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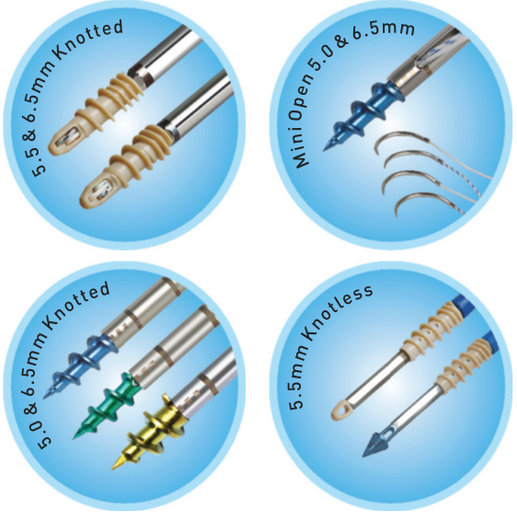

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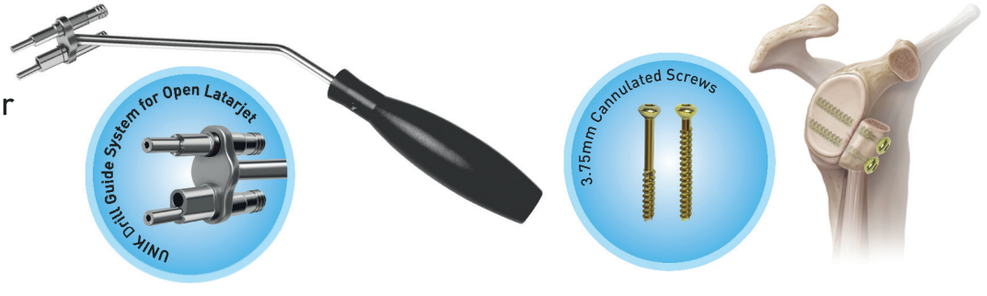

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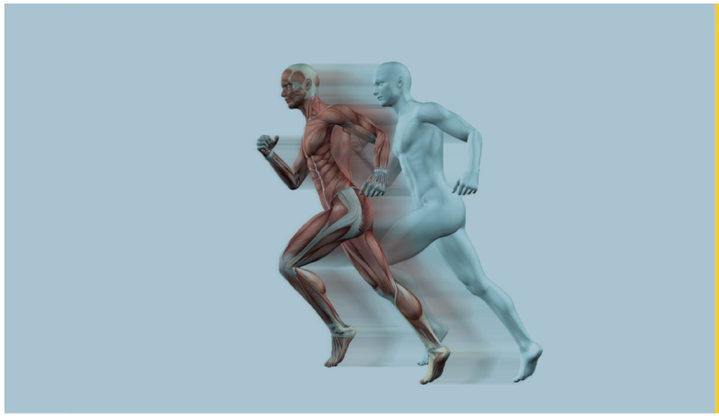

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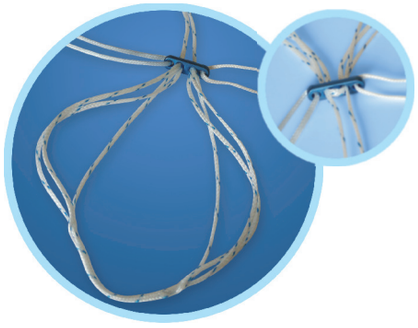

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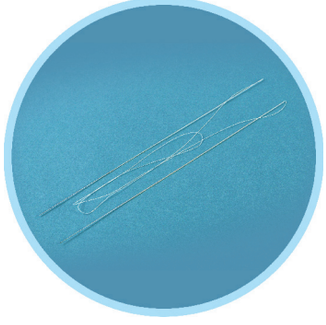

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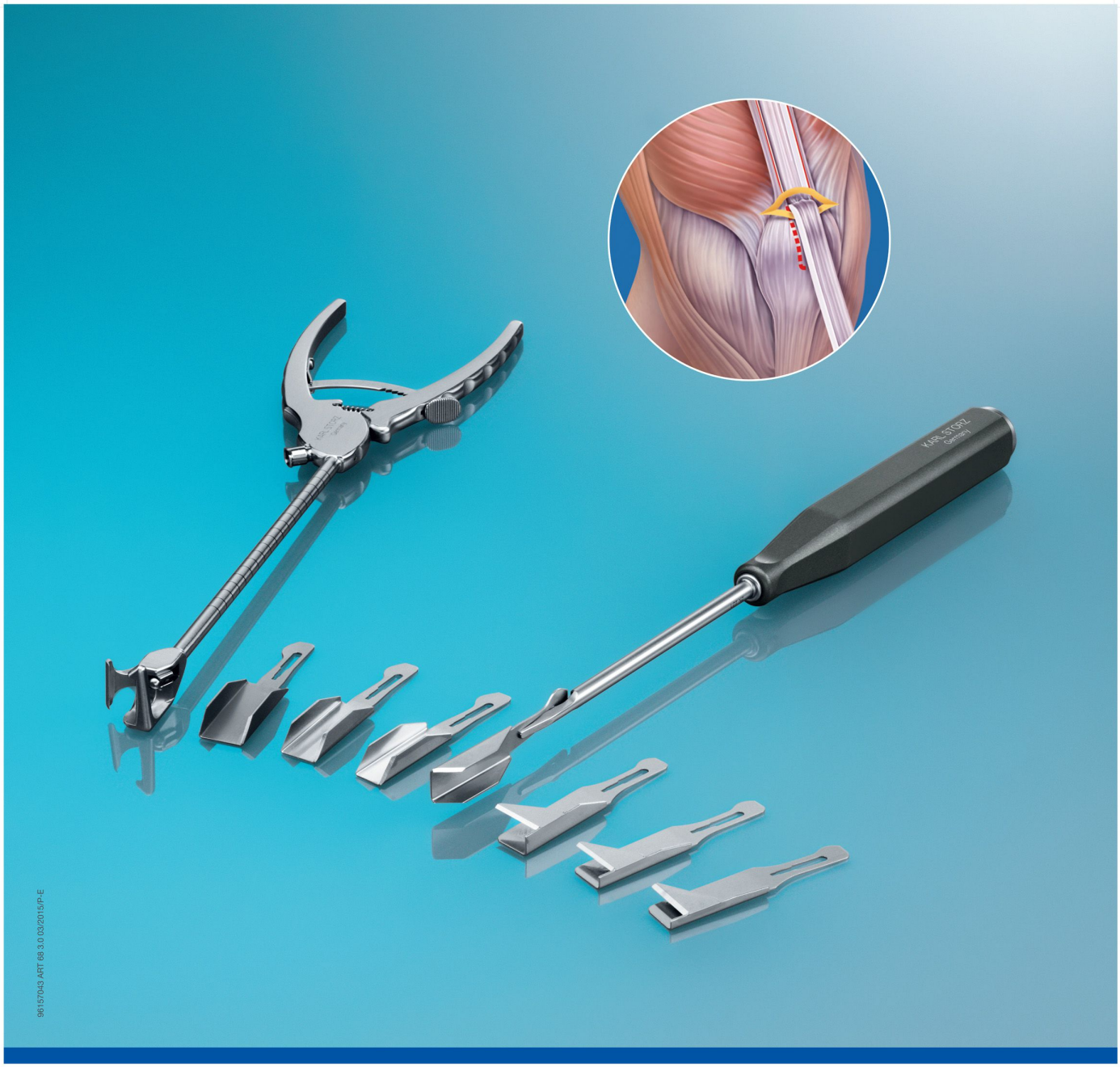

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Journal of Arthroscopy and Joint Surgery (JAJS) is committed to bring forth scientific manuscripts in the form of original research articles, current concept reviews, meta-analyses, case reports and letters to the editor. The focus of the Journal is to present wide-ranging, multi-disciplinary perspectives on the problems of the joints that are amenable with Arthroscopy and Arthroplasty. Though Arthroscopy and Arthroplasty entail surgical procedures, the Journal shall not restrict itself to these purely surgical procedures and will also encompass pharmacological, rehabilitative and physical measures that can prevent or postpone the execution of a surgical procedure. The Journal will also publish scientific research related to tissues other than joints that would ultimately have an effect on the joint function.

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Review article

The management of glenoid bone loss in shoulder arthroplasty

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ABSTRACT

Glenoid bone loss in shoulder arthroplasty poses a significant challenge for the surgeon managing this cohort of patients in both the primary and revision settings. This review article aims to review the methods of assessing glenoid bone loss and to report on the various techniques available to address it in both anatomical and reverse shoulder arthroplasty surgery.

1. Introduction

Shoulder arthroplasty is a reliable method in treating the symptoms associated with glenohumeral arthritis. The incidence of shoulder arthroplasty is increasing, however, the management of glenoid bone loss remains problematic and is associated with poorer clinical outcomes, instability and reduced implant survivorship.[1]

Glenoid bone loss can result in poor initial fixation and mal-positioning of the glenoid component of an anatomic shoulder replacement which in turn may lead to eccentric loading and accelerated polyethylene wear as well as premature loosening.[2–5] Indeed, Farron et al. reported >700% increase in micro-motion at the cement-bone interface and a 326% increase in contact stresses when the glenoid component is implanted in >10° retroversion.[3] This is relevant as up to 15% of patients with glenohumeral arthritis have posterior glenoid bone loss significant enough to make implantation of the glenoid prosthesis questionable without addressing the deficit.[6] This figure is significantly higher in the context of revision shoulder arthroplasty, and the loss of glenoid bone stock in Reverse Shoulder Arthroplasty (RSA) can also result in poorer outcomes.[7,8]

The risk of premature implant loosening and failure can be reduced with accurate pre-operative planning, correction of glenoid version and precise implant positioning and fixation.[2] The aim of this review is to provide an overview of the classification and investigation of glenoid bone loss in shoulder arthroplasty and to review the surgical strategies currently available to manage it.

2. Classification of glenoid bone loss

2.1. Primary glenoid bone loss

The characteristic wear pattern observed in glenohumeral osteoarthritis is one of posterior glenoid erosion associated with posterior humeral head subluxation. A second concavity may be formed when the bone loss associated with erosion is severe thus forming a biconcave deformity. Based on the patterns of wear observed from radiographs and CT scans of 151 patients with glenohumeral arthritis, Walch et al. proposed a classification system based upon the three glenoid morphologies observed.[6]

Type A (59%) was defined as central glenoid erosion with a centred humeral head. This was further subdivided based on the severity of erosion into A1 (minor) or A2 (major). Type B (32%) was defined as posterior humeral head subluxation and was further subdivided into B1 (joint space narrowing, subchondral sclerosis and osteophytes) and B2 (biconcave glenoid with posterior rim erosion). Type C (9%) was defined as glenoid retroversion >25% which is primarily dysplastic in origin. Bercik et al.[9] proposed the addition of a B3 and D glenoids with the B3 defined as mono-concave with pathologic retroversion of at least 15° or subluxation of 70%, or both (Fig. 1).

2.2. Secondary glenoid bone loss

Secondary glenoid bone loss may occur due to trauma, infection, glenoid component loosening and in the setting of revision arthroplasty.[10] Intra-operative glenoid bone loss encountered during revision shoulder arthroplasty was classified by Antuna et al. as central, peripheral and combined with each classification being further subdivided into mild, moderate or severe (Fig. 2).[11]

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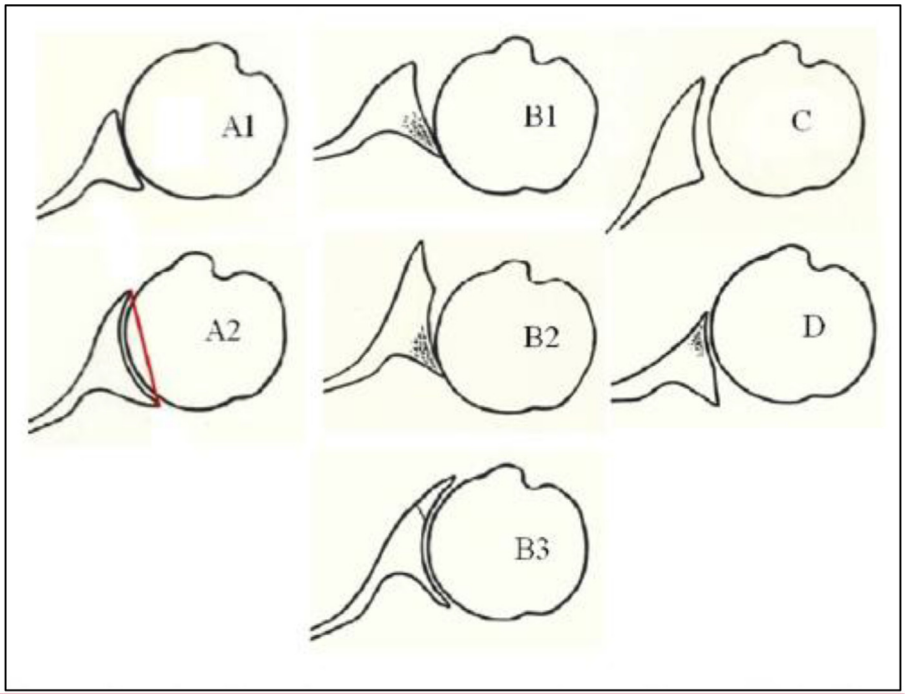

Fig. 1. Modified Walch Classification of glenoid erosion in primary glenohuemral arthritis. (Reprinted with permission from Elsevier from Bercik MJ, Kruse K, Yalizis M, Gauci M, Chaoui J, Walch G. A Modification to the Walch classification of the glenoid in primary glenohumeral osteoarthrits using three dimensional imaging. J Shoulder Elbow Surg. 2016 Oct; 25(10):1601–6.

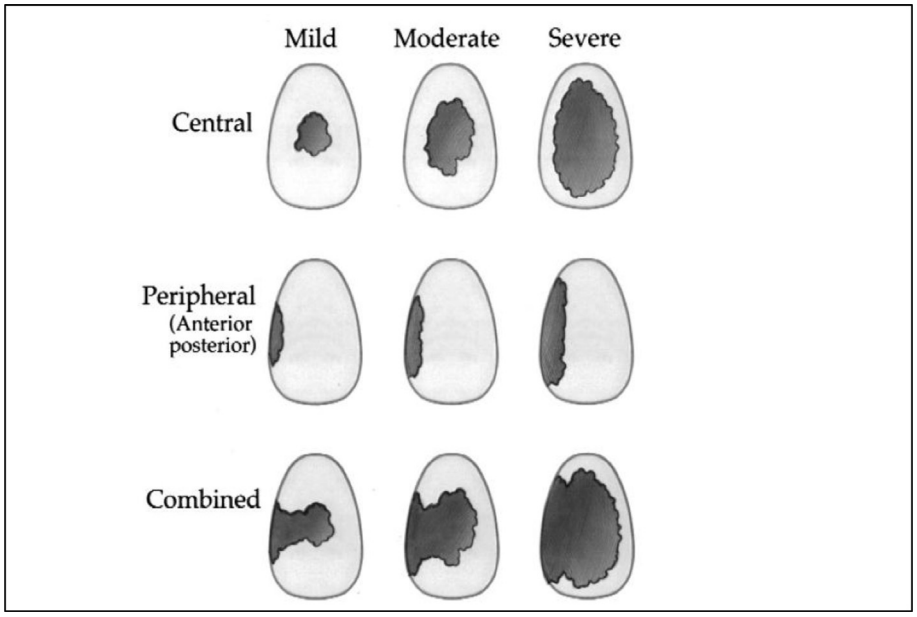

Fig. 2. Antuna classification of glenoid bone deficiencies after glenoid component removal (Reprinted with permission from Elsevier from Antuna SA, Sperling JW, Cofield RH, Rowland CM. Glenoid revision surgery after total shoulder arthroplasty. Journal of shoulder and elbow surgery. 2001; 10(3):217–24.).

3. Aetiology of posterior glenoid bone loss

Posterior glenoid bone loss commonly observed in osteoarthritic shoulders is thought to be initiated by posterior subluxation of the humeral head that may result in eccentric glenoid erosion due to increased, asymmetric posterior glenohumeral contact forces.[12] The finding of pre-osteoarthritic posterior subluxation of the humeral head was recently described by Domos et al. as the 'Walch B0' glenoid.[13] The aetiology of posterior humeral head subluxation however remains controversial and incompletely understood.

Walch et al. were the first to describe static posterior subluxation of the humeral head as a possible causative factor of glenohumeral osteoarthritis and hypothesized increased glenoid retroversion (mean value of 15°) was most likely reason for this occurring.[14] Knowles et al. similarly reported that patients with a

B2 osteoarthritic glenoid have 'significantly greater premorbid glenoid retroversion', suggesting this may be a contributing factor to posterior erosion.[12] However, other studies have questioned the link between pre-morbid glenoid retroversion and posterior glenoid erosion.[15–17] Based upon this conflicting evidence, Domos et al. postulated posterior humeral head subluxation may be multifactorial and related to a combination of bone and soft tissue factors including rotator cuff muscle imbalance and possible anterior capsular stiffness.[13]

4. Pre-operative planning in glenoid bone loss

The assessment of glenoid version and bone loss is essential when planning shoulder arthroplasty, as failure to do so may lead to intra-operative difficulties and poor outcomes due to inadequate correction of the deformity.[18] Pre-operative planning with plain radiographs is recommended and although glenoid bone loss and posterior humeral head subluxation can be appreciated on the axillary view, the use of radiographs alone may overestimate retroversion in 86% of cases.[19] Therefore in the presence of glenoid bone loss and retroversion, CT imaging is recommended to more accurately assess the glenoid anatomy.[20]

Glenoid version can be determined using standard two-dimensional (2D) axial CT slices along the plane of the scapula at the level of the coracoid tip using a method described by Friedman et al.[21] The scapula axis reference line is drawn from the tip of the medial border of the scapula to the centre of the glenoid. A second line, the glenoid line, is drawn from the anterior to the posterior glenoid rim and glenoid version is then measured as the angle between the glenoid line and the line perpindicular to the scapular axis (Fig. 3).

However, this technique is reliant on the 2D analysis of a three-dimensional (3D) structure and is dependent on the assumption that the anatomy of the scapula axis, and both the anterior and posterior glenoid rim, are all representative of normal pre-degenerative anatomy. The anterior glenoid is therefore a critical landmark in the assessment of posterior bone loss. A CT scan demonstrating the medial border of the scapula is also necessary and the position and angle of the CT scanner gantry is a factor in accurate interpretation of the Friedman version angle.[22]

As an alternative, 3D CT imaging can be used. In the Vault model method, 3D CT images can be constructed from the standard 2D CT images such that normal glenoid version was noted to be 1.63^0 of retroversion.[23] However, it also revealed that the shape of the glenoid vault was a highly congruent fit in normal glenoids and could be used to assess pathological glenoid bone loss.[24] Bicknell et al. also reported that the shape of the glenoid vault was consistent irrespective of age, sex or side and that the transverse and coronal planes of the glenoid were not altered in the presence of osteoarthritis.[25] This consistency in vault size can therefore be used in generating a vault model which can be aligned to the native vault that has not been affected by the arthritic process, thereby estimating the bone loss without the necessity of a scan of the contralateral side, which itself may be abnormal.[24,26]

The vault model has also been adapted into an alternative technique termed the glenoid vault method, which utilizes 3D reconstructed slices. Glenoid version is measured as the angle between the glenoid line and the line perpendicular to the glenoid vault axis. Using this method Matsumura et al. reported that the average glenoid retroversion in a normal shoulder using the conventional Friedman technique was $1.1^0 \pm 3.2^0$ compared to $8.9^0 + 2.7^0$ using the vault method suggesting that the Friedman technique may underestimate the severity of bone loss in the arthritic population.[27] However, this has not been confirmed in other studies and there is therefore no consensus as to which would be the most reliable way to assess version and bone loss, although there is increasing evidence that greater accuracy and reliability may be achieved with the use of 3D CT images and the vault model.[24,28,29]

5. The surgical management of glenoid bone loss

Although shoulder arthroplasty for the treatment of glenohumeral arthritis has in general demonstrated excellent long term outcomes, the management of significant glenoid erosion, and in particular the B2 glenoid, has been associated with less favourable outcomes, increased complication rates, ongoing posterior instability and reduced implant survivorship.[2,5,30,31]

The degree of glenoid bone loss and its location is variable and will determine the technique used to address the deficit. In general, posterior bone loss is encountered in glenohumeral osteoarthritis, anterior bone loss in chronic anterior glenohumeral instability and superior defects in rotator cuff arthropathy. Global defects may be encountered in the revision setting.[8] The choice of technique to address the bone loss is based on the size and location of the deficit.

5.1. Hemiarthroplasty

Total shoulder arthroplasty (TSA) is perceived to be the best treatment option for the management of shoulder arthritis.[32] However, hemiarthroplasty remains a viable treatment option in certain patient cohorts, particularly the young patient with concentric arthritis and in those with minimal glenoid wear.[33] It can also be advocated in those patients where there is insufficient glenoid bone stock for the implantation of a glenoid prosthesis, however, by not addressing the glenoid, pain and continued glenoid bone erosion may continue such that poor outcomes can be reported.[34]

The use of alternative materials for the humeral head, such as ceramic or Pyrolytic carbon (PyC), has been advocated, however there is currently no evidence to support their use over conventional materials.[35,36]

The use of a conventional hemiarthroplasty in conjunction with concentric reaming of the glenoid to correct glenoid version, has also been postulated as way to avoid the use of a glenoid implant in the younger patient.[37,38] The aim of a non–prosthetic glenoid arthroplasty, also known as 'Ream and Run', is to not only correct the version, but also to stimulate the formation of a fibrocartilage

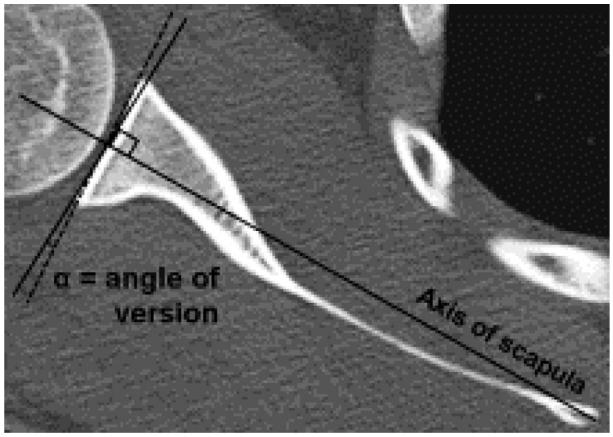

Fig. 3. Friedman method of calculating glenoid version (Reprinted with permission from Elsevier from Poon PC, Ting FS. A 2-dimensional glenoid vault method for measuring glenoid version on computed tomography. J Shoulder Elbow Surg. 2012 Mar; 21(3):329-35.

covering to the glenoid, which in a canine model can form by 24 weeks.[39] As an alternative, concentric reaming can also be combined with an interposition arthroplasty.[40] Long term outcomes with both of these cohorts are however mixed and patient selection is critical.[41–43]

5.2. Eccentric reaming

The most common method of managing the glenoid erosion in anatomical TSA, including of a B2 glenoid, is currently eccentric reaming with the use of a standard glenoid component.[44] This technique, also termed 'high side reaming', involves reaming the glenoid to correct glenoid version whilst also re-creating a concentric socket.[31] However, correcting the glenoid to within 5° of its ideal version may be difficult.[45,46]

It is widely accepted that eccentric reaming alone may be used to correct glenoid retroversion up to 15° or posterior bone loss less than 8 mm.[2,47–50] Although this technique medialises the joint line, a small degree of medialisation can be corrected by choosing an implant of appropriate thickness to recreate the native joint line.[44] However, excessive medialisation may result in complications due to the loss of glenoid bone stock.

Violation of the subchondral plate diminishes the cortical support critical to the stability of the glenoid prosthesis and may therefore lead to an increased risk of implant loosening and subsidence.[45,51–53] Cortical penetration of the glenoid implant due to narrowing of the glenoid vault, may occur and with progressive medialisation, the narrowing of the glenoid also leads to a reduced area of bone available for implantation of the glenoid implant.[49,54] As a result, the use of a smaller glenoid component may be necessary, which may in turn lead to a radial mismatch with the humeral head replacement. Excessive medialisation may also lead to inadequate tensioning of the rotator cuff muscles and therefore a poorer functional outcome and an increased risk of instability. Indeed, Walsh et al. reported that of 92 B2 glenoids managed with a TSA, 16.3% required revision surgery. 21% of cases demonstrated radiological glenoid loosening with 6.5% of the 92 requiring revision for loosening, a further 5.4% for posterior dislocation and 4.3% for other complications.[30]

5.3. Anatomic total shoulder arthroplasty with bone grafting

In cases where glenoid bone loss and retroversion are too great to correct with eccentric reaming alone, the use of bone grafting may be considered. The exact technique utilised is dependent upon the nature of the defect. Contained, central defects are amenable to impaction grafting however peripheral or combined defects are more challenging and require internal fixation of the bone graft to the native glenoid.[55] It is particularly indicated in cases involving more than 1 cm of posterior bone loss.[45] Resected humeral head, iliac crest autograft and allograft may all be utilised and may be performed as a one or two stage procedure. However, results of studies reporting glenoid bone grafting in TSA have been mixed.

The use of cancellous morsalized graft for central contained glenoid defects with a standard polyethylene glenoid implant has been reported with some success although more peripheral and uncontained defects pose more of a challenge.[49] In such cases block autograft has been secured to the native glenoid with screw fixation or by impaction. In a series reported by Sebesan et al., 12 patients who received a TSA with an all polyethylene glenoid and with a minimum of 24 months follow up, demonstrated graft healing in 83% of cases.[56]

However, differing results are reported when a mixture of all polyethylene and metal back glenoid implants are used. Steinman et al. demonstrated that in 28 shoulders with an average follow up of 63 months, 54% demonstrated evidence of lucency around the glenoid implant but that only 10% were considered to be radiographicaly loose.[57] Similarly, Klika et al. reported on 25 shoulders with a mean clinical follow up of 8.7 years where 92% of shoulders demonstrated a good clinical outcome despite 40% of glenoids being deemed at risk of failure.[58] Furthermore, Hill and Norris reported on 8 of 17 patients who had internally fixed glenoid bone graft with unsatisfactory functional results at long term follow up.[59]

What is not clear however, is whether these less than favourable results are secondary to the use of metal back glenoid implants, which have been shown to have increased polyethylene wear rates as compared to all polyethylene implants.[60] Furthermore, new 'platform' metalback glenoid implants such as the Universal Glenoid (Arthrex Inc, Naples, FL, USA) are now being released that may have the potential to allow some compression of a graft onto the native glenoid whilst also being retained in the later conversion to a reverse shoulder replacement. Although there is no data available as to the efficacy of these implants, they may offer a potential solution in the future.

Irrespective of what type of glenoid component is used, the need to perform bone grafting in conjunction with glenoid prosthesis implantation increases the risk of failure and some degree of radiographic lucency may be evident in over 50% of cases even in clinically asymptomatic patients.[2,50,57,58]

5.4. Augmented glenoid implants

Due to the limits in correction of glenoid deformity that can be achieved with eccentric reaming or bone grafting, augmented glenoid implants can also be considered. Their use is aimed at restoring glenoid anatomy whilst minimising further bone loss and glenoid medialisation associated with eccentric reaming whilst negating the risk of non-union associated with bone grafting techniques.[61] However, exact preparation of the native glenoid is necessary to accommodate the prosthesis and it is therefore a technically demanding procedure, with suboptimal seating predisposing to increased micro-motion and premature loosening.

Early metal backed wedge shaped glenoid augments were reported to have unacceptably high failure rates with 10 year survivorship as low as 31% thereby leading to their subsequent withdrawal.[61,62] All polyethylene glenoid augments have more recently been introduced and may hold promise for the future. These currently consist of either a posterior wedge shaped design (Exactech, Gainsville, FL, USA) or a posterior step design (DePuy, Warsaw, IN, USA) (Fig. 4a and b).[2] The morphology of the glenoid deformity and the design of the augment may have a significant effect of the forces transferred through the prosthesis, and influence the choice of implant used.[44] Both designs have been shown to be viable in cadaveric and simulation models, with a step-cut design demonstrating greater stability under cyclic eccentric loading by orientating the joint force vector perpendicular to the prosthesis.[55,62–64] This may therefore reduce shear stress at the interface between bone and prosthesis.[65]

There is however currently limited clinical data available regarding the outcomes of glenoid augments. Rice et al. reported the results of fourteen patients with mean follow up of five years treated with a keeled, all-polyethylene posteriorly augmented glenoid prosthesis.[66] The authors noted that although intermediate term pain relief was satisfactory, persistent posterior humeral head subluxation was not always corrected. Favorito et al. reported a series of 22 patients of posterior glenoid bone loss treated with stepped, all-polyethylene augmented glenoid component with 36 months mean follow up in which a statistically significant improvement in outcomes scores was observed as were two cases

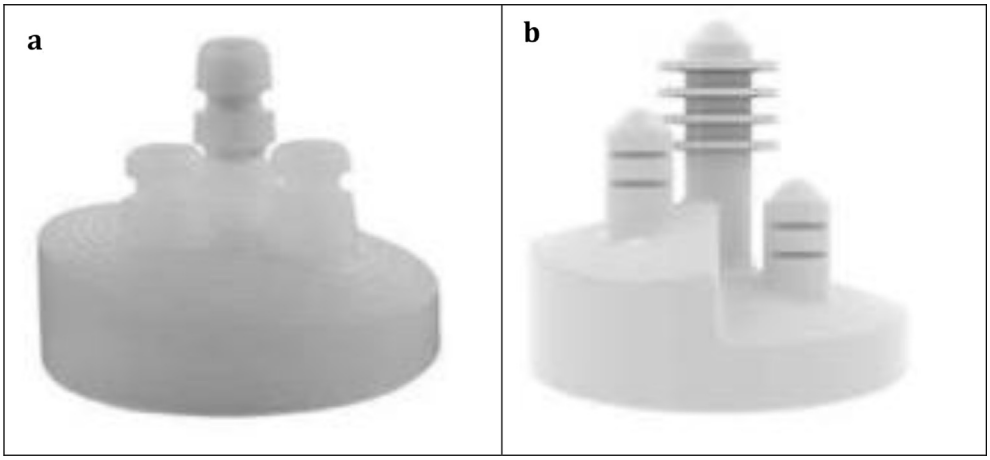

Fig. 4. a) Wedge shaped posterior glenoid augment (Exactech, Gainsville, FL, USA). **(b)**. Posterior step design glenoid augment (Depuy, Warsaw, IN, USA).

of prosthetic instability.[67] Trabecular metal augments used in association with a polyethylene glenoid implant have also recently been proposed as a means to correct retroversion of 25^0 or more with Sandow et al. reporting good outcomes of 10 patients at 24 months follow up.[68]

The use of augmented glenoids may therefore potentially be indicated in cases where glenoid retroversion is $> 15^\circ$, however long term data is still required to evaluate clinical outcomes and longevity.[69]

5.5. Reverse shoulder arthroplasty and bone grafting

Glenoid bone loss is common in Reverse Shoulder Arthroplasty (RSA) in both the primary and revision setting with abnormal glenoid bone wear being reported in up to 38% of cases.[70] Typically superior glenoid erosion is encountered secondary to the migration of the humeral head however posterior wear is also common and more global defects are seen in the revision setting.[71,72] However, the semi-constrained design and decreased reliance on soft tissue balancing, permits RSA to be more tolerant to retroversion and therefore may also minimise the risk of recurrent posterior humeral head subluxation commonly observed when performing anatomic shoulder arthroplasty in patients with a B2 glenoid.[2]

Similar principals to those used in the management of bone loss with anatomical shoulder replacements can be considered. However, one has to be mindful that eccentric reaming can result in excessive medialistaion, which may compromise baseplate fixation, result in notching and also adversely affect soft tissue tension such that the stability of the implant is compromised.

Baseplate stability is critical and will be dependent on both patient factors and design features related to the implant itself. The depth and volume of the glenoid is important, with bone loss medial to the coarcoid often requiring consideration of bone graft to provide enough support for the baseplate. The size of the glenoid vault is also critical, not only to provide support for the baseplate, but to provide purchase for additional screw fixation. Implant design and the method of fixation of the baseplate, are therefore also important considerations in operative planning.

Essentially there are two different baseplate designs utilising either a peg or a central screw. With the peg designs, divergent supplemental screw fixation is advocated to reduce micromotion and therefore an adequate volume of the glenoid vault is needed to accommodate the screws.[73] The central screw designs may be able to avoid this, as the compressive forces generated by the screw provide the primary fixation and compression with additional parallel locking screws being used to limit shear and torsion. One screw design, the Reverse Shoulder Prosthesis (DJO Global, Austin, TX, USA) generates 2000N of compressive force compared to 200N seen with the Grammont style peg and peripheral screws.[74] Where there is reasonable bone stock, the position of the baseplate can be optimised on the glenoid centerline as described by Matsen, such that bicortical screw fixation should be possible.[75] In instances where there is inadequate bone, an alternative centerline can be used so that the central screw passes along the axis of the scapular spine thereby optimising the bone stock that is available.[76]

The method of glenoid preparation prior to the placement of the graft will vary depending on the implant design and the method of grafting utilised. Adequate baseplate stability must be achieved and in several studies at least 50% contact has been shown to be necessary between the native glenoid and baseplate.[77–79] Depth of the glenoid vault is also important, however this varies depending on implant design. Werner et al. recommended at least 10–15 mm of the baseplate peg should pass into the native glenoid.[77] 10 mm was also the minimum recommended by Malhas et al. whereas Boileau et al. recommended a minimum of 8 mm depth when describing the bone increased offset (BIO) technique.[55,60] In the central screw designs, the use of the alternative glenoid line has been postulated as a technique to enhance implant fixation in cases with excessive bone loss.[76]

Baseplate position and orientation is also important when considering peripheral screw placement. Screws into the coracoid base and lateral scapular column tend to achieve the best fixation. Good graft incorporation has been described with only two peripheral screws in addition to the central peg and biomechanical studies have shown no difference in micro-motion of the baseplate when comparing two-screw and four-screw fixation.[80,81] In addition, screw divergence in the peg designed baseplates, have been shown to have a greater influence on fixation than the diameter or length of the screws.[73] However, this was not noted in the central screw designs, where four peripheral parallel locking screws gave optimal fixation.[74]

The compression of bone graft by the implant may also provide a more favourable environment for graft incorporation.[82] Most glenoid defects can be reconstructed as a single stage procedure. Humeral head autograft is most commonly used in the primary setting although structural allografts may yield equally acceptable results.[82] The size of the bone graft will be determined not only by the extent of the bone defect, but also the soft tissue tensioning. In cases of chronic medialisation, restoration of the normal joint line may not be possible and in such circumstances the use of a larger

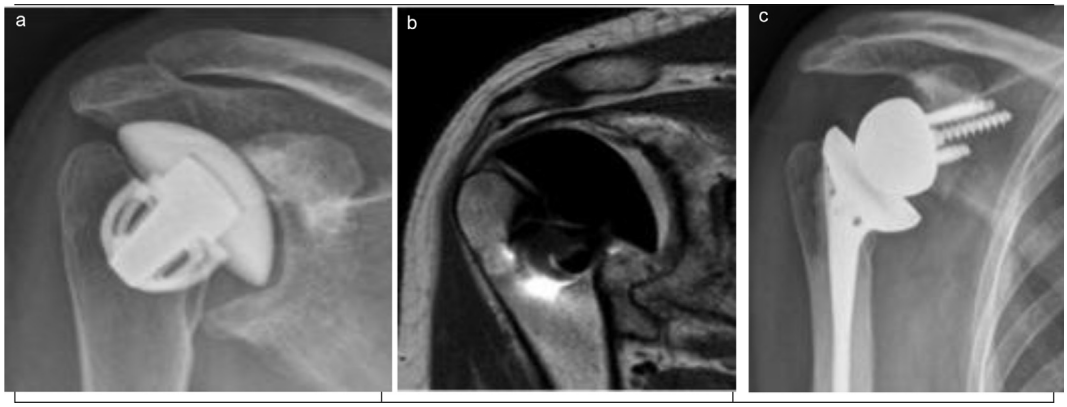

Fig. 5. ab,c. X-ray (a), and MRI scan (b) revealing significant medialisation of a ceramic head Affinis hemiarthroplasty (Mathys, Switzerland) revised to (c) a Reverse Shoulder Arthroplasty (DJO Global, Austin, TX, USA) with iliac crest autograft whilst preserving the rotator cuff.

glenosphere may help enhance stability and also cover the bone graft.[70,76]

There are multiple published studies regarding RSA with glenoid bone grafting in both primary and revision settings describing satisfactory outcomes.[8,60,71,72,76–78,82–86] Boileau et al. reported humeral head autograft incorporation rates of 98% in a study of 42 patients who underwent a BIO reverse shoulder arthroplasty.[60] Gupta et al. reported a mean increase in Constant score of 61 points in 94 patients with only one implant failure at mean follow up of 2.4 years in patients who had undergone RSA with bone grafting.[78] Similarly, but by using a central screw designed implant, Lorenzetti et al. reported on 57 patients treated with a primary RSA (Reverse Shoulder Prosthesis, DJO Surgical, Austin, TX, USA) with glenoid bone grafting for severe bone loss by using the alternative glenoid line. 98% graft incorporation was reported and no baseplate failures were recorded.[87]

In the revision setting, Wagner et al. described 41 patients who underwent RSA with bone grafting. The survival rate free of radiographic glenoid loosening at two and five years was 92% and 89% respectively. However, the authors noted that 75% of the implants that failed utilised cortico-cancellous rather than structural bone graft.[71] Melis et al. in a series of 29 revision RSAs with either allograft or iliac crest autograft reported a 76% graft incorporation rate and 8% glenoid loosening rate at mean follow up of 47 months.[85]

Although the most common indication for RSA remains rotator cuff arthropathy, its use is increasingly also being advocated in cases with significant glenoid bone loss but with an intact rotator cuff including in the B2 glenoid in elderly and low demand patients.[2,31,44,88] It is also becoming the prosthesis of choice in the revision settings (Fig. 5).[31,78]

5.6. Custom made implants

In instances of significant glenoid destruction such that stable fixation of a conventional glenoid baseplate is not technically achievable, the use of a custom made implant may be considered. However, the literature to support their use is currently limited.[89–92]

Computer-aided design and computer-aided manufacturing (CAD CAM) technology can be utilised to create a bespoke glenoid implant. The use of all polyethylene CAD CAM cemented glenoid implants has been suggested but for more challenging cases of glenoid bone loss a CAD CAM glenoid shell has been advocated (Stanmore Implants Worldwide - Stryker, MI, USA) (Fig. 6).[89–92] Chammaa et al. reported a series of 37 patients treated with CAD/CAM total shoulder replacements demonstrating 16% revision rate and 1 case of glenoid loosening at 5 year follow up.[89]

More recently, advances in 3D printing technology now make it possible to manufacture an implant which precisely matches the

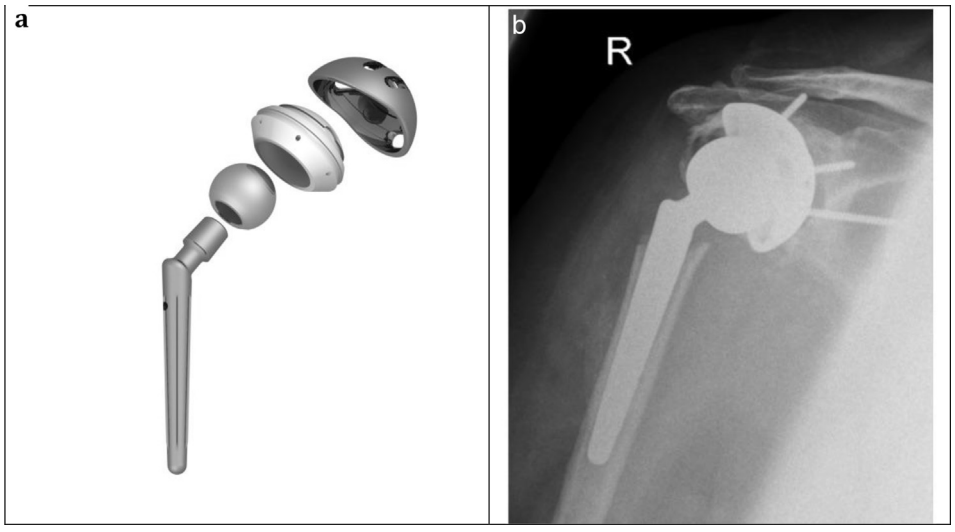

Fig. 6. a,b. (a & b) CAD CAM Glenoid shell and humeral stem (Stanmore Implants Worldwide - Stryker, MI, USA).

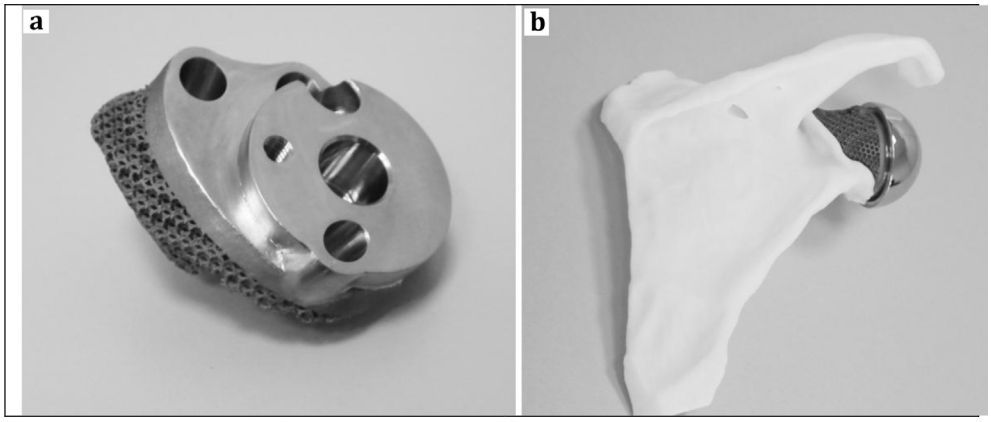

Fig. 7. a,b. (a & b) 3D printed CAD CAM glenoid baseplate - Glenius Glenoid Reconstruction System (Materialise NV, Leuven, Belgium).

glenoid deformity of an individual patient and facilitates incorporation of an osteoconductive porous structure to promote osteointegration; Glenius Glenoid Reconstruction System (Materialise NV, Leuven, Belgium) (Fig. 7). Although this holds much promise for the future, evidence to support their use is currently limited.[90]

5.7. Computer planning software and patient-specific instrumentation

Computer planning software and patient-specific instrumentation (PSI) may facilitate improved accuracy of glenoid component implantation, especially in challenging cases with significant glenoid bone loss and deformity.[93] Planning software enables the surgeon to optimise positioning of the desired glenoid implant and there have been multiple recent publications demonstrating its use can lead to more accurate orientation of the glenoid components.[50,94–97] Furthermore, poor glenosphere position in RSA can be associated with a limited arc of movement due to impingement, increased scapular notching, instability and loosening leading to catastrophic failure of the component.[98–100]

Whilst surgical planning can be optimised with the use of computer software, PSI has been developed to facilitate greater accuracy in the intra-operative execution of the pre-operative plan.

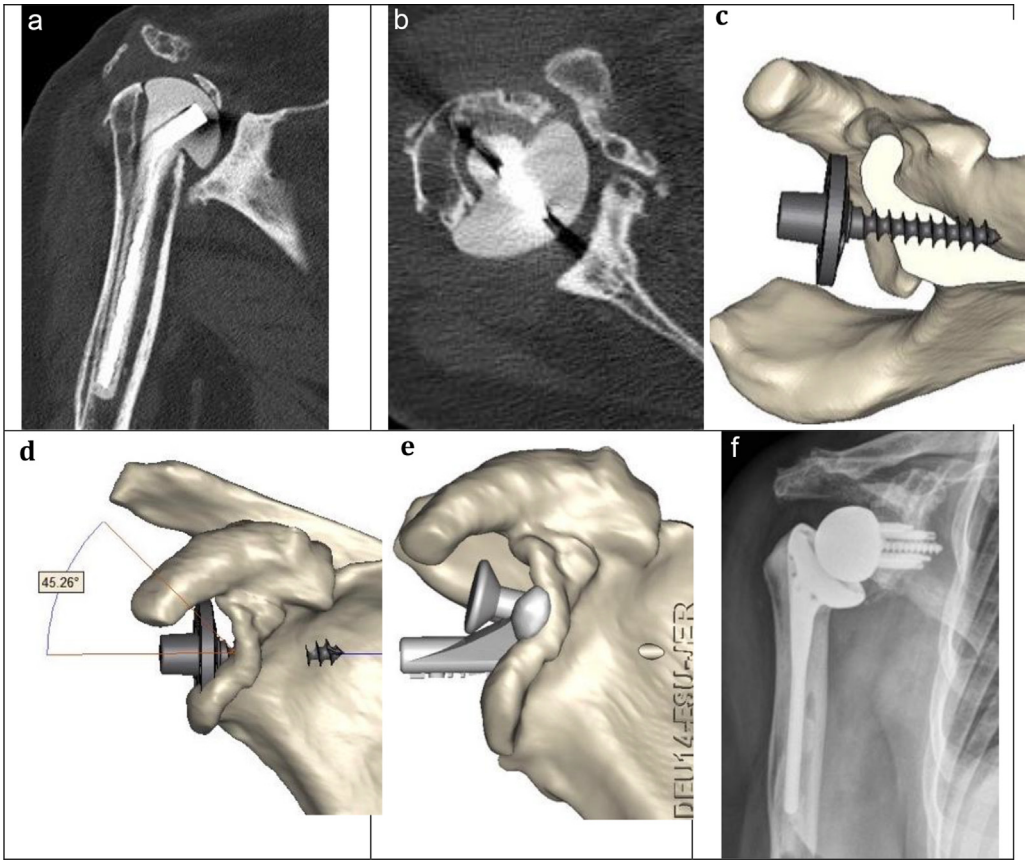

Fig. 8. a-f. RSP Matchpoint Reverse Shoulder Arthroplasty (DJO Global, Austin, TX, USA) for massive glenoid bone loss. (a) Pre-opertaive x-ray demonstrating cement spacer with medialisation. (b) Pre-operative CT scan revealing significant glenoid bone loss and posterior retroversion. (c & d) Preoperative planning with RSP baseplate positioned for bicortical fixation and graft compression (Materialise NV, Leuven, Belgium) (e) Matchpoint jig position for central drill hole preparation. (f) Post-operative x-ray following glenoid allograft grafting and RSP insertion.

The principles behind PSI include a pre-operative thin-cut CT scan of the whole scapula and ipsilateral humerus following a pre-defined protocol. The original two-dimensional images are subsequently uploaded to a three-dimensional image processing software system and subsequently converted into a precise three-dimensional model of the patient's scapula. The surgeon then uses pre-operative virtual surgical planning software to optimise the position of the glenoid component in a process that may vary according to each implant manufacturer. A patient specific guide is then designed to fit onto the surface and border of the glenoid such that minimal additional exposure is needed. The sterilisable guide is then manufactured into a 3D stereolithography model with drill cylinders positioned within it to orientate the glenoid preparation/drill hole (Fig. 8).

There are multiple recently published studies reporting improved implant positioning in both cadaveric models and in-vivo using planning software.[97,101–104] However, whilst initial reports are encouraging, the period of post-operative follow is currently insufficient to demonstrate improved patient outcomes and implant survivorship.[93]

5.8. Intra-operative navigation

The use of intra-operative navigation is well established in knee arthroplasty although its potential application in shoulder arthroplasty is relatively new and less well understood.[105] Like PSI, intra-operative navigation is designed to help execute the pre-operative plan and potentially enable more accurate implantation of the glenoid component in cases with glenoid deformity. Its theoretical advantages over PSI are that it provides intra-operative feedback and a real-time view of drilling depth, screw placement and implant orientation. It also has the benefit of allowing the surgical plan to be adjusted intra-operatively. Its drawbacks are increased cost, time and technical difficulty due to placement of intra-operative arrays and confirmation of anatomic landmarks. However, like PSI, there is currently limited evidence to support the use of intra-operative navigation in shoulder arthroplasty.[103,106–108] A recent meta-analysis by Sadoghi et al. concluded navigation allows for greater accuracy of glenoid version but the clinical benefit over standard techniques remains as yet, unproven.[105]

6. Conclusion

The management of glenoid bone loss in shoulder arthroplasty remains challenging and the recognition of patients with such a deformity pre-operatively is imperative. Such patients require additional pre-operative CT imaging to accurately assess the extent and morphology of glenoid bone loss.

There are varied techniques available to manage this difficult scenario. The evidence to support each is however largely limited to retrospective case series and there is currently no consensus as to the optimum method of treatment. The choice of procedure will therefore depend upon the morphology of the deformity, the patient, the experience of the surgeon and the design of the chosen implant.

Detailed pre-operative planning, an understanding of the indications and limitations of each technique and an appreciation of the intra-operative difficulties that may be encountered are essential to enhance clinical outcomes and minimise complications.

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Declaration of conflicting interests

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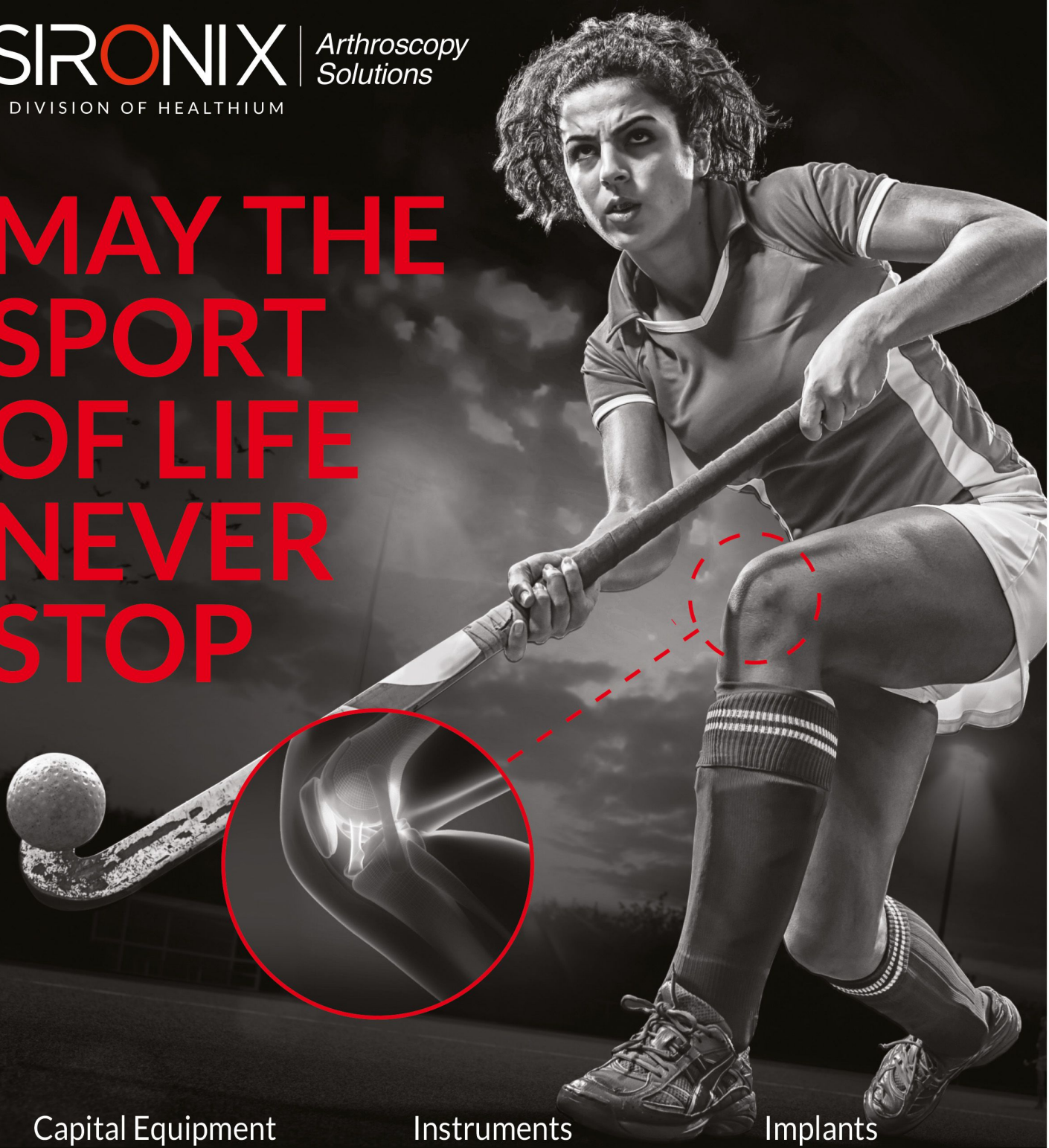

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