More on Smoking and Fracture Healing: Does Nicotine Replacement Therapy Negatively Influence Fracture Healing?

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SUMMARY

Cigarette smoking has been implicated in delayed fracture healing and fracture nonunion in human clinical studies as well as basic-science animal models. Nicotine has been frequently cited as the deleterious agent; however, in studies whose authors have examined the influence of nicotine on healing, negative results have appeared to be at least somewhat dose-dependent. The effects of nicotine on fracture healing with doses similar to those achieved with transdermal patches used for nicotine replacement have not been thoroughly evaluated.

The authors performed a controlled trial utilizing a rabbit tibial osteotomy model to assess the effects of “therapeutic” transdermal nicotine on osteotomy-site healing. A power analysis based on mechanical testing demonstrated that eleven rabbits per group were required; thus, the authors placed eleven animals in each group. The ability to sustain serum nicotine levels similar to those in humans using nicotine replacement therapy was confirmed via measurement of cotinine levels at fourteen and twenty-one days. Cotinine is a byproduct of nicotine metabolism with a longer half-life; thus, it is a good surrogate for serum nicotine levels. Assessment of osteotomy-site healing included radiographic callus measurement as well as mechanical torsional testing after the rabbits were killed, with the contralateral limb serving as a mechanical control. A nonunion was defined as 0 N-m of torsional strength of the specimen.

The authors were able to achieve clinically relevant cotinine levels in the test group that were comparable with those found in human subjects using transdermal nicotine replacement. The mean periosteal callus measurements were lower in the nicotine group, but the difference was not significant (p = 0.30). In terms of mechanical testing, the average torque to failure was 36% of that in the contralateral limb in the transdermal treatment group compared with a mean of 69% in the control group (osteotomy but no nicotine patch) (p = 0.028). Additionally, normalized stiffness was significantly lower in the treatment group (47%) in comparison with the control group (87%; p = 0.036). Finally, three nonunions occurred in the transdermal nicotine group compared with none in the control group; however, this difference was not significant (p = 0.062).
DISCUSSION

The recent literature demonstrates conflicting results with regard to the actual effect of nicotine on fracture healing. However, this study does demonstrate what appears to be a negative effect on fracture healing, at least in terms of torsional strength, associated with the use of transdermal nicotine. Additionally, the levels of cotinine, a nicotine metabolite, measured in this study appear to be clinically relevant when compared with the levels found in patients using transdermal nicotine replacement therapy.

Of note, this study involved a rabbit model, and the results are not directly comparable with those of human subjects. Additionally, the end point for mechanical testing was twenty-one days in this model, and the authors did not clarify the clinical relevance of this time point. The model would have been more valid had the same outcomes been examined chronologically. With that said, this investigation provides further insight into the potential negative effects of transdermal nicotine replacement therapy in patients with acute fractures.

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SUMMARY

Implant irritation after olecranon osteotomy or fracture fixation is a common problem. However, routine planned implant removal is uncommon after these procedures. The authors conducted a survey of 583 surgeons who were members of the Orthopaedic Trauma Association, American Shoulder and Elbow Surgeons, or the American Society for Surgery of the Hand. The majority of the surgeons thought that implant removal from the olecranon was required <30% of the time and that the surgeon who placed the implant was the one who should remove it. The authors also surveyed 138 patients who underwent olecranon osteotomy or fracture fixation. Eighty-nine patients (64.5%) underwent implant removal, and sixty-eight (76%) of them had the implants removed by a surgeon other than the original surgeon. Rates of implant removal were similar between tension-band-wire and plate constructs. Nineteen (39%) of forty-nine patients who did not have implants removed thought that they were functionally impaired due to their implants, and 73% stated that would undergo implant removal if they could be guaranteed a safe surgical procedure.

DISCUSSION

Commonly utilized implants for fixation of olecranon fractures or osteotomy sites are tension-band-wire or plate-and-screw constructs. It seems clear from this simple survey that implant-associated problems are not only common, but are much more common than surgeons think. Surgeons’ perceptions of implant removal rates for olecranon constructs are approximately one-half of the true rates, as indicated by this study. The authors rightly point out three potential reasons for this: patients may see other surgeons for implant removal, patients may not want to express dissatisfaction with a surgeon’s construct for fear of offending the surgeon, and/or the surgeon may hear only what he or she wants to hear. Patients also appear reluctant to request surgery if it is not specifically recommended.
Implant removal carries risks associated with surgery and is costly to both patients and the health-care system. That being said, frank and early discussions should be had with patients about the likelihood of implant removal after fixation of an olecranon fracture or osteotomy site. It is clear that surgeons underestimate the rates of irritation by their olecranon fracture or osteotomy constructs. They should (1) be aware that the rates are higher than they think, (2) understand that many patients choose to have their implants removed by other surgeons (for various reasons), and (3) incorporate the possible future need for implant removal into any informed-consent discussion with regard to surgery for olecranon fracture repair or surgery requiring olecranon osteotomy. Perhaps additional investigations into alternative methods of olecranon fixation that reduce implant-associated irritation are warranted, as indicated by the authors.

How Does Losing Cartilage Make a Better Functioning Wrist?

**SUMMARY**
The authors discuss their technique for dealing with distal radial malunions. Over a three-year period, the authors treated ten patients who had a distal radial malunion with a lesion on the carpus. Their approach was to debride matching areas of the carpus and radius so that there was no cartilage on either side of this now “kissing lesion.” There was a wide range of patient ages (seventeen to sixty-eight years), and patients were seen more than four months after the initial injury. The authors burred down up to 60% of the radial cartilage to obtain a smooth surface. Apparently, all the patients reported immediate relief of pain and an increase in the range of motion after an average duration of follow-up of twenty-eight months.

**DISCUSSION**
Patients were selected from a group with a distal radial fracture, wrist pain, and a malunited radius. The exact malunion that would demand entry into the cohort varied. The surgeons used a nonstandard approach to this problem. Their institute apparently does not require institutional approval for human subject testing. Del Piñal et al. made an intraoperative decision regarding whether they would perform osteotomy, use a vascularized osteochondral graft, or do an arthrodesis depending on their findings during arthroscopic surgery. I am not sure why the patients had better measured outcomes. Two of the patients may have had better results because they obtained soft-tissue coverage and repair of median nerve dysfunction; their outcomes probably had little to do with the intra-articular procedure. Because all the wrists were stiff before surgery, there is a chance that the increased range of motion allowed wrist function outside of the debrided area onto nearly normal cartilage. Removing hardware that is in the joint will also increase patient satisfaction. Also, this study involved a typical-for-hand-surgery population cohort—fewer than a dozen patients. Larger studies would be needed to convince me of the efficacy of the procedure, and they would need to have a treatment arm, such as osteotomy and/or arthroscopic release, with which to compare this offbeat technique.

Pin Care: What Should We Be Doing?

**SUMMARY**
Pin-site problems with external fixation, including infections, have been reported to occur at >40% of pin sites. However, surgeons still do not have a standard approach to pin care in an effort to reduce complications. The authors of this study reviewed data for fifty-six consecutive patients with a total of 204 external fixation pins that had been in place for a minimum of two weeks...
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SUMMARY
The diagnostic utility of manual stress views or gravity stress views in the context of isolated lateral malleolus ankle fractures remains in dispute. The authors of this study attempted to address the controversy with regard to the management of “stress-positive” ankle fractures that otherwise have a well-aligned mortise on standard radiographs. Patients with an isolated fibular fracture and a reduced talus underwent stress examination in the emergency room. Fractures were defined as stress-positive if there was talar subluxation, widening of the medial clear space of >4 mm, or medial widening to a width that was 1 mm more than that of the superior joint space. Ankles were reduced and immobilized in a cast, and treatment was discussed with the patients. Patients treated operatively underwent fibular fixation and syndesmotic testing via the Cotton test and/or external rotation stress test, with one or more screws placed in the event of a positive test. A blinded observer measured the medial clear space on radiographs at the initial stress test, postreduction, as well as at the time of osseous union. These data were used to compare the results among nonoperative, syndesmosis-stable operative, and syndesmosis-unstable operative groups.

A total of 114 patients were retrospectively included in the study; fifty-four had received definitive treatment with a cast, and sixty had undergone operative fixation. In the operative group, thirty-three patients (55%) were initially found to have a stable...
Hip replacement has shifted towards a younger, more active patient demographic with increased expectations. This has created a need for long-term implant bearing performance. In recent years, metal-on-metal hip constructs experienced increasing levels of adoption, peaking at 37% of US total hip procedures in 2007. However, this articular surface combination has declined to minimal usage due to concerns related to metal ion release. Surgeons are now showing a preference for highly crosslinked polyethylene (HXPE) liners, often in combination with a ceramic ball head, for their younger patients. First introduced in the 1990s, some HXPE liners demonstrated promising wear properties through the first decade of in vivo use. Zimmer’s Longevity® and Durasul® remelted highly crosslinked polyethylene (HXPE) hip implants have delivered predicted ultra-low in vivo wear at 12 years follow up in a six center study led by Massachusetts General Hospital. Nevertheless, recent studies have shown the potential for in vivo oxidation, which can affect long-term performance. The performance in the second and third decade of use is not known. Following years of research and development, Zimmer has addressed in vivo oxidation with a proprietary method of grafting (locking) Vitamin E to HXPE that prevents oxidation. The result is Vivacit-E Vitamin E Highly Crosslinked Polyethylene, a polyethylene hip liner that delivers on the critical performance characteristics of polyethylene.

- Exceptional oxidative stability
- Ultra-low wear
- Improved strength

Why Antioxidant Polyethylene?

Foundation of Antioxidant-Stabilized Polyethylene

Oxidative stability is one of the primary drivers of long-term polyethylene clinical performance. Irreversible and progressive oxidation occurs when free radicals created during irradiation crosslinking or in vivo cyclic loading during normal activity come in contact with oxygen. The oxidation process results in decreased mechanical properties and increased wear. Preventing oxidation requires the quenching of free radicals before they can react with oxygen. The antioxidant activity of Vitamin E (alpha-tocopherol) is due to hydrogen donation from the hydroxyl (OH) group on the chroman ring to a free radical on the polyethylene chain as shown in Figure 1. This reaction quenches the free radical and eliminates its ability to react with oxygen.
Processing Vitamin E Polyethylene for Optimized Performance

Blending vs. Soaking
There are two common methods used to incorporate Vitamin E into Ultra High Molecular Weight Polyethylene (UHMWPE). The first method is called “soaked” and the second method is called “blended.”

Zimmer researched the soaking method, but determined it did not provide the best outcomes. Blending involves mixing Vitamin E into polyethylene powder prior to compression molding. These blocks containing Vitamin E are then irradiation crosslinked. Since the Vitamin E is combined with the starting powder, a very uniform distribution of Vitamin E throughout the polyethylene can be achieved.

Grafting: Permanent Bonding of Vitamin E to Polyethylene
Zimmer’s proprietary process efficiently grafts (locks) 75-90% of the Vitamin E to the polyethylene with covalent bonds, or the chemical link of two atoms through the sharing of electrons. A high level of grafting ensures that the optimal concentration of Vitamin E will be retained in the liner to prevent oxidation.18,19 Grafting is accomplished through high dose warm e-beam irradiation with Vitamin E present in the polyethylene. Research by Massachusetts General Hospital demonstrates a significant increase in the percentage of grafted Vitamin E through warm versus cold irradiation as shown in Figure 2.14

Exceptional Oxidative Stability
Vivacit-E HXPE Prevents Oxidation and Maintains Performance Properties after Extended Accelerated Aging
The exceptional oxidative stability of Vivacit-E HXPE was proven through aggressive accelerated aging testing. Vivacit-E HXPE underwent accelerated aging in pure oxygen under high temperature and pressure in accordance with ASTM F2003.8 This extreme aging is intended to force oxygen into the material and induce oxidation. The percent retention of tensile strength for unaged and aged samples of Vivacit-E HXPE, remelted HXPE and gamma-irradiated conventional polyethylene is shown in Figure 3. As can be seen in this graph, gamma-irradiated conventional polyethylene dramatically decreases in tensile strength after four weeks of accelerated aging. As expected, there is a significant delay in mechanical property degradation of the remelted HXPE as compared to gamma-irradiated conventional polyethylene. Vivacit-E HXPE exhibits a negligible decrease in tensile strength after 24 weeks of aggressive aging and no measurable oxidation. This test proves that the Vitamin E in Vivacit-E HXPE actively and continuously prevents oxidation during extreme oxidative challenge.8

Figure 2. Increased Vitamin E grafting of warm irradiated Vitamin E HXPE over cold irradiated Vitamin E HXPE.14

Figure 3. Retention of tensile strength at each aging interval per material.8
Prevents Oxidation-Inducing Lipid Absorption
Highly crosslinked polyethylenes were developed to maintain long-term oxidative stability on the shelf and in vivo. Recent retrieval studies are showing signs of oxidation in HXPE materials that were originally thought to be permanently stabilized.\(^3\)-\(^6\)

Figure 4 shows the oxidation of a four year old annealed retrieval with a maximum Oxidation Index above 1.\(^4\) Oxidation Index values greater than 1.5 have been correlated to the loss of mechanical properties, which may lead to fatigue damage in vivo.\(^21\)

Vivacit-E HXPE absorbs significantly less lipid-rich fluid than gamma-irradiated conventional polyethylene and remelted HXPE. The exact mechanism by which Vitamin E reduces fluid absorption is not well understood, but is most likely due to Vitamin E occupying free volume in the polyethylene that reduces the space that can be occupied by lipids. Since the Vitamin E in Vivacit-E HXPE is grafted to the polymer after irradiation, it is resistant to displacement by the lipid environment.\(^22\) Figure 5 shows the oxidation due to lipid absorption of gamma-irradiated conventional polyethylene, remelted HXPE and Vivacit-E HXPE as a function of time.

Ultra –Low Wear
The predecessor to Vivacit-E HXPE, Longevity HXPE, demonstrates ultra-low wear performance clinically and in simulator testing. Vivacit-E HXPE has the same effective e-beam irradiation dose as Longevity HXPE to obtain similar crosslink density and wear performance. Vivacit-E HXPE showed a 96% reduction in wear compared to gamma-irradiated conventional polyethylene (Figure 6) and comparable wear to clinically proven Longevity HXPE in standard 5 million cycle wear simulator testing.\(^2,9\)-\(^11\) To prove the long-term ultra-low wear properties of Vivacit-E HXPE, a 45 million cycle wear test was run (Figure 7). The test proved Vivacit-E HXPE has very low wear even after long-term simulator testing.\(^23\)
ImprovedStrength

The remelting process in Longevity HXPE is designed to provide oxidative stability, but results in a slight reduction of mechanical strength. Since Vivacit-E HXPE is stabilized with Vitamin E and not remelted, it retains the strength of gamma-irradiated conventional polyethylene as shown in Figures 8 and 9. Due to the continuous prevention of oxidative aging, the strength of Vivacit-E HXPE is maintained even after extreme accelerated aging.8, 12, 13

Conclusion

The increased utilization of total hip arthroplasty on a younger patient population requires the orthopedic industry to develop implants that are designed for long-term performance. To meet this need, Vivacit-E HXPE was developed to be Zimmer’s longest-lasting and most durable polyethylene hip liner. Vivacit-E HXPE delivers on the three critical performance criteria of polyethylene: oxidative stability, wear and mechanical strength, without compromise.

References:
1. National Inpatient Sample, Hospital Cost and Utilization Project, Agency for Healthcare Research and Quality, US DHH.

Note: Bench testing is not necessarily indicative of clinical performance.

Note: Zimmer, Vivacit-E, Longevity and Durasul are trademarks of Zimmer, Inc.

X3 is a trademark of Howmedica Osteonics Corp, (Stryker)
Intraoperative Comminution of the Lateral Wall When Treating Trochanteric Proximal Femoral Fractures May Not Adversely Affect Outcome

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SUMMARY

In this study, 165 patients from South Korea with a trochanteric proximal femoral fracture with an intact lateral wall preoperatively were treated with medullary nailing and evaluated for the incidence of intraoperative lateral wall comminution and its effect on the outcome. Thirty-six patients (22%) sustained a lateral wall fracture, and two (6%) of those fractures settled into an unacceptable position. This is compared with fracture settling in two (2%) of the 129 patients (78% of the series) with no comminution of the lateral wall. The difference was not statistically significant. The authors concluded that lateral wall comminution is relatively uncommon and not usually of great clinical relevance even if it does occur because settling occurred at almost the same rate with and without lateral wall comminution in their study.

DISCUSSION

Although lateral wall comminution of trochanteric proximal femoral fractures is thought to have a destabilizing effect and lead to poor results, there is not a lot of data in the literature to support this contention. The importance of lateral wall comminution is clinically relevant because many treatment decisions (for example, nail versus plate, type of plate, and activity status decisions)...
What Is the Difference Between Tibial Malrotation and Normal Rotation in Terms of Function After Intramedullary Nailing?

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SUMMARY
The authors of this study used validated functional outcome measures to evaluate patients with tibial malrotation after locked intramedullary nailing (IMN). The authors hypothesized that tibial malrotation would lead to impaired functional outcomes. They identified patients with a unilateral tibial shaft fracture who had undergone IMN during a four-year period and scheduled them for a single clinic visit. Assessment was done with axial computed tomography (CT) and goniometric measurement of tibial rotation. Functional outcomes were assessed with the Lower Extremity Functional Scale (LEFS), Olerud-Molander ankle score, and six-minute walk test.

Complete data were gathered for seventy patients with a mean age of 37.1 years at the time of injury. Of these patients, twenty-nine (41%) were identified as having tibial malrotation, which was defined as a difference of ≥10° in comparison with the rotation of the contralateral limb on CT scans. More specifically, twenty-four patients presented with external rotation deformity and five presented with internal rotation deformity, ranging from 32.8° to 14.6°, respectively. A mean difference of 1.8 points on the LEFS in favor of patients with normal rotation (70.8 points in the malrotation group versus 72.6 points in the normal rotation group, p = 0.41) was noted. The results of the Olerud-Molander ankle score and six-minute walk test also were not statistically significant. After stratification according to sex, no significant difference between the two groups for the three functional tests was reported. A comparison of the CT scans and clinical measurements revealed a kappa value of 0.29 (p = 0.84).

The authors concluded that adult patients who have ≥10° of tibial malrotation following locked IMN for the treatment of tibial shaft fractures have no intermediate-term difference in functional outcomes when compared with patients with normal rotation.

DISCUSSION
The strengths of this study include its methodology and overall structure. It is one of the few studies whose authors assessed tibial malrotation in the intermediate term with validated functional outcome measures and CT scans. The effect of “malrotation” of a tibial fracture has not been well documented, as its intraoperative and clinical assessment is challenging.

An interesting detail in this paper is the kappa value for the comparison between the goniometry measurements and CT scans: 0.29. This highlights the importance of finding cost-effective alternatives for measuring immediate postoperative tibial rotation in this patient population.

The conclusion that malrotation of ≥10° was not clinically important was based on the use of the LEFS. A difference in the LEFS score of 9 points between patients with and those without tibial malrotation was considered to be clinically important. Binkley et al. evaluated scale development, measurement properties, and clinical application of the LEFS and found that the minimal detectable change (MDC) was 9 points (90% confidence interval [CI]) (Phys Ther. 1999 Apr;79[4]:371-83). They also found that 9 scale points (90% CI) was the minimal clinically important difference (MCID). One of the limitations of that study was that the LEFS was used for 107 patients with a wide range of orthopaedic conditions, from ligament strain to osteoarthritis, and only eight (7%) had a fracture of a lower limb. No record of malrotation was noted in this latter group of patients. The validity of applying the LEFS to this trauma population is not clear. It is also possible that the instrument, even if valid to apply to this injury, is not sensitive for determining deficits from malrotation. A scale that assesses higher function (i.e., sports, running, or heavy work) might identify differences between the groups.
Physiologic tibial torsion asymmetry of 0° to 14° has been reported (J Bone Joint Surg Br. 1980 May;62[2]:238-42), so some malrotation can be tolerated. In the study by Theriault et al., only six patients had >20° of malrotation. The authors did not compare this “malrotated” (>20°) group with the “normal” (<10°) group. With only six patients with >20° of malrotation, there would be a risk for a type-II error that would be corrected only by increasing the number of patients with malrotation. Although this study was well done, we believe that the conclusions overstate the data. At some point, malrotation can and will be a problem. Surgeons should continue to attempt to recreate normal tibial torsion after stabilization of a tibial shaft fracture. If malrotation is noticed by the surgeon or patient, the surgeon should assess the degree of rotation and symptoms prior to deciding that no intervention is warranted.

Displaced Femoral Neck Fractures in the Elderly

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REVIEW

The strengths of the study by Chammout et al. include its randomized controlled design, long-term follow-up duration of seventeen years, and intention-to-treat analysis. The authors did a great job reviewing the current literature, and their results support published data. They concluded that total hip arthroplasty (THA) provides better hip function and is followed by significantly fewer reoperations compared with open reduction and internal fixation (ORIF) without increasing mortality in healthy elderly patients with a displaced femoral neck fracture. Several aspects of the management of femoral neck fractures need to be considered. They include the success rate of THA versus hemiarthroplasty (HA) and of HA versus ORIF, surgeon experience, and patient factors that allow a surgeon to differentiate treatment for the spectrum of patients, ranging from those who are older than seventy-five years, are nonambulatory, have multiple comorbidities, and are cognitively impaired to healthy, active patients who are older than sixty years but younger than seventy-five years.

Parker et al. compared HA and ORIF for displaced intracapsular hip fractures in the elderly and found that the ORIF group had a shorter duration of anesthesia, less blood loss, and lower transfusion requirements. However, ninety of the 160 patients in the ORIF group required, in total, an additional 111 procedures compared with only fifteen additional operations for twelve of the 163 patients in the HA group. The authors also showed that ORIF is associated with less initial trauma and therefore has a tendency to reduce mortality in the elderly (older than ninety years) and cognitively impaired population.

Keating et al. reviewed the functional outcomes and clinical parameters of three alternatives (THA, HA, and ORIF) for the management of femoral neck fractures in a randomized study of previously healthy mobile patients. They found poor outcomes in the ORIF group, which showed a high rate of revision, especially in the younger patients (sixty to seventy years old). However, less marked differences were found between the THA and HA groups, with the former showing superior functional outcomes at two years. A concern about this study has been that less experienced surgeons performed the ORIF.

Several studies have compared the function of patients who underwent THA with the function of those who underwent HA. Blomfeldt et al. compared the results of bipolar HA with those of THA for displaced intracapsular fractures of the femoral neck in elderly patients and found that, although the surgical time and estimated blood loss were higher for THA, THA provided better function than bipolar HA one year postoperatively, without an increase in the complication or mortality rate. Although the aforementioned study had a follow-up duration of only one year, several studies have shown the same results after a longer period of follow-up. Baker et al. found that, at the time of final follow-up (three years), the walking distance in the HA group, compared with preinjury ambulatory status, had decreased significantly whereas it had increased in the THA group. Although both groups had higher Oxford hip scores and lower Short Form-36 scores postoperatively, the THA group had fewer complications.

Surgeon experience also plays an important role in patient outcomes. Rehnberg and Olerud compared different techniques for the treatment of 222 patients with a mean age of eighty years and found that the experience of the surgeon predicted a better implant position (p = 0.084). Although the finding was not statistically significant, surgeon experience is an important factor for consideration in any therapeutic intervention. Another study showed that experienced surgeons had shorter operating room
times, better reduction, better implant position, and fewer patient complications. Small statistical differences have been found in several studies, indicating that surgeon experience does have an effect on patient outcome. However, the statistical significance of experience is far less in comparison with the effect of other variables.

Patient demographics and activity status are important characteristics when deciding on definitive treatment for a displaced femoral neck fracture. Older patients with multiple comorbidities and a short life expectancy are less likely to benefit from THA and more likely to benefit from unipolar HA. Randomized trials have shown that unipolar HA is the treatment of choice for patients who are cognitively impaired and for those with limited mobility.

With an aging population, consideration must be given to being selective when it comes to managing patients with a displaced femoral neck fracture. The type of surgical management, age of the patient, surgeon experience, and most importantly, preinjury activity status should be looked at carefully and acknowledged during preoperative planning. Understanding the complications and possibilities for repeat intervention as well as the physiology of the patient is the key to a successful long-term outcome in the management of femoral neck fractures in the elderly.

Studies have demonstrated improved outcomes for older patients with a femoral neck fracture treated with THA as compared with those who have undergone HA. Acceptance of THA as the definitive answer for an older patient with a femoral neck fracture should be tempered by considering surgeon experience, patient physiology, and functional level. Large multicenter prospective studies are necessary to determine which patient population is best managed with what operation and by which surgeon.

REFERENCES


