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Case report

Traumatic acute stem rupture in stress shielding bone resorption of a bipolar radial head arthroplasty: case report and literature review

Carlo Cardile[1], Paolo Arrigoni[2], Carlo Cazzaniga[1], Carlo Zaolino[2], Paolo Ragni[1], Pietro Simone Randelli [2,3]

[1]U.O. Ortopedia e Traumatologia Ospedale Salvini , Asst Rhodense, Garbagnate M.se, Milano, Italy; [2]U.O. Clinica Ortopedica e Traumatologica Universitaria CTO, Asst Pini-CTO, Milano, Italy; [3]Dipartimento di Scienze Biomediche per la Salute, Università degli Studi di Milano, Milano, Italy

Abstract. Bone resorption around the proximal portion of the stem of a radial head prosthesis is a frequent phenomenon. In the vast majority of cases it is not correlated with to be without clinical manifestations. This radiographic sign, refers to the stress shielding effect has been more described in total hip replacement surgery. Few authors have noticed this phenomenon in radial head replacement. however, given the increasing number of these procedures, a careful surveillance is required in patients presenting this sign. We report a literature review and a case presentation of proximal stem rupture following a trauma in association to radiological periprosthetic bone resorption due to stress shielding and treated with revision surgery. (www.actabiomedica.it)

Keywords: Radial head Arthroplasty, stress shielding, fractures, stem rupture, bone resorption.

Introduction

Radial head replacement procedure is the treatment solution in case of multifragmentary radial head fractures. This is particularly true in cases of comminution, dislocation or associated ligament injuries that cannot be treated with reduction and fixation surgery procedure. This is alternative to radial head excision surgery, that has been considered golden treatment for a long period of time. In the last years the number of radial head replacements has increased thanks to the evolution of the implants due to improvement in materials, design, surgical technique and surgical instruments, which has led to better clinical outcome and radiographic results (1).

Compared to radial head excision, the radial head replacement surgery has the goal to reproduce normal joint anatomy and kinematics, restoring radial-humeral and proximal radio-ulnar joint (PRUJ) relationships.

This result can be achieved from a biomechanical point of view through three types of implants: anatomical replacements, bipolar design prostheses and loose fit stems.

Each of these types, regardless of the materials used and the implant technique, (cemented or cementless) reported similar survival rates from the results in the literature, although some techniques showed less need for revision surgery procedure.

A 47-year-old patient treated with a press fit 3Dpore titanium stem radial head prosthesis (ANTEA, Adler Ortho, Cormano, Italy) suffered of a stem rupture requiring surgical revision procedure for prosthesis removal and implant of an enlarged metaphysis prosthesis. Patient obtained good clinical outcome at six months follow-up, evaluated with Mayo Elbow Performance Score (MEPS), with absence of pain and complete range of motion (ROM).

Case Report

In November 2019, a 47-year-old female patient, right-handed manual worker without significant concomitant pathologies, showed up at our emergency department left elbow trauma. X-ray showed a radial head pluri-fragmentary fracture with joint involvement (type III modified MASON).

Figure 1. Fracture modified MASON III type pre-operative X-ray

Figure 2. post-operative X-ray

On November 4 the patient was treated for radial head replacement with a bipolar radial head prosthesis with a titanium stem 3dpore technology (ANTEA, Adler Ortho, Cormano), due to the impossibility to perform reduction and fixation related to the comminution of the fracture. Post-operative x-ray showed good implant positioning, good diaphyseal fit and absence of overstuffing.

At 1, 3 and 6 months follow-up evaluations patient X-ray excluded signs of mobilization. Since the X-ray control at 1 month reabsorption was shown at osteotomy site, reaching 3 mm of exposure of the proximal part of the stem at 6 months.

Not showing any symptoms, the patient continued the post-operative rehabilitation protocol.

On June 2020 patient returned to our ER for blunt trauma of the left elbow from an accidental fall. X-ray showed the rupture of the prosthetic stem, in the area of bone resorption.

Prosthesis revision surgery was performed for total removal of the implant. The broken component and remaining part of the prosthetic stem were substituted. The remaining portion of the stem tenaciously integrated to the residual diaphysis with evidence of new bone apposition within the titanium trabeculae and after some unsuccessful attempts, a partial longitudinal osteotomy, performed with saw and mini-chisels, was necessary for the complete removal.

The removed implant was sent to the manufacturer to perform technical analyzes and evaluations to search for the causes of the prosthetic implant rupture.

Considering the young age of the patient, bone loss was considered manageable with the same implant. We planned to reimplant a undersized implant with a cemented technique to avoid intra-operative fracture in the research for press fit.

After regularization of the fracture line a cemented size 1 stem was chosen. To balance bone loss increased by the quantity removed, a metaphyseal offset +5 mm was implanted with associated the epiphyseal component maintaining the previous size of 17.5 mm in diameter.

After definite component implant, full ROM and no signs of instability were found at the dynamic intra-operatory evaluation. Intra e post-operative X-ray confirmed the correct positioning of the implant.

After surgery prophylaxis for heterotopic ossifica-

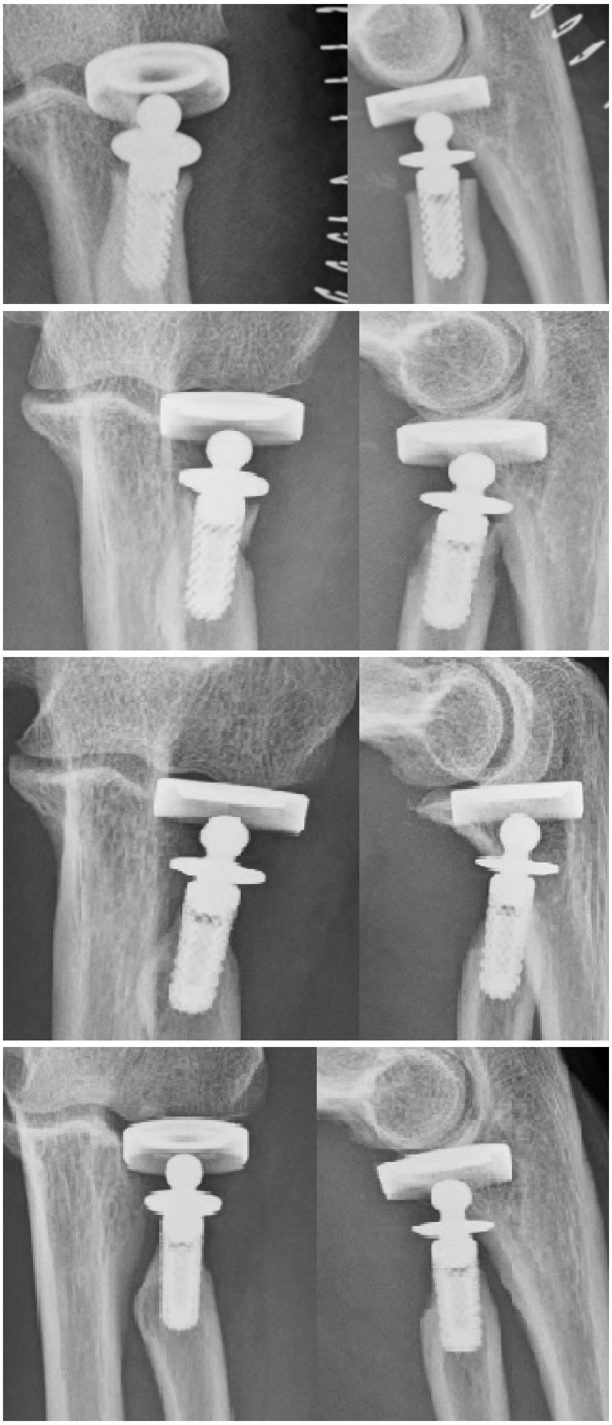

Figure 3. Progressive bone resorption: a) x-ray post-operative, b)x-ray at 1 month, c) x -ray at 3 months, d) x-ray at 6 months

tion was performed and the duration of rehabilitation was 40 days.

At follow up evaluation at 1, 3 and 6 months a valid progression of ROM recovery was observed with good clinical outcome obtained. At X-ray control no heterotopic ossification and no signs of implant mobilization were observed at the bone cement interface together with no signs of osteolysis or bone resorption.

At 10 months evaluation we observed full ROM recovery with excellent MEPS (98) and X-ray showed no differences with previous controls.

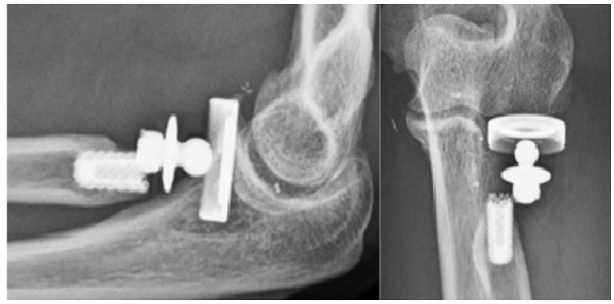

Figure 4. Post traumatic acute stem rupture.

Figure 5. Intraoperative view of residual stem well integrated and total implant removal.

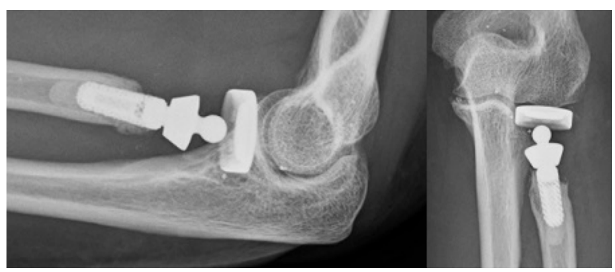

Figure 6. X-ray after revision.

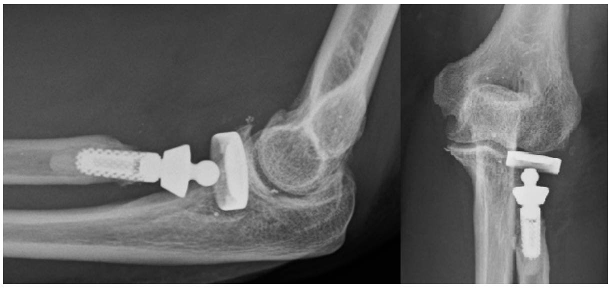

Figure 7. X-ray 10 months Follow Up

Figure 8. Full ROM recovery

Discussion

Radial head arthroplasty (RHA) is indicated in the acute treatment of modified MASON type IV fractures while optimal treatment of modified MASON type III fractures was not possible to identify, as Pogliacomi et al. (2) described in their retrospective study. Pogliacomi also concluded that outcomes are similar in modified mason III fractures operated with ORIF, RHA or Radial Head Resection.

However, in young people, RHA should be the best choice in Management of Type III fractures that are not suitable for reduction and fixation techniques due to a high risk of failure or in case of failure of previous reduction and fixation surgery instead RHR should be considered in older people.

The existing prosthetic models are summarized in modular monobloc and fixed, bipolar and loose stem.

Each of these has advantages and disadvantages although clinical outcomes are comparable as stated by Delclaux et al. (3) In their literature review the major complications that lead to revision surgery are mechanical implant failure, overstuffing, erosion of the capitulum humeri , instability, neurological injuries, implant disassembly and arthrosis.

Kodde et Al published a medium term retrospective study (mean follow up 48 months) on 30 patients with short stem press fit bipolar prostheses, reporting that none of these had radiological signs of stem loosening. However, 92% of the cases presented signs of radiographic osteolysis in GREWAL zones 1-7 (around the proximal portion of the stem), without significant correlation with any clinical sign or the necessity for revision surgery due to stem mobilization. (4)

Grewal classified radiolucencies around the stem as NONE, MILD, MODERATE, SEVERE based on how many of the 7 areas they described were involved in the phenomenon, adopting the areas described by Gruen (5). The same scheme is reported applied in our case.

Our case presented stress shielding in zones 1-7, but remained asymptomatic up to the known trauma that identified the area affected by resorption as an "area of minor resistance", resulting in the breakage of the uncovered prosthesis stem portion, by transferring load forces into this zone.

Chanlalit et al. describe the phenomenon of stress shielding as bone resorption first periosteal and then

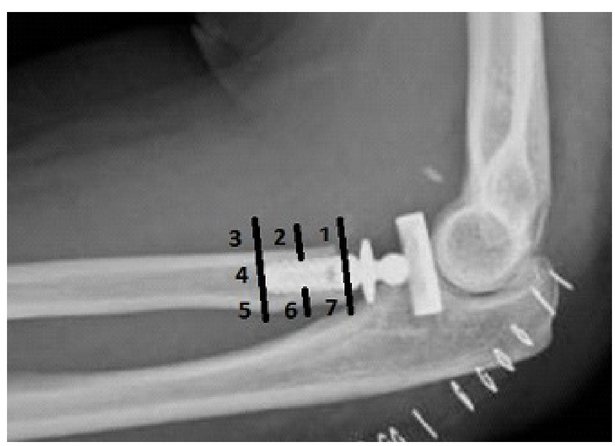

Figure 9. Zonal evaluation of radiographic changes on lateral x-ray using hip method developed by Gruen

endosteal which occurs around the stem of rigid implants in the proximity of the osteotomy area. (6)

This process, characterized radiographically by a blunt and convex aspect of the bone proximal to the radial shaft that embraces the prosthetic stem, is described as consistent with the WOLFF law of bone remodeling. In fact, the load transfer is directed from the radial humerus joint to the head-stem of the prosthesis and which transfer it to the radial endosteal cortex near the middle distal region of the stem resulting in a load reduction for the proximal portion.

The authors also propose a classification for bone resorption from stress shielding, based on degree of involvement and progression of the phenomenon, divided in 5 categories : I cortical thinning, IIa partially exposed, IIb circunferentially exposed, III impending mechanical failure.

In our case, prior to the trauma, bone resorption phenomenon due to stress shielding was observed in post-operative follow-up X-ray. Periosteal and endosteal resorption at the proximal third of the radial shaft evolved with progression characteristics up to stage 2b in x-ray at 6 months, complicated in mechanical failure due to post-traumatic stem rupture. .

Again Chanlalit et Al in their work describe stress shielding around cemented or uncemented fixed stems as a very common phenomenon, but asymptomatic in most cases and independent of stem length, shape and coating. Although they report that a statistically significant conclusion between cemented and uncemented group is not possible due to subgroup smallness. (6)

In their cohort also appear that only cemented long stem implants demonstrate less stress shielding phenomenon, assuming that this is justified by the osteotomy level typical of these implants which is close to the bicipital tuberosity of the radius. In fact, although not normally progressive, the phenomenon can sometimes evolve in stages 2B and 3 of the classification described by them, without ever extending to the bicipital tuberosity of the radius.

Popowic et al. examined 51 cemented long-stem bipolar prostheses at 8.4-year mean follow-up looking for radiolucency, osteolysis and bone resorption sign in the GREWAL zones. (7). They found that 53% of patients had radiolucent zones, 31% bone resorption in Gruen zone 1-7, and 10% showed progressive BALLOON-SHAPED osteolysis in midstem region (zones 2,3,5 and 6) with thinning cortical and stem migration. The authors concluded that stem migration in cemented implants occurred only in patients with balloon shaped osteolysis. Even in case of complete proximal radius resorption, distal portion of the stem remained rigidly fixed in the cement.

The amount of resorbed bone depends on the elastic modulus of the implant. More rigid implants can increase stress shielding phenomenon and consequently proximal bone resorption.

Stress Shielding is also influenced by multiple factors, such as: construction material, prosthesis design and type of mechanical fixation (straight stem, anatomical stem, distal press-fit, proximal fit and distal fill). Anatomical titanium porous coated femoral implants showed less bone resorption compared to cobalt-chromium implants. (8)

In the study of Rotini et Al. on the comparison between monopolar and bipolar implants, analyzed 31 patients undergoing radial head replacement through clinical-radiographic parameters, including periprosthetic and bone resorption. The authors concluded that there is no statistically significant correlation between the type of implant and bone resorption. (9)

They also described a bone resorption classification based on X-ray imaging and dividing it in 3 grades: grade 0 no resorption, grade 1 resorption> 3mm at the deepest point, grade 2 resorption> 3mm at the deepest point. In their series 9 case presented bone resorption and only 3 of them were classified as grade 2. Of these 3 cases, 2 presented good clinical results and only one needed prosthetic revision surgery at 20 months of follow-up due diagnosed as aseptic loosening. The author concluded that radial head prostheses require periodic follow-up control to check the possible evolution of bone resorption, even in asymptomatic patients.

In our case we hypothesized that implant rupture was conditioned by the bone resorption which has become a minor resistance site of the stem because bone uncovered. However, it is likely that bone resorption itself, in the absence of trauma, as demonstrated in the pre-rupture follow-ups, would not have caused any clinical symptoms, also considering that a longitudinal osteotomy was necessary for the stem removal procedure due to the valid osteointegration of the stem. The trauma, due to its unfavorable biomechanical configuration, led to the rupture of the stem in its minor resistence site. It is therefore conceivable that a valid trauma as in the case of the patient described, in the absence of resorption, could have caused a periprosthetic diaphyseal fracture of much more complex management.

Conclusions

From literature review, stress shielding is a very common phenomenon following radial head replacement surgery but little emphasized as it is usually asymptomatic.

Given the increasing number of radial head replacement surgery due to implant improving in materials and design and the good outcome results even in young patients, in our opinion, the orthopedic surgeon must be prepared to know any post-operative problems associated to this procedure. In particular, he must know how to recognize bone failure signs, but distinguishing the real alarm bells towards conditions such as resorption from stress shielding, which deserves careful observation over time even in asymptomatic patients, without the necessity to perform revision surgery if clinical conditions are stable at follow-up.

Conflicts of interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article.

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Correspondence:
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Dr Carlo Cardile,
viale Forlanini 95 Garbagnate Milanese, 20024 Milano, Italy
ORCID: https://orcid.org/0000-0002-8215-7145
Email: carcardi@icloud.com