smooth surface with HA coating has been shown to have inferior results in hip arthroplasties.[20] The glenoid component was the same for Delta III with uncemented and cemented stems, and we cannot explain why the glenoid seemed to come loose more often when combined with an uncemented stem. When compared with Delta Xtend (cemented stem), we cannot conclude on the reasons for increased risk for glenoid loosening for Delta III (uncemented stem), and several factors probably contribute to this. Implant design changes, patient selection, and surgeons' experience may all influence the risk of revision.

Intraoperative fractures can occur both in the humerus and glenoid. These fractures are uncommon complications that can be difficult to manage. Humeral fractures have been more common than glenoid fractures in earlier reports and have been reported in 1.8% of patients.[36] Only 0.8% intraoperative fractures were reported in our study, and there were more fractures on the glenoid side. Only 1 humeral fracture was reported with the use of uncemented stems despite the described increased risk with reaming and press-fit stems.[16] With more experience and more implant options, the surgeon may lower the threshold for revising an implant that earlier would be left in place with a poor functional result. Despite this, we found a lower risk of revision in the later years of the study period.

Strengths and limitations

The primary strengths of this study are the high number of arthroplasties included on a national level, long follow-up time, and the high completeness of reporting to the NAR (90.8% for primaries and 84.6% for revisions).[15] This allowed us to evaluate rare complications that would otherwise be impossible to assess at a single institution.

Only surgical revisions were reported, and we had no information on postoperative complications that were managed nonoperatively or reoperations without involvement of the components. Most acromial and scapular spine fractures were probably managed nonoperatively and not reported. We had no access to X-rays, and, accordingly, radiological findings could not be evaluated. The reasons for revision were reported by the surgeon immediately after surgery. Unexpected positive perioperative bacterial samples from revision surgeries would be identified later and not reported to the register. We suspect that some of the unknown reasons for revision, and some revisions due to aseptic loosening or pain alone, may in fact be low-grade infections that were not suspected at the time of surgery due to the lack of clinical manifestations of infection. As a consequence of this, the register will collect results from bacterial samples from all revision surgeries in the future. The NAR has only recently added patient-reported outcome measures to the registration, and no patient-reported outcome measure results were available for this study. The 2 prostheses compared have been used in 2 different time periods. This resulted in a longer mean follow-up for

the Delta III arthroplasties than for Delta Xtend. Shorter follow-up may underestimate the risk of some of the complications known to occur late such as loosening. To partly compensate for this, we analyzed the risk of revision with endpoint at 10 years for all implants, censoring events occurring after. Also, the fact that the 2 designs were used in different time periods means that other time-dependent differences (ie, surgical technique, surgeon's threshold for revision surgery, instrumentation, and infection prevention strategies) could have influenced our results. Cementing was not a randomized variable; cemented and uncemented stems were used in different patient populations. Delta III with uncemented stem was used in many patients with inflammatory arthritis, whereas the uncemented stem in Delta Xtend was used mainly for patients with primary osteoarthritis and rotator cuff arthropathy who have better bone quality and expected lower risk of loosening. The large increase in the use of shoulder arthroplasties has led to a much larger number of arthroplasties in the Delta Xtend groups than in the Delta III groups, which could also influence the outcome.

Conclusion

We found that Delta III (uncemented stem) had a higher risk of revision compared with Delta Xtend (cemented stem). The reasons for revision have changed, and both loosening and infection have become less of a problem in the more recent years. This register study cannot determine whether the differences found were caused by differences in implant design or by other factors that changed during the study period. Instability is still a main concern, and alternative solutions to the original Grammont design are still being explored to address this.

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