International Orthopaedics (SICOT) (2016) 40:2355–2363
DOI 10.1007/s00264-016-3255-7

ORIGINAL PAPER

Total shoulder replacement using a bone ingrowth central peg polyethylene glenoid component: a prospective clinical and computed tomography study with short- to mid-term follow-up

Giovanni Merolla[1] · Giovanni Ciaramella[1] · Elisabetta Fabbri[2] · Gilles Walch[3] · Paolo Paladini[1] · Giuseppe Porcellini[1]

Received: 20 March 2016 / Accepted: 19 July 2016 / Published online: 10 August 2016
© SICOT aisbl 2016

Abstract
Aim of the study To assess the clinical and computed tomography (CT) outcomes of shoulder replacement with a novel bone ingrowth all-polyethylene glenoid component (APGC).
Methods Twenty-eight patients (30 shoulders) with osteoarthritis, mean age 62.3 years (range, 45–75), were implanted with the novel component between 2011 and 2013. Patients were evaluated by active range of motion (ROM), Constant-Murley score (CMS), simple shoulder test (SST), X-rays, and multidetector CT at two months and at a mean follow-up of 31 months (range, 24–39). Early and late follow-up CT scans were available for 21/30 shoulders.
Results Median ROM increased from 105 to 160° for anterior elevation, from 100 to 160° for lateral elevation, from 20 to 40° for external rotation, and from 2 to 10 points for internal rotation (all $p < 0.001$). CMS rose from 30 to 80.5 points and SST from 2.5 to 11 (both $p < 0.0001$). None of the glenoid components migrated. Progressive radiolucency was seen in 28/30 shoulders. There was a strong correlation between greater bone ingrowth (median Arnold score: 7) and lower radiolucency score (median Yian score: 2) at the last follow-up ($p < 0.001$). Osteolysis around the central peg was seen in two shoulders. There was no correlation between clinical scores and CT findings ($p > 0.05$).
Discussion The partially cemented glenoid component for TSR assessed in this study resulted in satisfactory shoulder function at an early follow-up. The glenoid prosthesis was stable, with few radiolucent lines and good central peg bone ingrowth.
Conclusions The satisfactory bone ingrowth documented on CT is encouraging and supports the use of the new prosthesis. Long-term follow-up studies can confirm if this device represents a rational alternative to fully cemented polyethylene glenoids.

Keywords Shoulder · Arthroplasty · Glenoid component · Bone ingrowth

✉ Giovanni Merolla
giovannimerolla@hotmail.com

[1] Shoulder and Elbow Unit, D. Cervesi Hospital, Via L.V. Beethoven 5, Cattolica (RN) 47841, Italy

[2] Research and Innovation Department, AUSL della Romagna, Rimini, Italy

[3] Centre Orthopédique Santy, Lyon, France

Introduction

Total shoulder replacement (TSR) is a viable treatment option to relieve pain and improve shoulder function in patients with degenerative glenohumeral conditions. However, glenoid component loosening remains the main long-term complication [1, 2] and glenoid replacement in young individuals with high physical demands is highly controversial [3]. Although several studies have examined the potential factors involved in failure of shoulder arthroplasty, there is no agreement on the most appropriate glenoid component design [4]. Radiolucency at the bone-cement interface of all-polyethylene glenoid components (APGC) is common, and its progression can lead to symptomatic glenoid loosening, involving pain and instability [5]. Mean annualized rates of 7.3 % and 1.2 % have been reported respectively for asymptomatic radiolucent lines and symptomatic glenoid loosening [1]. In addition, radiolucency is significantly reduced in pegged APGC compared with keeled components [6]. Changes in glenoid design [7] and cementation techniques have been devised, to improve glenoid stability [8], and new

biomaterials enhancing implant-bone fixation have been explored [9, 10]. In a canine model, Wirth et al. found that APGC with a bone ingrowth central peg exhibited greater mechanical strength than a cemented keeled component [11]. However, the clinical and radiographic outcomes of the first partially cemented APGC were inconsistent, with some authors reporting early migration and failure of osteointegration [12] and others describing satisfactory results with high rates of central peg incorporation [7, 13, 14]. Osteointegration of the uncemented central peg has been explored with plain X-rays [7, 15] and computed tomography (CT) in short-[16], mid-[13] and long-term [17] follow-up studies. The adoption of high-resolution CT has reduced artifacts, enabling an analytical interpretation of prosthetic detail and providing important prognostic data to evaluate the risk of glenoid loosening.

The present study examined the clinical and multi-detector computed tomography (CT) outcomes of TSR using a novel APGC with a bone ingrowth central peg in a series of patients with shoulder osteoarthritis (OA).

Materials and methods

Study Population and Design

Forty consecutive patients who underwent TSR with an all-polyethylene pegged bone ingrowth glenoid component (Aequalis PERFOM Cortiloc™, Tornier SAS, Montbonnot Saint Martin, France) between July 2011 and August 2013 were invited to participate in this prospective study that was approved by the institutional review board (Prot. No. 4251/2015/I.5/91). Inclusion criteria were a pre-operative diagnosis of primary shoulder OA and a minimum follow-up of 24 months. Seven patients refused their consent, and three had incomplete clinical and radiographic data, leaving 28 patients (30 shoulders) with a mean follow-up of 31 months (range, 24–39). Their demographics and preoperative diagnoses are reported in Table 1.

Pre-operative radiographic imaging

Plain radiographs (anterior-posterior Grashey, Y lateral, and axillary views) were obtained. OA was graded on X-rays as type 1, 2, or 3 according to the classification of Samilson and Prieto [18] as modified by Gerber [19]; glenoid morphology was evaluated on axial CT scans using established criteria [20] (Fig. 1). OA was grade 2 in four shoulders (13 %) and grade 3 in 26 shoulders (87 %). The pre-operative glenoid wear pattern included the following types: A1 (2; 7 %), A2 (11; 36 %), B1 (15; 50 %), and B2 (2; 7 %).

Table 1 Demographics and preoperative diagnosis of the study population

Variable	Data
Patients (no.)	28
Shoulder (no.)	30
Age (years) (mean ± SD) (range)	62.3 ± 8.9 (45–75)
Gender (males/females) (%)	15/13 (53/47)
Dominant shoulders (no.)(%)	20 (71 %)
BMI (mean ± SD)	25.6 ± 3.7
Osteoarthritis grade (no.) (%)	
Type 2	4 (15)
Type 3	24 (85)
Mean FU (months ± SD) (range)	31 ± 3.2 (24–39)

Osteoarthritis graded as type 1, 2 or 3 according to Samilson and Prieto [18] as modified by Gerber [19]

SD standard deviation, *BMI*: body mass index, *FU* follow-up

Prosthesis design

All patients received the non-constrained Aequalis Ascend™ prosthesis, which has a high molecular weight polyethylene convex-back glenoid component (CortiLoc™) with four pegs; the upper and the two lower pegs (5 mm) are fully cemented, whereas the longer, central peg is provided with six fins for cancellous bone ingrowth (Fig. 2). The humeral component has a monoblock titanium spray-coated press-fit stem, with a female taper connection and humeral head offset.

Surgical procedure

The shoulder was exposed using a deltopectoral approach and lesser tuberosity osteotomy in continuity with the subscapularis tendon. Humeral head osteotomy at the anatomical neck was performed by the free hand technique. After complete capsule resection the joint was exposed with

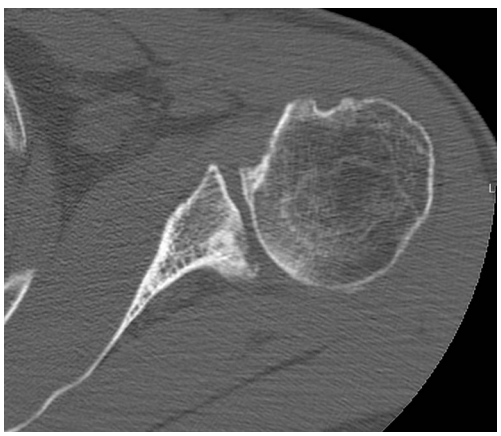

Fig. 1 Pre-operative axial CT scan showing shoulder osteoarthritis with narrowing and sclerosis of the posterior glenoid rim and biconcave surface (type B2 glenoid morphology). The humeral head is subluxated posteriorly

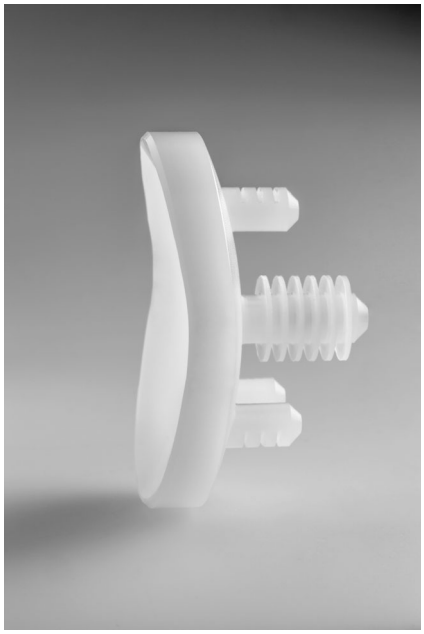

Fig. 2 The polyethylene glenoid component (Aequalis PERFOM Cortiloc™, Tornier SAS, Montbonnot Saint Martin, France) with a flanged bone-ingrowth central peg used in the study

retractors. A central guide hole was drilled to ream the glenoid surface; in patients with B1 and B2 morphology, the glenoid surface was reamed in the appropriate direction and to the appropriate extent ("asymmetric reaming") to restore the correct version (0-10°). The subchondral bone was exposed, and the surface was smoothed to enhance bone-prosthesis contact. Three additional holes were then drilled to insert the trial component and test intrinsic stability (Fig. 3a). The final glenoid component was fixed using low-viscosity cement (Cemex® System, TecresS.p.A, Sommacampagna, Italy) for the peripheral pegs, and finely morselized bone around the fins for the bone ingrowth central peg (Fig. 3b). The cementation procedure involved vacuum mixing and high pressurization, to reduce the effects of mechanical bonds at the prosthesis-cement-bone interface [21]. As regards the humeral component, the medullary canal was bored with an awl. The methaphysis was prepared with rasps of increasing size, carefully preserving and gently packing the cancellous bone, while maintaining the correct humeral retroversion (20–30°). The appropriate stem and humeral head size were selected using trial components, and implant stability and mobility were tested. The definitive press-fit humeral component and humeral head were impacted. The subscapularis was reattached with bone sutures and the wound was closed in layers. The arm was immobilized in a sling for four to six weeks. Passive mobilization in the scapular plane was allowed from the first post-operative day; active assisted exercises, including internal and external shoulder rotation, were initiated at four to six weeks and strength exercises at eight weeks.

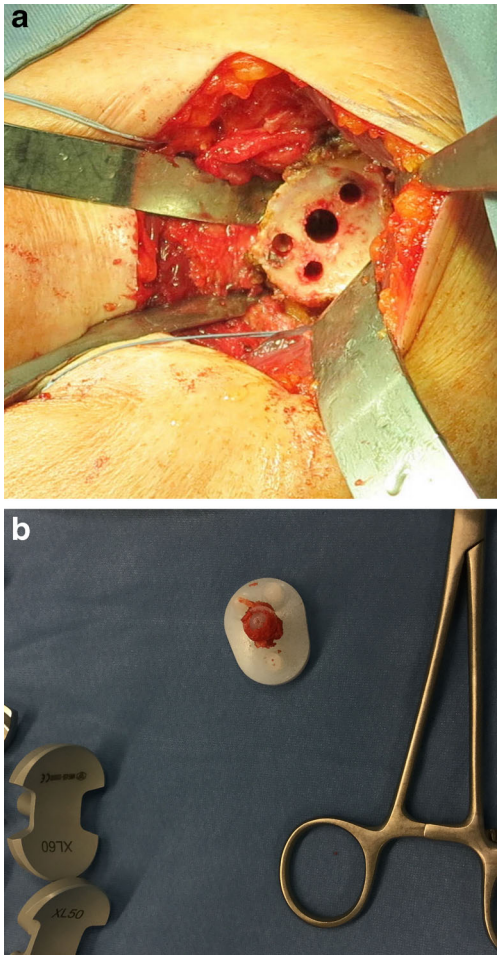

Fig. 3 **a** Intra-operative image showing the four holes for glenoid component fixation. **b** Preparation of the morselized bone graft around the central peg before the insertion of the glenoid component

Clinical evaluation and outcome measures

Patients underwent clinical evaluation before surgery, in the early post-operative period (2 months, including standard plain radiographs), and at the latest follow-up by assessment of active range of motion (ROM), Constant Murley score (CMS) and related subscores [22] (daily living activities, DLA; pain, mobility, and strength), and simple shoulder test (SST) [23]. Active ROM was measured by two raters (PP ad GC) with a goniometer as anterior elevation (AAE), lateral elevation (ALE), and external rotation (ER) with the patient standing. Internal rotation (IR) was expressed as points, based on the patient's ability to reach down their spine with the thumb (Appley scratch test). Post-operative active shoulder mobility and passive mobility (except IR) were compared. Patient satisfaction (PTSAT) was graded on a 10-point visual analog scale (VAS) scale. ROM and clinical scores were measured by two raters who did not take part in the surgical procedures.

Multi-detectorCT data acquisition and analysis

All subjects (30 shoulders) were evaluated by CT at a mean follow-up of 31 months (range, 24–39), whereas 21/30 underwent CT scanning in the early post-operative period (range, 3–60 days). Scans were obtained with a 64-detector apparatus (General Electric 64, Fairfield, CT, USA); 0.625 mm axial scans were acquired in supine position with the arm adducted and in >90° of abduction, to reduce artifact generation, also using B50 algorithms [21]. Images were reconstructed in oblique paracoronal and parasagittal planes aligned to the glenoid orientation. Yian CT scores, calculated for 4-pegged APGC, ranged from 0 (no radiolucency) to 18 (maximum radiolucency) [24]. Since the central peg of the component evaluated in our study was uncemented and had six radial fins, bone ingrowth was assessed by the criteria of Arnold et al.[13], modified for application to this peg (modified Arnold score). The CT scans depicted ten compartments between the fins, on each side of the core diameter of the central peg (i.e., five above and five below in paracoronal view). The absence/presence of bone in each compartment was scored from 10 (bone in all 10 compartments) to 0 (bone in no compartment). Acquisitions and measurements were made separately by two radiologists of our department with more than ten years experience in shoulder imaging, who were blinded to demographic and clinical data. Each CT scan, acquired in the early postoperative period and at the last follow-up visit, was scored twice by the raters.

Statistical analysis

A descriptive analysis of the variables was conducted by calculating mean, SD, median and interquartile range (IQR), as appropriate. Correlations between CT scores, clinical variables and demographic data were sought using non-parametric Spearman's test, Mann–Whitney and Kruskal-Wallis test. Inter-rater agreement was measured by Cohen's kappa (k). The difference between pre- and post-operative clinical scores and CT data was analyzed with the Wilcoxon signed-rank test. Significance was set at p <0.05. The Stata Intercooled 9.2 software was used for all statistical tests.

Results

Age, gender, dominance, and body mass index were not significantly associated with post-operative clinical scores or ROM (p >0.05; Spearman's and Kruskal-Wallis tests).

Clinical outcomes

Active ROM increased significantly, with a median increase change from pre-operative of 65° for AAE (p <0.001; IQR:30, Wilcoxon test), 67° for ALE (p <0.001; IQR: 30), 15° for ER (p <0.001; IQR: 40), and 6 points for IR (p <0.001; IQR:4) (Table 2). Passive and active ROM on each plane of movement exhibited significant differences ($p < 0.001$). Pre-operative and post-operative clinical scores were significantly different, with a median change of 48.5 points for CMS ($p < 0.0001$;IQR: 16) and 8 points for SST ($p < 0.0001$; IQR: 4), yielding good to excellent scores (Table 3). CMS subscores also improved significantly from pre-operative: 5 points for pain ($p < 0.0001$; IQR: 5), 9 points for DLA ($p < 0.0001$; IQR: 4), 24 points for mobility ($p < 0.0001$; IQR: 10), and 3 points for strength ($p = 0.0013$; IQR: 8) (Table 3). As regards DLA, all 28 patients returned to work without limitations and 19/28 (67.8 %) resumed recreational/sport activities. In particular, seven subjects resumed their part-time job as artisans and 12 returned to their amateur sports [golf ($n = 2$), cycling ($n = 3$), running ($n = 2$), skiing ($n = 2$), tennis ($n = 2$), and fitness ($n = 1$)]. PTSAT was 9.5 ± 5.31 (range 8–10); 95 % of patients were satisfied or very satisfied. Inter-rater and intra-rater agreement was good ($k = 0.81$–0.84).

Early post-operative radiographic assessment

Radiographs taken 60 days from the procedure documented implant stability and good component positioning in all shoulders. Radiolucency around the glenoid component was found in three patients (<0.5 mm, involving two areas in one patient and one area in 2 patients).

CT outcomes and correlation with clinical scores

Mean glenoid version values were $2° \pm 0.4°$ retroversion preoperatively and $1.5° \pm 0.4°$ anteversion in the prosthesis [25]. The CT scores given by two raters at the two follow-up visits are reported in Table 4. Bone around the central peg was detected in 28/30 shoulders (Fig. 4a-b). At the latest follow-up radiolucent lines were seen in 25/30 shoulders by rater 1 and in 27/30 shoulders by rater 2; their distribution is reported in Fig. 5. The early post-operative and latest follow-up CT scores were significantly different in 21/30 shoulders according to the two raters (p <0.05)

Table 2 Yian scoring system for radiolucency for each area of the pegged glenoid component as recorded on CT scans

ROM	Pre-operative	Post-operative	P value (Wilcoxon's test)
AAE (°)	105 (35)	160 (20)	$p < 0.001$
ALE (°)	100 (30)	160 (20)	$p < 0.001$
ER (°)	20 (45)	40 (10)	$p < 0.001$
IR (points)	2 (4)	10 (2)	$p < 0.001$

Values are expressed as median with interquartile range in brackets

ROM range of motion, *AAE* active anterior elevation (sagittal plane), *ALE* active lateral elevation (scapular plane), *ER* external rotation, *IR* internal rotation (Appley scratch test)

Table 3 Preoperative and postoperative active range of motion

Variable	Pre-operative	Post-operative	p value (Wilcoxon's test)
Constant-Murley score	30 (20)	80.5 (7)	$p < 0.0001$
Pain	0 (5)	15 (0)*	$p < 0.0001$
DLA	0 (4)	10 (0)	$p < 0.0001$
Mobility	24 (8)	49 (2)	$p < 0.0001$
Strength	2 (5)	7.5 (6)	$p = 0.0013$
SST	2.5 (5)	11 (1)	$p < 0.0001$

*All subjects reported complete pain relief

Values are expressed as median with interquartile range in brackets based on the Constant scoring system

Mobility: 40 points are allotted to movement and are divided equally as follows

Anterior elevation: 2 points for each 30° of motion (0 points = 0-30°; 10 points = 151-180°)

Lateral elevation: 2 points for each 30° of motion (0 points = 0-30°; 10 points = 151-180°)

External rotation. 2 points = hand behind head with elbow held forward and 10 points = all listed ER movements up to and including full elevation from top of head

Internal rotation. 0 = dorsum of hand on lateral thigh; 10 = dorsum of hand on interscapular region

Pain: 0 = severe; 5 = moderate; 10 = mild; 15 = none

Strength: number of pounds resisted up to a maximum of 25

DLA Daily living activities, *SST* Simple shoulder test

(Table 4). As regards the early post-operative assessment, the Yian and the Arnold score did not correlate significantly ($p = 0.171$; Spearman's rank test), whereas a strong correlation was found between greater bone filling of central peg compartments and better (lower) Yian score at the latest follow-up ($p < 0.001$; Spearman's rho = −0.67) (Fig. 6). The median Yian score increased by 2 points (IQR: 1) for observer 1 and by 1 point (IQR: 2) for observer 2; the median modified Arnold score increase was 1 point (IQR: 2) for rater 1 and 1 point (IQR: 3) for rater 2 (Table 4). Central peg osteolysis (no bone all round) was detected in two shoulders by both raters (Fig. 7); excellent bone ingrowth (involving 8/10 or 9/10 compartments) was found in seven shoulders. Bone ingrowth never involved all ten compartments.

ROM and clinical scores did not significantly correlate with the final follow-up CT scores ($p > 0.05$; Spearman's test), and pre-operative glenoid morphology did not correlate with clinical and radiographic scores ($p > 0.05$; Spearman's test). Inter-rater agreement yielded post-operative k values ranging from 0.71 to 0.76 (Yian score) and from 0.89 to 0.92 (modified Arnold score), whereas the k values for the last follow-up ranged from 0.67 to 0.69 and from 0.81 to 083, respectively. Intra-observer agreement was good ($k = 0.84$–0.91).

Discussion

APGC are associated with longer prosthesis survival compared with metal-backed implants [1, 2]; nevertheless, loosening still accounts for about 39 % of TSR complications [26] at 8 to 10 years. New biomaterials have been developed to improve glenoid fixation, including porous tantalum-coated [27], partially cemented [28] and hybrid glenoids [29]. Wirth et al.[11] compared a design with a fluted uncemented central peg with conventional keeled glenoids in canine shoulders; they found bone ingrowth around the peg flanges and a significant increase in mean fixation strength from zero to three months that was maintained at six months. The authors subsequently published their clinical and radiographic results of human TSR using the same type of bone ingrowth glenoid at a mean follow-up of three (clinical outcomes) or four years

Table 4 CT assessment of the Cortiloc™ glenoid component with a bone-ingrowth central peg

	Yian score			Modified Arnold score		
	Post-operative*	Latest follow-up**	P value	Post-operative*	Latest follow-up**	P value
Rater 1	0 (1)	2 (1)	0.0047	8 (2)	7 (2)	0.038
Rater 2	0 (1)	2 (2)	0.0012	8 (2)	7 (2)	0.048

Values are expressed as median with interquartile range in brackets

*mean 12 ± 2 days in 21/30 shoulders (70 %)

** mean 31 ± 3.2 months in 30 shoulders

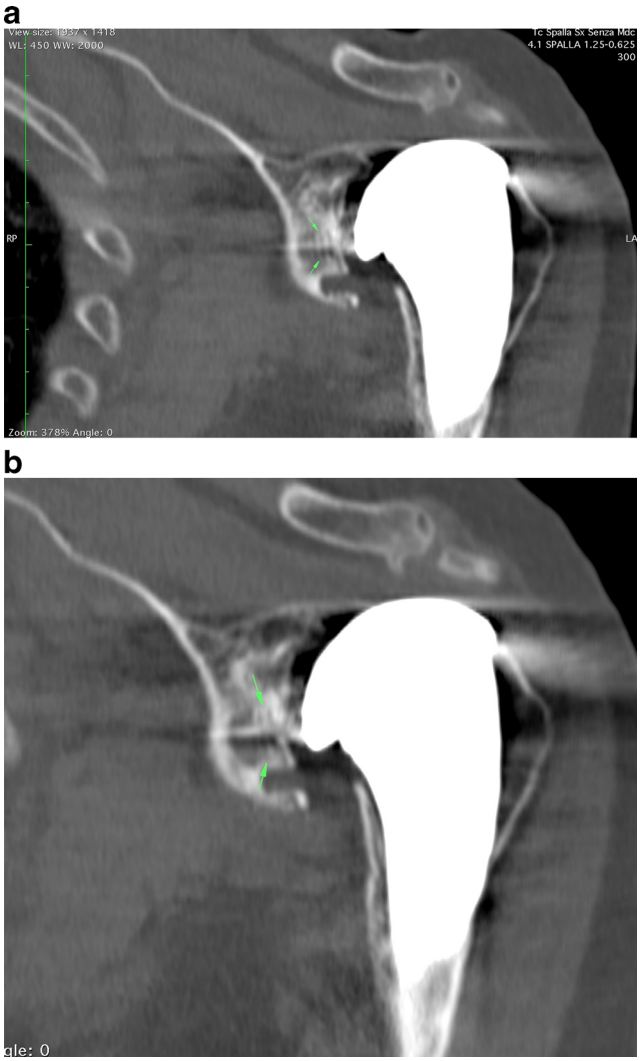

Fig. 4 **a** Coronal CT scan of the Cortiloc^{TM}glenoid component at two month follow-up. The central peg shows optimal bone ingrowth with filling of 8/10 bone compartments (*green arrows*) and absence of radiolucent lines around the peripheral cemented pegs. **b** Coronal CT scan of the same patient as in **a** at 29 months. A remarkable bone ingrowth persists around the central peg (6/10 compartments) (*green arrows*) and no radiolucency is detected around the peripheral pegs

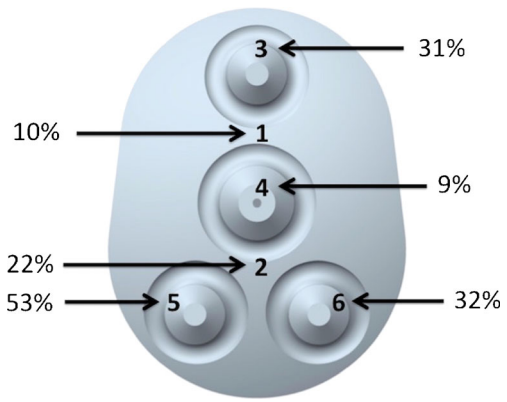

Fig. 5 Distribution of the radiolucencies in the six areas of the glenoid component according to Yian et al [24]

(radiographic outcomes) [7]. Encouragingly, the implants provided stable and durable fixation.

In this study we assessed a novel bone ingrowth APGC (Cortiloc^{TM}) provided with six fins around the central peg [28], whereas the early, partially cemented component introduced in 2002 had four fins [7]. The two additional fins around the central peg in the Cortiloc^{TM} glenoid may be biomechanically relevant and may be capable of fostering bone ingrowth. It is reasonable that the large diameter of the central peg and the multiple fins may result in greater bone growth in the compartments between the flanges, thus enhancing glenoid component stability. The CT findings of the present study seem to be in line with this hypothesis, although they clearly need support from long-term CT evaluation.

A recent study with a short-to-medium follow-up has described stable radiographic and clinical outcomes for Cortiloc^{TM} glenoid prostheses [28]. The present work is the first to assess bone ingrowth and stability of the Cortiloc^{TM} glenoid in primary OA patients using multidetector CT.

Glenoid radiolucency and loosening have extensively been evaluated by CT [12, 13, 16, 24, 30, 31] also in terms of central peg bone ingrowth [12, 13, 16]. The preliminary findings of the present study, with a mean follow-up of 31 months, are encouraging, especially the shoulder mobility and clinical scores. The most interesting data come from CT evaluation, which showed central peg bone ingrowth in 93 % of shoulders, with bone in a median of 7/10 compartments around the central peg at the last follow-up. The Yian and modified Arnold scores changed significantly from the early post-operative to the latest follow-up assessment in 21/30 shoulders, but did not correlate with clinical scores, despite the fact that pain relief, shoulder mobility, and clinical scores were higher than would be expected for TSR at this time point. Such outcomes are likely the result of the inclusion criteria applied, i.e. only patients with concentric shoulder arthritis and an intact rotator cuff. In addition, most patients had A1 and A2 glenoid morphology (only two had a B2 glenoid), making them ideal candidates for anatomical shoulder replacement. Radiolucency was seen in 93 % of shoulders and mainly affected the peripheral pegs; radiolucent lines were marked in the two patients with central peg osteolysis. In line with literature data [30, 31], and despite the advanced cementing technique applied, radiolucent lines were found already in the immediate post-operative radiographs and were progressive. Their significance remains elusive. Moreover, according to our clinical experience and to the literature, patients better tolerate polyethylene glenoids (albeit poorly performing and radiographically at risk) than metal-backed implants [1]. Bone thermal necrosis due to heat production during glenoid cementation [32] contributes to generation of immediate and progressive radiolucent lines, suggesting that cement should be used in limited amount in glenoid replacement, indirectly supporting bone ingrowth glenoid components like the one used in the present study. The reasons for the failure of bone ingrowth in our two patients with central peg

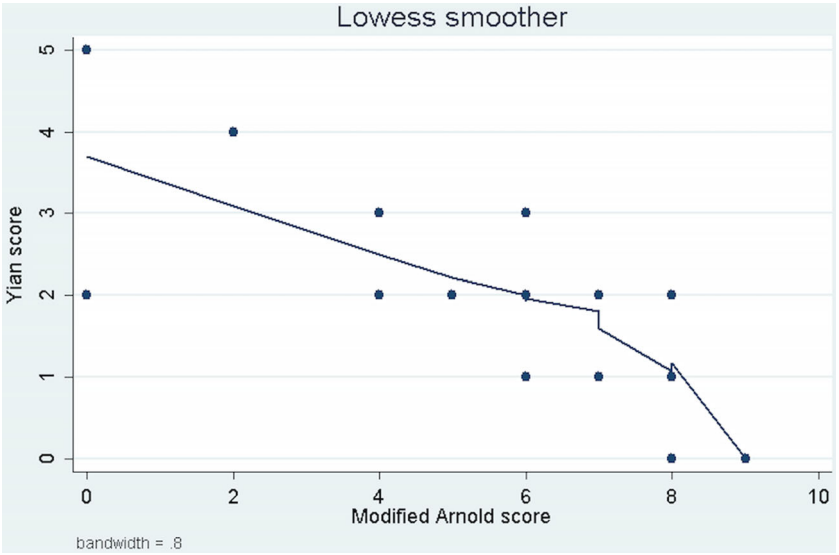

Fig. 6 The diagram shows a high correlation between the bone filling of the central peg compartments (modified Arnold score) and radiolucency around the peripheral pegs (Yian score)

osteolysis remain unclear; the amount of subchondral bone removed during glenoid replacement might be involved. The two patients had pre-operative type A2 and type B1 glenoids, and a standard preparation technique was used in both, removing a minimal amount of subchondral bone to restore correct glenoid morphology (version and inclination). These two patients should be considered as having "at risk" glenoids and will require annual follow-up by CT. We are aware that 31-month follow-up does not enable excluding the risk of long-term central peg osteolysis in the 28 components exhibiting good to satisfactory osteointegration. Most glenoid components are stable at two to three years [13, 14, 21], and the long-term assessment, in terms of functional prognosis and implant survivorship is in line with our experience of complete glenoid loosening, which is depicted on X-rays at five to ten years follow-up in fully cemented components. Even though some authors have hypothesized a role for unrecognized low-grade infections [33] or aseptic loosening [34] in patients with loose glenoid components, the present data do not allow speculations on this aspect.

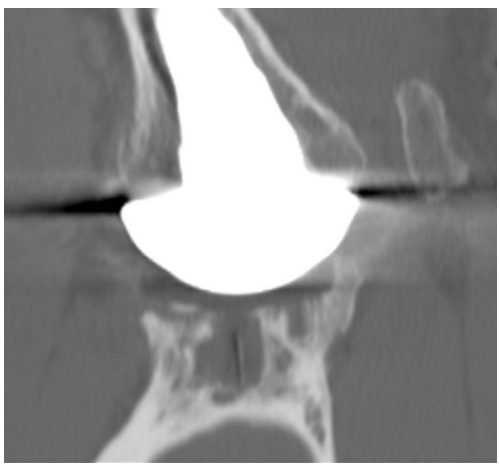

Fig. 7 Coronal CT scan acquired with the arm in > 90° of abduction, to prevent artifact generation. Bone is detected in none of the ten compartments; severe osteolysis is visible around the central peg of the Cortiloc™ glenoid component. Radiolucent lines around the peripheral pegs are also present (Yian score: 5)

Recent findings suggest that patient-specific bone instrumentation ensures better glenoid component positioning than do standard devices [35]; however, it has been reported that the degree of component seating around a partially cemented glenoid component was not associated with radiolucency, and that complete seating was not necessary to achieve radiographic implant stability [36]. The values of glenoid retroversion (2°) found in our patients were lower than those (>10°) reported to be associated with high shear stress and related risk of glenoid failure [37]. Glenoid bone density may also affect bone ingrowth [21], but the available data do not allow drawing conclusions. Our results with the Cortiloc™ glenoid are partially in line with those of the first model of bone ingrowth glenoid component [12, 13, 16]. Arnold et al.[13] reported that autologous bone packed around the inter-fin compartments of the central peg and minimal cementation around the peripheral pegs ensured satisfactory bone presence at 24 months. Vidil et al. [16] demonstrated complete bone ingrowth around the central peg in 21/26 shoulders, partial ingrowth in four, and no ingrowth in one at 12 months. Fast, early migration, focal radiolucency and absence of osteointegration were detected in 6/11 glenoid components by Nuttal et al. [12], who attributed the lack of initial fixation to early movement of the glenoid component, as measured by radiostereometric analysis. The reasons for different CT findings obtained in the same glenoid prostheses are unclear. However, caution is needed when comparing the Cortiloc™ findings to those of the Anchor Peg™ [12, 13, 16], given their different design and peg configurations. All the patients enrolled in the present study had primary OA, as the populations described by

Nuttal et al. and Arnold et al., whereas Vidil et al. recruited patients with primary (18), post-traumatic (5), and rheumatoid arthritis (3), and did not correlate their results with pre-operative diagnosis. Also, none of these studies described or correlated pre-operative glenoid morphology with postoperative CT findings. Overall, there is no discrepancy between our data and those reported by Arnold et al. [13] with regard to central peg bone ingrowth and radiolucency around the peripheral pegs, since these authors stress the importance of bone growth in inter-fin compartments of the central peg in reducing the overall rate of radiolucency around the glenoid component. Our CT data are also in line with those described by Vidil et al. [16], even though they reported osteointegration and peripheral peg radiolucency only at one year.

Early and late CT evaluation and blind radiological examination are the main strengths of this study. Its limitations include the mid-term follow-up, the small sample size, and the incomplete double CT assessment, involving only 21/30 shoulders (70 %).

Despite these limitations, we conclude that the partially cemented glenoid component for TSR assessed in this study resulted in satisfactory shoulder function at a mean follow-up of 31 months. The glenoid prosthesis was stable, with few radiolucent lines and good central peg bone ingrowth. Although the significance of radiolucent lines remains elusive, their progression needs to be monitored over the years, since their increase in number and size has the potential to result in complete loosening of the glenoid component [38–40]. New research projects, now in progress at our unit, will explore the CT performance of the Cortiloc™ glenoid at five to ten year follow-up, to establish whether it is a rational and judicious alternative to fully cemented polyethylene glenoids.

References

1. Papadonikolakis A, Neradilek MB, Matsen FA (2013) Failure of the glenoid component in anatomic total shoulder arthroplasty: a systematic review of the English-language literature between 2006 and 2012. J Bone Joint Surg Am 95:2205–12. doi:10.2106/JBJS.L.00552
2. Papadonikolakis A, Matsen FA (2014) Metal-Backed Glenoid Components Have a Higher Rate of Failure and Fail by backed glenoid components have a higher rate of failure and fail by different modes in comparison with all-polyethylene components: a systematic review. J Bone Joint Surg Am 96:1041–1047. doi:10.2106/JBJS.M.00674
3. Sayegh ET, Mascarenhas R, Chalmers PN et al (2015) Surgical treatment options for glenohumeral arthritis in young patients: a systematic review and meta-analysis. Arthroscopy 31:1156–1166.e8. doi:10.1016/j.arthro.2014.11.012
4. Wiater JM, Fabing MH (2009) Shoulder arthroplasty: prosthetic options and indications. J Am Acad Orthop Surg 17:415–25
5. Merolla G, Campi F, Paladini P et al (2009) Correlation between radiographic risk for glenoid component loosening and clinical scores in shoulder arthroplasty. Chir Organi Mov 93(Suppl 1): S29–34. doi:10.1007/s12306-009-0008-4
6. Edwards TB, Labriola JE, Stanley RJ et al (2010) Radiographic comparison of pegged and keeled glenoid components using modern cementing techniques: a prospective randomized study. J Shoulder Elb Surg 19:251–7. doi:10.1016/j.jse.2009.10.013
7. Wirth MA, Loredo R, Garcia G et al (2012) Total shoulder arthroplasty with an all-polyethylene pegged bone-ingrowth glenoid component: a clinical and radiographic outcome study. J Bone Joint Surg Am 94:260–7. doi:10.2106/JBJS.J.01400
8. Raiss P, Sowa B, Bruckner T et al (2012) Pressurisation leads to better cement penetration into the glenoid bone: a cadaveric study. J Bone Joint Surg Br Vol 94:671–7. doi:10.1302/0301-620X.94B5.28831
9. Budge MD, Kurdziel MD, Baker KC, Wiater JM (2013) A biomechanical analysis of initial fixation options for porous-tantalum-backed glenoid components. J Shoulder Elb Surg 22:709–15. doi:10.1016/j.jse.2012.07.001
10. Jones AC, Arns CH, Sheppard AP et al (2007) Assessment of bone ingrowth into porous biomaterials using MICRO-CT. Biomaterials 28:2491–504. doi:10.1016/j.biomaterials.2007.01.046
11. Wirth MA, Korvick DL, Basamania CJ et al (2001) Radiologic, mechanical, and histologic evaluation of 2 glenoid prosthesis designs in a canine model. J Shoulder Elb Surg 10:140–8. doi:10.1067/mse.2001.112021
12. Nuttall D, Haines JF, Trail IA (2012) The early migration of a partially cemented fluted pegged glenoid component using radiostereometric analysis. J Shoulder Elb Surg 21:1191–6. doi:10.1016/j.jse.2011.07.028
13. Arnold RM, High RR, Grosshans KT et al (2011) Bone presence between the central peg's radial fins of a partially cemented pegged all poly glenoid component suggest few radiolucencies. J Shoulder Elb Surg 20:315–21. doi:10.1016/j.jse.2010.05.025
14. Noyes MP, Meccia B, Spencer EE (2015) Five- to ten-year follow-up with a partially cemented all-polyethylene bone-ingrowth glenoid component. J Shoulder Elb Surg 24:1458–62. doi:10.1016/j.jse.2015.02.018
15. Groh GI (2010) Survival and radiographic analysis of a glenoid component with a cementless fluted central peg. J Shoulder Elb Surg 19:1265–8. doi:10.1016/j.jse.2010.03.012
16. Vidil A, Valenti P, Guichoux F, Barthas JH (2013) CT scan evaluation of glenoid component fixation: a prospective study of 27 minimally cemented shoulder arthroplasties. Eur J Orthop Surg Traumatol 23:521–5. doi:10.1007/s00590-012-1126-5
17. Nuttall D, Haines JF, Trail IA (2011) The early migration of a partially cemented fluted pegged glenoid component using radiostereometric analysis. J Shoulder Elb Surg 1–6. doi:10.1016/j.jse.2011.07.028
18. Samilson RL, Prieto V (1983) Dislocation arthropathy of the shoulder. J Bone Joint Surg Am 65:456–60
19. Gerber C (1992) Latissimus dorsi transfer for the treatment of irreparable tears of the rotator cuff. Clin Orthop Relat Res 152–60
20. Walch G, Badet R, Boulahia A, Khoury A (1999) Morphologic study of the glenoid in primary glenohumeral osteoarthritis. J Arthroplast 14:756–60
21. Merolla G, Amore B, Paladini P et al (2014) Computed tomography quantification of bone density adjacent to cemented pegged polyethylene glenoid components in shoulder arthroplasty. Eur J Orthop Surg Traumatol 24:753–61. doi:10.1007/s00590-013-1368-x
22. Constant CR, Murley AH (1987) A clinical method of functional assessment of the shoulder. Clin Orthop Relat Res 160–4
23. Godfrey J, Hamman R, Lowenstein S et al (2006) Reliability, validity, and responsiveness of the simple shoulder test: psychometric properties by age and injury type. J Shoulder Elb Surg 16:260–7. doi:10.1016/j.jse.2006.07.003
24. Yian EH, Werner CML, Nyffeler RW et al (2005) Radiographic and computed tomography analysis of cemented pegged polyethylene

glenoid components in total shoulder replacement. J Bone Joint Surg Am 87:1928–36. doi:10.2106/JBJS.D.02675
25. Friedman RJ, Hawthorne KB, Genez BM (1992) The use of computerized tomography in the measurement of glenoid version. J Bone Joint Surg Am 74:1032–7
26. Bohsali KI, Wirth MA, Rockwood CA (2006) Complications of total shoulder arthroplasty. J Bone Joint Surg Am 88:2279–92. doi:10.2106/JBJS.F.00125
27. Merolla G, Chin P, Sasyniuk TM, Porcellini G (2016) Total shoulder arthroplasty with a second- generation tantalum trabecular metal-backed glenoid component. 98:1–6. doi:10.1302/0301-620X.98B1.36620
28. Parks DL, Casagrande DJ, Schrumpf MA, et al. (2015) Radiographic and clinical outcomes of total shoulder arthroplasty with an all-polyethylene pegged bone ingrowth glenoid component : prospective short- to medium-term follow-up. J Shoulder and Elb Surg 1–10. doi:10.1016/j.jse.2015.07.008
29. Gulotta LV, Chambers KL, Warren RF et al (2015) No Differences in Early Results of a Hybrid Glenoid Compared With a Pegged Implant. Clin Orthop Relat Res 473:3918–3924. doi:10.1007/s11999-015-4558-5
30. Mileti J, Boardman ND, Sperling JW et al (2004) Radiographic analysis of polyethylene glenoid components using modern cementing techniques. J Shoulder Elb Surg 13:492–498. doi:10.1016/j.jse.2004.03.001
31. Nagels J, Valstar ER, Stokdijk M, Rozing PM (2002) Patterns of loosening of the glenoid component. J Bone Joint Surg Br Vol 84:83–7
32. Churchill RS, Boorman RS, Fehringer E V, Matsen FA (2004) Glenoid cementing may generate sufficient heat to endanger the surrounding bone. Clin Orthop Relat Res 76–9
33. Lucas RM, Hsu JE, Whitney IJ et al (2016) Loose glenoid components in revision shoulder arthroplasty: is there an association with positive cultures? J Shoulder Elb Surg. doi:10.1016/j.jse.2015.12.026
34. Levy O, Iyer S, Atoun E et al (2013) Propionibacterium acnes: an underestimated etiology in the pathogenesis of osteoarthritis? J Shoulder Elb Surg 22:505–11. doi:10.1016/j.jse.2012.07.007
35. Iannotti JP, Weiner S, Rodriguez E et al (2015) Three-dimensional imaging and templating improve glenoid implant positioning. J Bone Joint Surg Am 97:651–8. doi:10.2106/JBJS.N.00493
36. Dilisio MF, May NR, Vincent SA et al (2015) The association of incomplete glenoid component seating and periprosthetic glenoid radiolucencies after total shoulder arthroplasty. J Shoulder Elb Surg 101:1–6. doi:10.1016/j.jse.2015.08.005
37. Farron A, Terrier A, Büchler P (2006) Risks of loosening of a prosthetic glenoid implanted in retroversion. J Shoulder Elb Surg 15:521–6. doi:10.1016/j.jse.2005.10.003
38. Matsen FA 3rd (2015) The ream and run: not for every patient, every surgeon or every problem. Int Orthop 39:255–61. doi:10.1007/s00264-014-2641-2
39. Gazielly DF, Scarlat MM, Verborgt O (2015) Long-term survival of teh glenoid components in total shoulder replacement for osteoarthritis. Int Orthop 39:285–9
40. Schnetzke M, Coda S, Walch G, Loew M (2015) Clinical and radiological results of a cementless short stem shoulder prostheses at minimum follow-up of two years. Int Orthop 39:1351–7