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Survivorship of autologous structural bone graft at a minimum of 2 years when used to address significant glenoid bone loss in primary and revision shoulder arthroplasty: a computed tomographic and clinical review

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Background: Severe glenoid bone loss remains a challenge in patients requiring shoulder arthroplasty and often requires autogenous bone grafting. The purpose of this study was to assess the integrity of the bone graft at 2 years in a series of primary and revision shoulder replacements where glenoid bone loss was managed using a structural autograft (humeral head or iliac crest bone graft) in combination with a trabecular titanium (TT) implant.

Methods: Ethical approval was sought, and the study has a portfolio study status by the NIHR (17/YH/0318). We contacted patients who had primary and revision shoulder arthroplasty with Lima Axioma TT metal-back glenoid with autologous bone graft and were more than 2 years since their operation. All eligible patients underwent computed tomographic evaluation, clinical review, and scoring. Early failures of composite fixation and patients who had revision procedures were excluded (2 patients).

Results: Forty-one patients (43 shoulders) with a mean age of 65 years (range 33-85 years) were reviewed. There were 24 women and 17 men. The average follow-up period was 40 months (range 24-59 months). Primary arthroplasty was performed in 24 shoulders, whereas 19 shoulders had revision arthroplasty. Twenty-five shoulders had reverse shoulder replacement and 18 had anatomic shoulder replacement. Twenty-four shoulders had graft taken from the humeral head, and 19 had iliac crest bone graft, reflecting the number of revisions. We used Wrightington classification for porous metal implant and bone graft incorporation. Satisfactory bone graft incorporation (>50%) was seen in 40 shoulders, and only 3 patients had <50% graft incorporation. The scans at 2 years or later showed no significant deterioration in the bone graft from the early postoperative scans. Average forward elevation improved from 50° (preoperative) to 98° (range 35°-150°). The mean improvement in mean Oxford Shoulder Score was 16 (preoperative, 15; postoperative, 31) and the mean improvement in Constant score improvement was 36 (preoperative, 12; postoperative, 48). The mean postoperative American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form (ASES) score was 64 (range 30-85).

Ethical approval was sought and the study was granted portfolio status by the National Institute of Health Research (17/YH/0318).

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Conclusion: The use of TT in conjunction with autologous bone graft provides a reliable method of addressing glenoid bone defects in primary and revision shoulder arthroplasty. This graft–trabecular metal composite has been shown to integrate well and remain largely unchanged over a 2-year period. A stable baseplate is essential in difficult primary and revision arthroplasty situations. The stability of this construct in our series is reflected in the satisfactory outcomes.

Level of evidence: Level IV; Case Series; Treatment Study

Keywords: Glenoid; bone loss; glenoid reconstruction; autologous bone graft; survivorship; shoulder arthroplasty

Reconstructing glenoid bony deficiency in primary and revision shoulder surgery is a major challenge.[8,15,17,18] Glenoid bone deficiencies frequently compromise glenoid component fixation,[32] which can lead to early failure and complications such as instability, dislocation, and scapular notching.[14,15,27] Multiple strategies are available to address this problem.[18,27] Structural bone grafts offer an option to improve component positioning and reduce the risk of long-term component loosening.[13,14,22,26,31,32]

Humeral head autograft and tricortical iliac crest bone graft have become the established techniques to manage glenoid bone loss in primary and revision shoulder arthroplasty cases, respectively.[5,6,25] The long-term outcomes of these structural bone grafts, however, remains unknown. Substantial resorption and subsidence remains a concern.[12,25] Multiple studies have used radiographs to assess bone graft resorption, baseplate stability, and loosening and have expressed a need for a quantitative assessment of graft integration and resorption.[13,15,18]

All patients had sequential radiographs (at 3, 6, and 12 months and yearly thereafter) and computed tomographic (CT) scans performed between 3-6 months to confirm graft incorporation as part of our routine follow-up. In addition, as part of this study, all patients had an additional CT scan at a minimum of 24 months following surgery.

Our primary hypothesis was that humeral or Iliac bone crest structural autografts would heal to native bone and integrate with Trabecular Titanium (TT) as a single construct and ultimately not undergo resorption.

Materials and methods

Patient group

This is a single-center study. We used our prospective arthroplasty database to identify patients who had undergone complex primary or revision shoulder arthroplasty using the Lima SMR Axioma TT implant (Lima, Udine, Italy) (Fig. 1) together with an autologous structural bone graft taken from either the humeral head or as a bicortical iliac crest bone graft.

The inclusion criteria were all patients who had more than 2 years' follow-up since operation and had not undergone any subsequent revision procedures. All eligible patients were contacted, and the ones who agreed to take part in the study were invited for a clinical and radiologic review. Informed consent was obtained from all the patients at the time of consultation. We excluded patients who required allograft supplementation or where impaction grafting had been used in the first instance. We also excluded patients who had undergone subsequent revision surgery to the baseplate. Four patients either declined to participate or lived overseas and thus were not available for the final review. Of the 45 patients contacted, 41 agreed to participate in the study and had full clinical and radiologic assessment.

Operative technique

A standard deltopectoral approach was used in all the patients. Humeral head graft was used in cases where humeral bone stock was preserved. In cases where the humeral head was inadequate and in revision cases, autologous iliac crest bone graft was harvested. The surgical techniques have been described previously[17]; however, the salient features of both the techniques are described here.

Humeral head graft technique

This technique to harvest structural autograft from native humeral head is similar to the bony increased offset–reverse shoulder arthroplasty technique as described by Boileau et al,[5] even though it is performed in a different fashion. A guidewire is placed in the humeral head and advanced to engage the lateral cortex (taking care not to injure the axillary nerve). Initial reaming is done to achieve conformity with the backside of the baseplate. A central hole for the TT peg is created using a central peg drill. The chosen peg and baseplate are implanted into the humeral head and Lima's Graftalogy saw is used to separate the outer surface of the graft from the surrounding bone. A reamer of larger diameter than the baseplate is used to ensure a structural cortical rim of graft. The remaining neck is cut with a sagittal saw and the graft shaped using rongeurs (n = 24; Fig. 2).

Iliac crest bone graft harvest technique

The graft is harvested from the lateral wall of the ilium, preserving a superior bridge of bone to avoid any stress riser and also keeping intact the iliac contour. The inner and outer tables of the ileum are exposed, and a guidewire is inserted via a template, from outside to inside keeping the superior bone bridge intact. After reaming the outer surface to match the baseplate concavity, a central peg hole is drilled and the chosen peg and baseplate implanted. The implant–bone graft composite is then removed from the ilium using the Graftalogy barrel reamer. The graft can then be shaped using rongeurs (n = 19; Fig. 3).

Figure 1 Lima SMR Axioma Trabecular Titanium (TT) implant.

Implant description

This TT implant has demonstrated excellent osseous integration in animal models and has been used successfully in hip revision surgery.[2,3,4,7,10,19,21,24,29] It is composed of a 3-dimensional hexagonal lattice of titanium with high porosity (Fig. 4), manufactured through electron beam melting and designed to mimic cancellous bone. The highly porous titanium optimizes press-fit in native bone as a result of high friction. In the presence of a suitable strain environment, precursor cells will differentiate into osteoblasts on the porous TT surface.

In addition to the press-fit fixation, the baseplate-graft composite is stabilized using two 6.5-mm-diameter screws at the 12- and 6-o'clock positions. This is to apply initial compression of the graft until integration occurs. Preoperative planning with CT scan is used to assess the morphology of the glenoid defect, template implant, and graft size. It also helps us to plan the thickness required to correct the version and defect. The graft is shaped to correct the defect and is secured behind the baseplate. We use burr and saw to optimize the contour between the graft and native glenoid. The shape of the graft depends on whether there was a peripheral, superior, or central glenoid defect. Added to that, a patient-specific guide was generated from CT scan images to improve alignment of the glenoid component.

As a part of our protocol, if a good compression and stable fixation was achieved, we completed the operation as per standard technique. If the baseplate-graft composite was unstable as a result of suboptimal compression screw purchase or poor native vault bone, a staged procedure was undertaken. The glenoid baseplate and bone graft were left in situ but the humeral component was not implanted. A CT scan was undertaken at 3 months to assess integration. If this was satisfactory, a second operation was performed to insert the glenosphere and humeral component (Fig. 5). Only 2 patients in our cohort underwent staged procedures. Both of them had Antuna grade 4 bone loss (severe bone loss and medialization of the glenoid with >10 mm remaining vault depth).

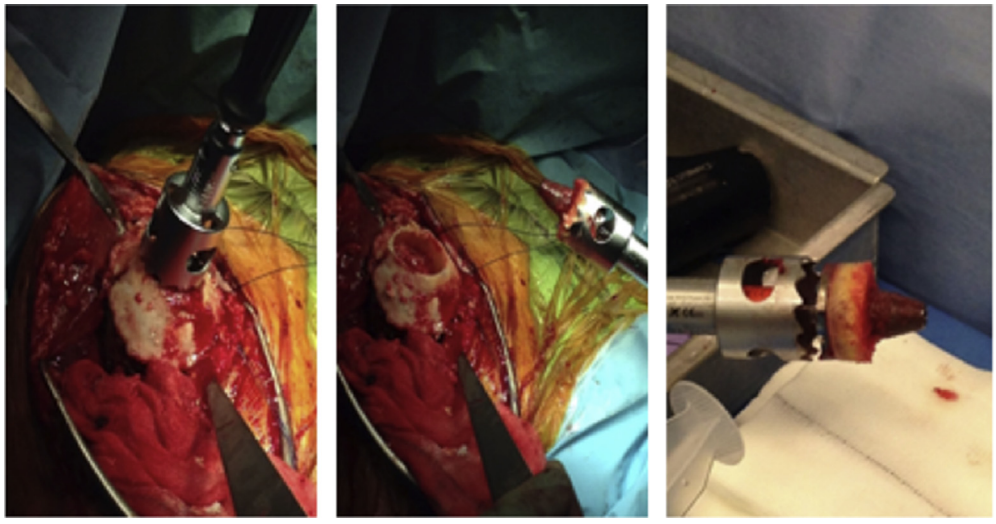

Figure 2 Bone graft harvest from the humeral head.

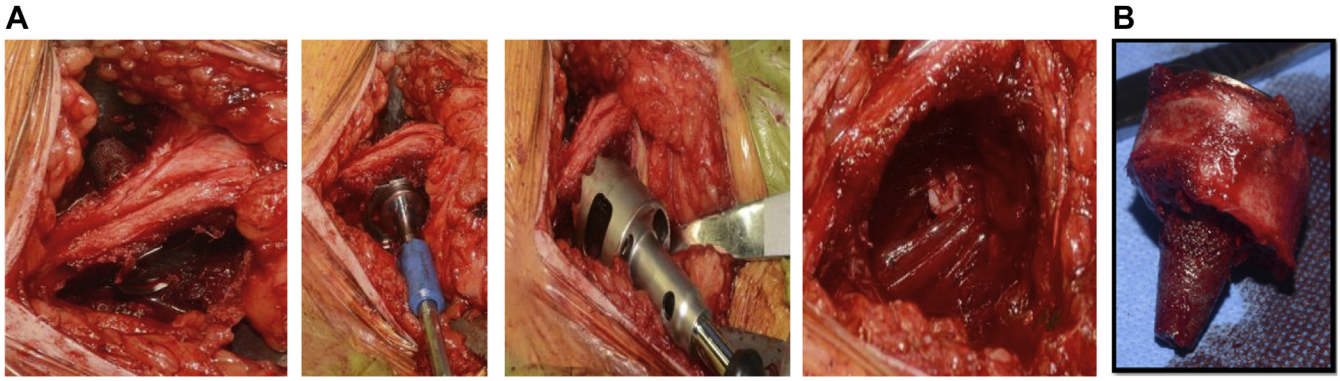

Figure 3 (**A**) Bone graft harvest from the iliac crest. (**B**) Cross section of bone graft implant composite (Lima Axioma TT metal-back glenoid baseplate platform) and glenoid baseplate and bone graft ready for implantation.

Both of these patients had previously been found to have infection in the shoulder and had undergone removal of implant, polymethylmethacrylate cement, and débridement.

Rehabilitation

Postoperatively, the arm was placed in a shoulder immobilizer. The subsequent program of physical therapy was tailored to individual patient needs. In most cases, however, early passive range of motion was initiated with external rotation limited to 0° to protect any subscapularis repair. At 3 weeks, active assisted exercises were started to allow maximum range of motion. When this was complete, strengthening exercises were initiated. With a small number of patients who were frail, active mobilization was delayed a further 3 weeks.

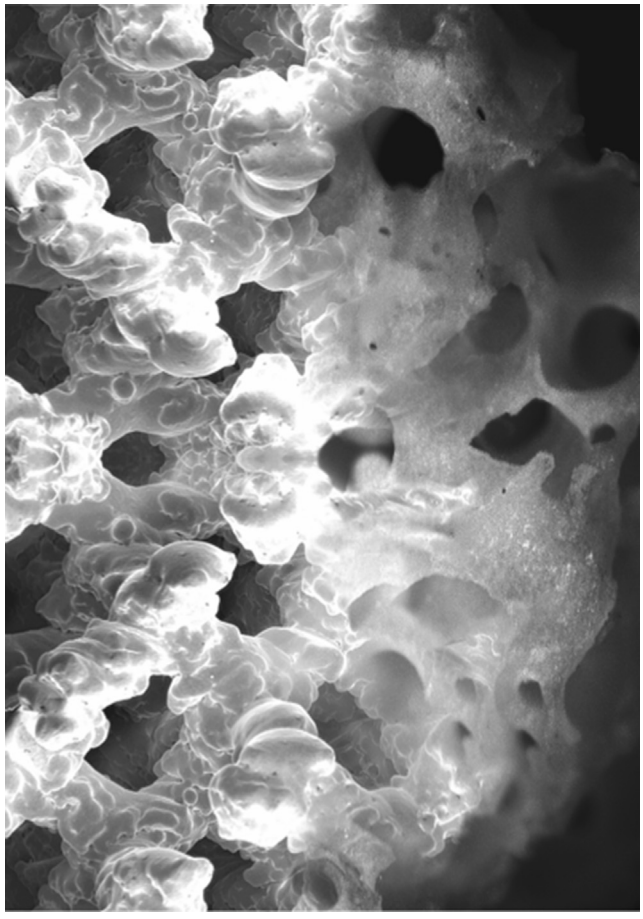

Figure 4 Three-dimensional hexagonal lattice of trabecular titanium.

Radiologic assessment

Preoperative radiographs and CT scans were reviewed to assess the glenoid bone defect and version of glenoid using the Friedman method.[9] CT scans were assessed to template the implant size, peg length, correction required, and graft thickness.

All the patients enrolled into the study had standard anteroposterior and axillary-view radiographs and CT scan (Siemens

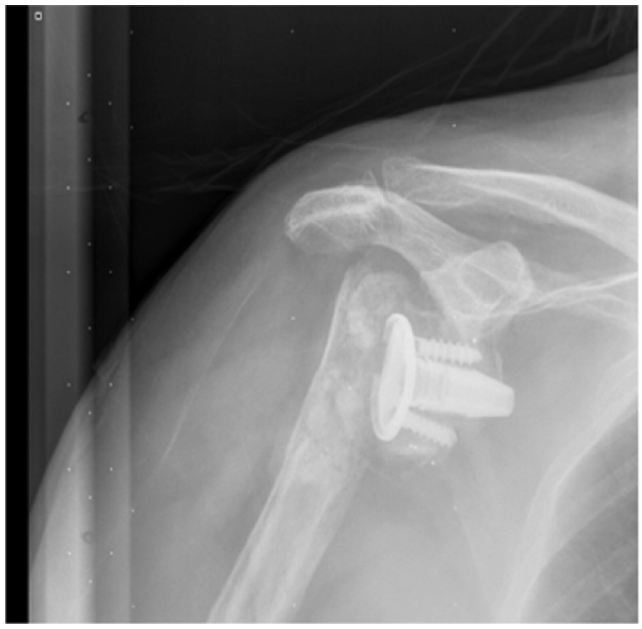

Figure 5 Two-stage reconstruction.

Table I Modified Walch classification[1]

Concentric type A wear	1. Minor erosion 2. Major erosion
Eccentric type B wear	1. Posterior erosion 2. Biconcave glenoid 3. Neoglenoid fully eroded away the paleoglenoid
Type C	Glenoid retroversion >25°
Type D	Anterior erosion with anterior humeral head subluxation

[Siemens Healthcare, Erlangen, Germany] SOMATOM Definition AS+128-slice; in 1-mm slices and metal artifact–reducing protocol using iMAR [Siemens Healthcare] software). Modified Walch classification was used to assess glenoid wear in cases of primary shoulder arthroplasty where a glenoid component had not been implanted previously.[1] Table I shows different grades of modified classification.

In revisions involving a glenoid component, volume and depth of the vault are the 2 important factors to consider. Bony deficits were graded as per the modified Antuna classification[11,17] as shown in Table II. A vault depth of minimum 10 mm is needed for central peg accommodation, and the glenoid volume should be sufficient to allow 2 peripheral screws to achieve initial fixation.[18] We use CT scan to estimate graft thickness and any angular correction of version by creating a wedge graft taking into account the least eroded part of glenoid. The peg length was then predetermined taking into account the graft thickness and aiming for a minimum length of 6 mm of cylindrical TT implantation into the native glenoid. In practice, the most common configuration is with a small-R baseplate and extra-long stem (12×29.3-mm, 16 mm of TT) that complements a 10 mm graft width. Perioperative alignment guides were used in the majority of cases.

We used the classification system described by Granville-Chapman[17] (Table III) to assess the osseointegration of glenoid peg and incorporation of graft with the native glenoid (Fig. 6).

Table II Modified Antuna[11] classification with severe glenoid loss

	Modified Antuna classification	No. of shoulders
1	Grade 1 (mild bone loss).	2
2	Grade 2 (moderate bone loss with intact vault, ie, central/ contained defect, intact periphery).	4
3	Grade 3 (severe eccentric peripheral defect with some intact vault wall, ie, uncontained defect resulting in >20° version or 50% loss of glenoid width).	6
4	Grade 4 (severe bone loss and medialization of the glenoid with >10 mm remaining vault depth)	7
5	Grade 5 (severe bone loss with <10 mm of vault depth remaining with or without a fractured vault remnant)	

Table III Assessment quantification of bone graft integration into implant peg and host bone[17]

Peg		Graft	
1	No integration	A	Lysis
2	<50% integration	B	No incorporation, no lysis
3	>50% integration	C	Partial incorporation
4	Complete integration	D	Complete incorporation

This is a CT-based classification looking into the integration between peg and native bone and the union between the peg graft and native glenoid. Finally, we also assessed notching using the Nerot classification (Table IV).[28,34]

Radiographic assessment of bone graft incorporation and volumetric change

Three authors (J.S., S.O., and K.N.) assessed the postoperative CT scans to evaluate osseointegration of the glenoid peg with the native glenoid and graft integration and incorporation with native glenoid.

Crossing trabecular bone and no visible gap between the peg and native glenoid were the markers for integration. Images in axial and coronal planes were reviewed in bony windows. To standardize the methodology, we scrolled across the baseplate to look for the porous titanium portion of the peg, the bone graft, and

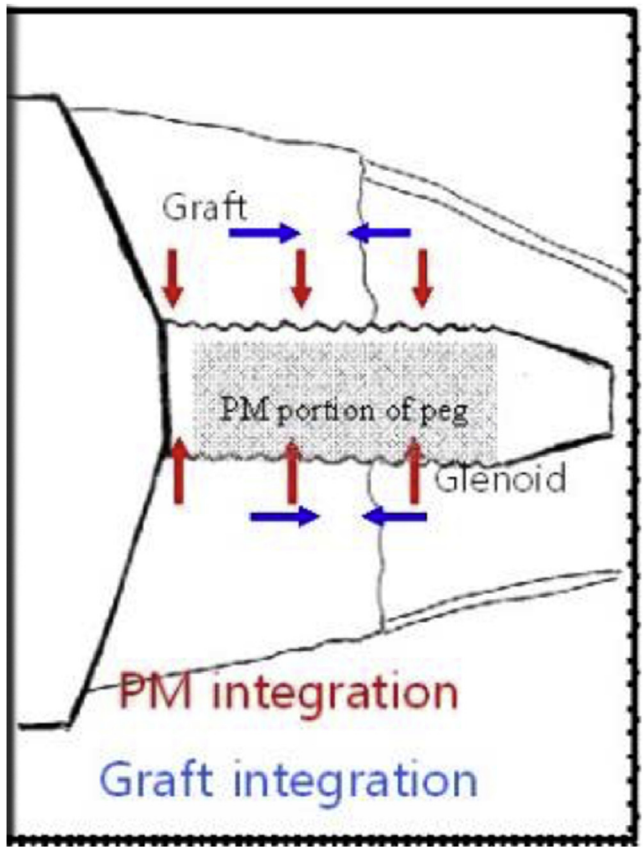

Figure 6 Granville-Chapman classification system[17] for osseointegration of glenoid peg and incorporation of bone graft.

Table IV Classification of notching as per Nerot[28,34]

0	No notch
1	Small notch
2	Notch with condensation
3	Erosion involving the inferior screw
4	Loosening of baseplate and peg

native glenoid to grade peg integration and bone graft incorporation. Serial postoperative CT scans (3- and 6-month and latest ones) were reviewed if there was evidence of partial incorporation or <50% integration of peg and notching to look for interval changes. Figure 6 shows assessment of peg integration with the graft and native glenoid as demonstrated by red arrows and graded as no or <50% integration (1 or 2) and >50% or complete integration (3 or 4) (Tables III and VI as per Granville-Chapman classification[17]). Assessment of graft glenoid incorporation as indicated by blue arrows is graded from A-D. We simplified this to full or partial integration vs. no integration or graft lysis (Tables III and VI).

To determine the volume of the bone graft, we scrolled around the coronal and axial planes and used the back of the baseplate and distance from the central peg as fixed points to determine the volume of the bone graft. We used the mathematical formula of the volume of a cylinder, $\pi R_1^2 h$ (R_1 being the radius of the bone graft and h, the height). From this, we subtracted the volume of the Peg using the same formula $\pi R_2^2 h$ (where R_2 is the radius of the peg) (Fig. 7). To simplify the calculations, we used the following formula:

$$\pi (R_1^2 - R_2^2) h$$

We used an average of 3 readings of both R_1 and R_2 in the coronal, sagittal, and axial slices of the CT scans.

Clinical assessment

All patients underwent clinical assessment comprising range of movement assessment, Oxford Shoulder Score, Constant shoulder score, and American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form (ASES) score. These were compared to preoperative scores where available. ASES scores were introduced later into our practice for postoperative assessment only.

Statistical analysis

Descriptive statistics are reported as mean, median, and range for continuous measures and percentage for discrete measures. A paired t test was used to compare the preoperative vs. postoperative changes in range of movement, Oxford Shoulder Scores, Constant shoulder scores, and ASES.

Results

Forty-one patients (43 shoulders) with a mean age of 65 years (33-85 years) were reviewed. There were 24 women and 17 men. The average follow-up period was 40 months (range 24-59 months).

Primary arthroplasty was performed in 24 shoulders, whereas 19 shoulders had revision arthroplasty. Of the 24 primary shoulder arthroplasties, 16 were diagnosed with severe osteoarthritis including cuff tear arthropathy, 4 with rheumatoid arthritis, 3 shoulders with post-trauma sequelae, and 1 shoulder had a diagnosis of avascular necrosis. Most glenoids in the primary arthroplasty group were type B2 (n = 11) followed by type C (n = 5), B3 (n =

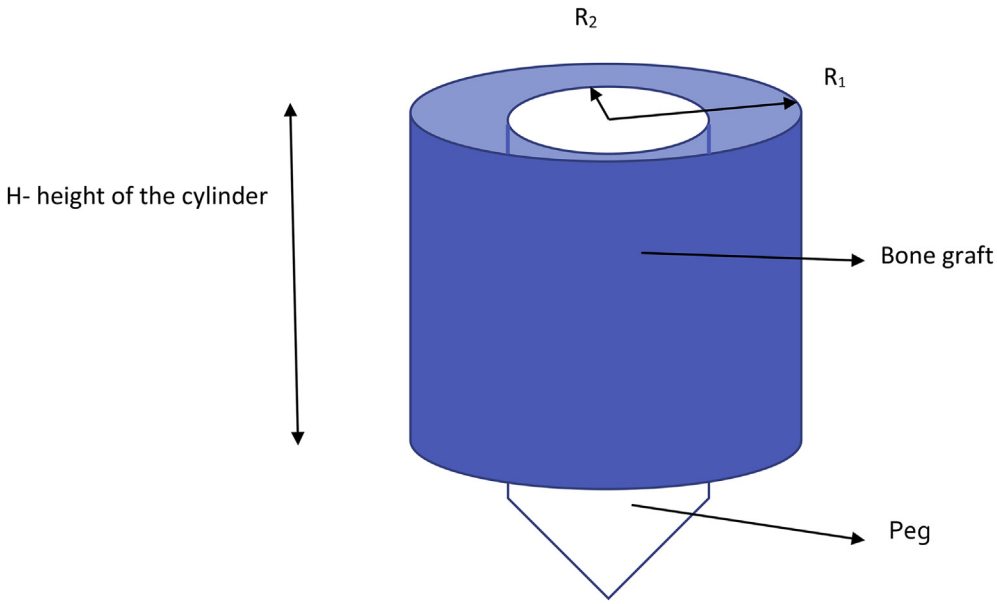

Figure 7 Schematic descriptions of the volume of cylinder concept applied to the implant bone graft composite.

Table V Indications for primary and revision shoulder arthroplasty

	No. of cases
Primary shoulder arthroplasty	24
Walch grades	
A2	1
B2	11
B3	4
C	5
D	1
Trauma	2
Revision shoulder arthroplasty	19
Hemiarthroplasty	8
Copeland resurfacing	6
Prosthetic joint infection	4
Aseptic glenoid loosening	1

4), and A2 (n = 1). Three cases were post-traumatic following fractures of the glenoid and as such could not be classified.

Revision arthroplasty was performed in 19 cases, of which 8 cases had a previous shoulder hemiarthroplasty, 6 cases had a prior shoulder resurfacing procedure, 4 cases required revision as a consequence of prosthetic joint infection, and 1 shoulder had aseptic loosening of a total shoulder replacement (Table V). Of the total 24 primary arthroplasties performed, 12 were anatomic shoulder replacements (ASRs) and 12 reverse shoulder replacements (RSRs). On the other hand, in the revision scenario, 13 cases (68%) were RSRs and 6 were ASRs. The choice for ASR vs. RSR depended on both preoperative imaging and intraoperative assessment of the rotator cuff. The decision to perform ASR or RSR was made by the treating surgeon at his discretion. Factors used in consideration were patient's age, comorbidities including rheumatoid arthritis, presence of intact cuff, glenoid retroversion, and glenoid defect.

Table VI Bone graft incorporation and volume change over a minimum of 2-year interval

		P value
Peg integration, n		
>50%	42	
<50%	1	
Bone graft, n		
Complete incorporation	40	
Partial incorporation	2	
No incorporation	1	
Glenoid bone graft volume change, π ($R_1^2 - R_1^2$) h, mm^3, mean (range)		.28
3-6-mo CT scan	7444 (3246-15,910)	
2-yr CT scan	7032 (2265-15,063)	

Using the modified Antuna classification, 2 cases were grade 1 (mild bone loss). Four had grade 2, that is, moderate bone loss with an intact vault. Six had grade 3, which is severe eccentric peripheral defect with some intact vault wall. Seven had grade 4 with severe bone loss and medialization with little or no remaining vault. There were no Antuna grade 5s in the series.

Radiographic outcomes

Satisfactory bone graft incorporation (>50%) was seen in 40 shoulders, and only 3 patients had <50% graft incorporation using the Wrightington classification for the porous titanium implant and bone graft incorporation. The scans at 2 years showed no significant deterioration in the bone graft from the early postoperative scans (Table VI). One of the 3 cases developed lucency on the 6-month scan and clinically and radiologically a grossly loose glenoid at 1-year review. The patient was offered revision to a longer peg and grafting but the patient opted for conservative treatment. Four years since operation, there has not been any further deterioration in clinical and radiologic signs.

Two other patients had some resorption of bone graft seen at the 3- and 6-month scans, and these radiologic changes have been static on subsequent scans. Two-year CT scans confirmed no further radiologic change, and the patients had reasonable clinical function.

Volumetric assessment

Using the above-mentioned formula, the mean volume of the graft in the immediate postoperative CT scans was noted to be 7444 mm^3(range 3246-15,910). The volume of the bone graft in the final CT scans was 7032 mm^3 (range 2265-15,063). There was no statistically significant difference noted between the 2 volumes measured (*P* value .28) (Table VI).

Clinical outcomes

Average forward elevation improved from 50° (preoperation) to 98° postoperation (range 35°-150°). The mean improvement in Oxford Shoulder score was 16 (preoperative, 15; postoperative, 31) and the mean improvement in Constant score was 36 (preoperative, 12; postoperative, 48). The mean final postoperative ASES score was 64 (range 30-85) (Table VII). Table VIII compares range of motion and functional outcome for both RSRs and ASRs at a minimum of 2-year follow-up.

Complications and reoperations

Four of the 18 ASRs (22%; all revision procedures) developed cuff insufficiency or failure and needed revision surgery. Three ASRs were revised to RSRs at an average of

Table VII Range of movements and functional outcome at ≥2-year interval

	Preoperative	Latest follow-up	Improvement (degrees)
Range of movement (degrees)			
Average elevation	51	98 (30-150)	47
Average abduction	46	95 (35-150)	52
Functional outcome			
Constant score	12 (2-39)	48 (14-91)	36
Oxford Shoulder Score	15 (3-30)	31 (7-48)	16
ASES score		64 (15-100)	

ASES, American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form.

Table VIII Range of movement and functional outcome for reverse and anatomic shoulder replacements at 2-year follow-up

Procedure	Constant score	Oxford Shoulder Score	ASES score	Average elevation (degrees)	Average abduction (degrees)
RSR					
Primary (n = 12)	54	37	76	104	93
Revision (n = 13)	35	24	52	90	76
ASR					
Primary (n = 12)	48	33	67	100	84
Revision (n = 6)	42	27	54	88	88

RSR, reverse shoulder replacement; *ASR*, anatomic shoulder replacement; *ASES*, American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form.

Table IX Incidence of various complications in our series at a minimum of 2-year follow-up

	Complications	No. of cases
1	Cuff failure	
	Revision from anatomic to reverse	3
	Revision to a bigger humeral head	1
	Subscapularis failure and instability	2
2	Acromial stress failure	1
3	Postoperative infection (DAIR)	1
4	Loosening >50%, revision offered	1
5	Iliac crest hematoma requiring admission	1
6	Brachial plexopathy with good recovery	1
7	Scapular spine fracture	1
8	Notching	9
	Grade 1	6
	Grade 2	2
	Grade 3	1

DAIR, débridement, antibiotics, and implant retention.

25 months (20-36 months). The baseplate–bone graft composites were intact at the time of revision. One patient was revised to a larger humeral head because of instability within the first week. Unfortunately, this instability has persisted because of additional cuff failure. The patient has been offered revision surgery to reverse total shoulder replacement. Currently this has not been undertaken, and the patient remains under review. At the last follow-up and CT scan evaluation (56 months since the primary procedure), the bone graft has successfully incorporated.

In an additional 2 patients with ASR, the subscapularis tendon was noted to be deficient. However, both the patients opted for a nonoperative approach, and both were pain-free at the final follow-up. One patient sustained transient postoperative brachial plexopathy that fully resolved. In 1 patient, an acromial stress fracture was diagnosed postoperatively. This was treated nonoperatively, and the patient made a full recovery. Similarly, 1 patient was also diagnosed with a scapular spine fracture (as a result of trauma) and again was treated nonoperatively, and the patient made a full recovery.

Finally, a high incidence of notching was noted (9/25 shoulders, 36%) in the follow-up CT scans. However, this was not associated with any loosening of the baseplate or any other adverse clinical outcomes (Table IX).

Discussion

Newer implants with metal-backed porous titanium peg prosthesis (like the Lima SMR Axioma TT) have extended the scope of glenoid reconstruction arthroplasty and capacity for single-stage reimplantation. However, evaluating structural bone graft incorporation and porous metal integration has been a challenge, with radiographs only offering a qualitative assessment.[15] Radiographs do not allow for complete quantitative assessment of bone graft

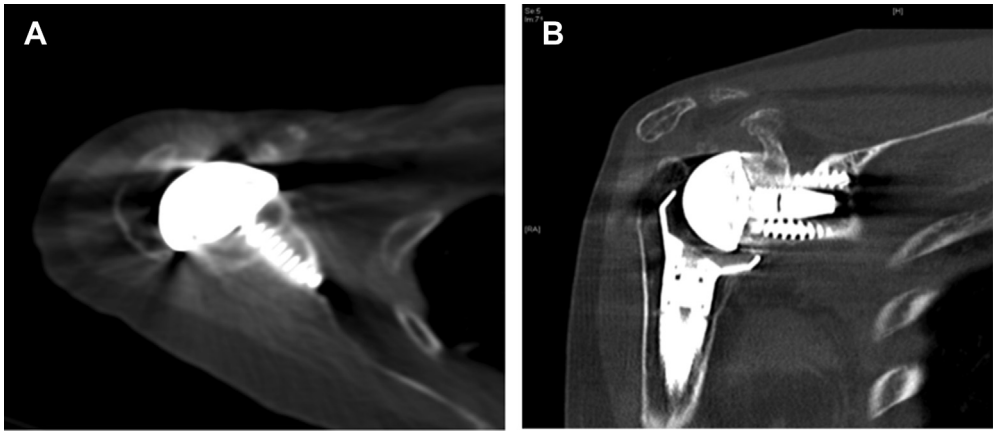

Figure 8 (**A**) Axial and (**B**) coronal computed tomographic views showing intact bone graft and complete peg intergation and bone graft incorporation at a 2-year interval.

incorporation and resorption, as any such assessment is limited.[30,33] Radiostereographic analysis has been used to assess migration but again does not allow for any quantitative assessment of any incorporated bone graft.[23] We believe this is the first study to evaluate autogenous bone graft, when used to reconstruct a deficient glenoid that has been assessed by CT scan.

In this study, we evaluated volume changes in bone grafts as seen on CT scans of between 3 and 6 months following surgery as against 2 years and beyond using the volumetric assessment as described. We did not identify any statistically significant volume change of the grafts ($P = .28$). In addition, the CT scans at 2 years or later revealed 98% complete or more than 50% peg osseointegration. Added to that, in 95% of cases the bone graft was fully or partially incorporated (Fig. 8).

We believe there are a number of explanations for this. First, and as stated above, CT scans particularly with the new metal artifact–reduction software do allow for a more accurate interpretation of the status of the bone graft compared with plain radiographs. Second, we are able to produce an implant–bone graft composite, which in the majority of cases allow immediate fixation both by peg integration into host bone but also compression and screw fixation. We believe this construct is under compression initially with the screw fixation and subsequently by forces crossing the shoulder joint. Finally, it is also of note that the majority of our autogenous bone grafts are made up of cancellous bone.

Four of the 18 ASRs underwent revision due to cuff failure or insufficiency and 2 patients had instability due to subscapularis insufficiency (ie, total incidence of cuff failure and instability was 30%). We would say that this occurred as a result of clinician error, in that for complex primary cases it is equally important to attend to the soft tissues as well as any glenoid bone loss, however severe. It is also important in ASR that the glenoid joint line be correctly restored. The use of an implant–autogenous bone graft composite while restoring alignment and glenoid bone can result in lateralization of the glenoid component, and as a consequence overstuffing of the joint. However, if the graft is too thin, it can be prone to fracture under compression. There is, thus, a compromise in graft structural integrity and accuracy of joint line restoration. At this time, our practice has moved toward doing reverse shoulder arthroplasty rather than anatomic (ASR) in most complex glenoid situations as it is much more forgiving and may benefit from joint line lateralization.

Our study, however, has limitations. It was not possible to follow all the patients in our cohort because a proportion of our patients were unable to participate for various logistic reasons. We were, nevertheless, able to recall 41 patients (43 shoulders) from a cohort of 45 for the study. We also excluded early failures of the composite fixation (2 patients). Of these, one patient in retrospect had an un-reconstructable glenoid with this technique and the second failed because of too short a peg length. Previous work in our series has highlighted the need for at least 6 mm of the cylindrical portion of the TT Axioma peg within native glenoid.[16] We determined that 10 mm of original vault depth is needed to accommodate the peg and that space for at least 2 fixation screws is a prerequisite for the implant–bone composite technique. In cases where the vault depth is less than 10 mm and no space exists for 2 fixation screws, the options of hemiarthroplasty and custom glenoid implant should be considered.

The rate of notching in our series was 36%, which is consistent with the literature. Mahylis et al[15] noted 30% notching in their series, which is lower than the 54% noted by Melis et al[20] Wagner et al[32] noted 8% notching in their series. We have subsequently modified our technique by

using larger glenospheres (40 and 44 mm) and have reduced this incidence of notching.[17]

With regard to donor site morbidity, 1 patient in our series required readmission for an iliac crest hematoma. A second patient also sustained a fracture of the ilium, which resulted in prolonged discomfort. With this in mind for a number of subsequent cases, we have used femoral head allografts as an alternative to the iliac crest. We do, however, acknowledge previous work by Iannotti et al[12] that demonstrated resorption greater than 50% and incorporation less than 50% with structural allografts. The outcomes of this group with our technique are not yet known. Recent advancements in the manufacture of patient-specific custom implants may represent another alternative to bone when humeral head is not available.

Conclusion

The use of TT in conjunction with autologous bone graft provides a reliable method of addressing glenoid bone defects in primary and revision shoulder arthroplasty. The graft has been shown to integrate well and remain largely unchanged over a 2-year period. A stable baseplate is essential in difficult primary and revision situations, and the stability of the construct in our series is reflected in the satisfactory outcomes in these difficult patient groups.

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