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Preventing Early Femoral Failures in Hip Resurfacing:
Outcomes of a Risk-Stratification Protocol in 5117 Cases

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Abstract:	Background: Early femoral failures remain the most common early failure mode following hip resurfacing arthroplasty. This study evaluates the effectiveness of a fracture prevention protocol incorporating antiresorptive medication and protected weight-bearing therapy based on identified risk factors. Methods: A fracture prevention protocol was initiated in March 2010 based on preoperative femoral neck T-scores and BMI. High-risk patients received alendronate for one year and followed a 10-week protected weight bearing regimen. Intermediate- and moderate-risk patients received alendronate for six months without altered weight bearing. The control cohort (n=528) included untreated patients prior to March 2010. Results: Across all groups, early femoral failures were reduced from 1.5% to 0.2% (p<0.0001). High-risk patients showed the largest reduction (20% to 1.8%, p=0.03). Intermediate-risk patients improved from 2.1% to 0.2% (p=0.0002). A statistically significant reduction was not observed in the moderate-risk group (0.8% to 0.2%, p=0.12). Conclusion: The implementation of a fracture prevention protocol based on T-score and BMI significantly reduced early femoral failures after hip resurfacing. While alendronate has been effective in high- and moderate-risk populations, alternate strategies are under consideration for groups where benefit was not statistically confirmed. These findings support tailoring perioperative care to optimize outcomes.

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Introduction

Metal-on-metal (MoM) hip resurfacing arthroplasty (HRA) is a bone-sparing alternative to traditional total hip replacement (THR) that offers superior functional outcomes (1-9), greater durability in young patients (10-17), and reduced 10-year all-cause mortality (18-20) when compared to THR. THR can be complicated by periprosthetic femoral fractures in the early postoperative period; HRA does not present this risk, but it does come with its own unique set of potential early femoral complications, including femoral neck fracture (FNF) or early femoral head collapse (EHC). Understanding and mitigating these early femoral failures (EFF) is essential to maximizing the longevity and outcomes of HRA.

Following HRA, EFFs remain one of the most common early failure modes. EFFs are defined as acute fractures of the neck within 6 months of surgery or gradual collapse of the head within 2 years of surgery. We suggest these two distinct failure modes both represent biological failures of the proximal femur, instigated primarily by compromised bone integrity rather than issues with implant design. We previously identified risk factors for EFF (21) and demonstrated that the rate of EFF could be reduced significantly in the highest risk group (22). Building on these findings, we expanded our EFF-prevention protocol to include moderate-risk groups. We now report on the outcomes of our complete fracture prevention protocol, including both the high- and moderate-risk groups.

Acute FNFs, defined as fractures occurring within the first 6-months postoperative, can occur from minimal or no trauma. In available published reports, the incidence of FNF varies between 0-4% (23-29), with our own data indicating a rate of 1.5% (21). Suspected risk factors include patient age, weight, sex, bone quality, varus femoral stem position, and intraoperative notching. Additionally, delayed EHCs, which present as gradual shifts in component position between 6 months and 2 years postoperative, are often misattributed to osteonecrosis, but these instead may result from stress fractures at the head-neck junction (28). We consider EFF to encompass both acute FNFs and delayed EHCs within the first 2 years, differentiating them from late femoral loosening.

Several potential factors contribute to EFF. Femoral vascularity is inherently disrupted by surgical exposure and head resection required for HRA. Further, the presence of the implant redistributes mechanical forces within the proximal femoral bone, decreasing forces to some regions while increasing stresses to areas that previously were exposed to lower stresses. This combination can lead to localized bone resorption, stress redistribution, and microdamage, which can precipitate EFFs. This risk is further influenced by postoperative bone resorption, which occurs for about 3 months postoperatively and then returns to baseline at 6 months (30, 31), potentially weakening the bone precisely when the patient is increasing their post-operative activity levels.

This current study is our third in a series of studies aimed at understanding the risks for EFF and to decrease the incidence of biological failures of the proximal femur. Some reports have implicated technical factors as causative, such as femoral notching, varus stem position, and leaving reamed femoral bone uncovered. Others have implicated biological factors, such as femoral head cysts, increased age, and female sex as risk factors (27, 28, 32). In our first study of EFF (21), we analyzed the effects of bone mineral density in the femoral neck (T-score), patient sex, diagnosis, body mass index (BMI), femoral implant fixation type, age, and femoral component size on EFF in 373 cases. A multivariate analysis identified only low bone density in the femoral neck (T-score < 0) and BMI >29 as risk factors. Sex and age were dependent variables, while bone density was found to be the independent primary risk factor. In our second study in the series on EFF prevention (33), we implemented a targeted intervention for the highest-risk patients (T-score <-1.5), combining antiresorptive therapy (alendronate) with a staged weight-bearing (WB) protocol. This approach reduced EFF rates in this group from 10% to 0%. Encouraged by these findings, we subsequently expanded the protocol to include moderate-risk patients, recognizing that statistical validation would be more challenging given the lower baseline EFF incidence in this group. This expanded fracture prevention protocol has been in place since March 2010.

Herein, we present the outcomes of this comprehensive approach, comparing EFF rates in our treated study cohort to an untreated historical control group, with a goal to further clarify and reduce the risk of EFFs in HRA patients.

Methods

The senior author (TPG) routinely performs HRA on all patients with severe degenerative arthritis who have enough acetabular and femoral bone stock to allow this operation. As our results have improved with surgeon experience and improved perioperative protocols, we have expanded indications to include nearly all age groups as well as cases with greater bone deficiency of the head and socket. In our practice, females have never been excluded from HRA. Expanding our indications for resurfacing has led to higher risk cases (osteoporosis, increased age, large femoral defects from cysts or osteonecrosis) being included in our HRA group over time.

We started using the Biomet Magnum-ReCap™ implants for all HRA cases in 2005 (34). In 2007, we switched to uncemented femoral fixation in all cases (35). All implants in this study were Biomet Magnum-ReCap™, and all surgeries were performed utilizing the posterior, minimally-invasive capsular sparing approach (36).

In July 2006, we began routinely testing femoral neck bone density on all patients preoperatively with Dual Energy X-ray Absorptiometry (DEXA) scans. In September 2008 we started our first intervention to attempt to decrease risk of EFF in the highest risk group. Therefore, the control group for this study includes all 528 cases between these dates, as well as untreated moderate risk cases between 2008 and the implementation of the complete protocol **(**Table 1**)** in March 2010. All cases were included until August 2023. All EFF were included, but any patients lost to follow-up before 2 years postoperative were excluded.

We define our study groups in Table 1. The low-risk group (Group 1) was comprised of cases with a T-score $\geq$ 0 and BMI < 30. For these cases modifications to the standard recovery protocol were made Patients were allowed to bear weight as tolerated and typically use crutches for 1-2 weeks followed by a cane for 1-2 weeks. They were advised to gradually advance walking distance to 1 mile by 6 weeks. They were cautioned to avoid impact sports, lifting more than 50 pounds, or fall-risk activities (ex. bike, ladder, ice) for 6 months. Virtually unrestricted activity is resumed at that time; running and heavy lifting is encouraged. Extreme activities such as slide tackling in soccer, ski jumping, martial arts competition, and rock climbing were discouraged until one

year. The intermediate-risk group (Group 2) had a T-score between 0 and -1.5 and a BMI < 30. They followed a similar protocol as Group 1 but with alendronate prescribed for 6 months postoperative. The moderate-risk group (Group 3), which is defined by T-score > -1.5 and BMI ≥ 30, were also put on 6 months of alendronate with no other changes from the standard postoperative protocol.

The high-risk group (Group 4) is defined by T-score ≤ -1.5 and BMI < 30. This group follows a protected weight bearing protocol for 10 weeks and takes alendronate for 1 year. At 6 months they are also released to unrestricted activity. The highest-risk group (Group 5), defined by T-score ≤ -1.5 and BMI ≥ 30, also follows the same postoperative protocol as Group 4.

All statistical analyses were performed using the XLSTAT (Addinsoft, New York, NY) at a 95% confidence interval. We identified significant differences between group means using paired, 2-tailed Student's t-test and between rates using two-sample proportion Z-tests.

Results

The overall rate of EFF for the entire resurfacing cohort was reduced from 1.5% to 0.2% (p<0.0001) following the implementation of a selective program of protected ambulation and antiresorptive medication (Table 1).

The greatest reduction in EFF was observed in the highest-risk patients (Group 5). In this group, rate of EFF dropped from 20% to 1.8% (p=0.03), confirming our previous report that EFF could be reduced in the highest-risk group (33). Further, EFF was reduced in the high-risk group (Group 4) from 9.7% to 0.2% (p<0.0001).

For patients in the moderate-risk group (Group 3), we observed a reduction in EFF rate from 0.8% to 0.2%; however, this did not reach statistical significance (p=0.12). In the intermediate-risk group (Group 2), EFF rate dropped from 2.1% to 0.2%, which did constitute a statistically significant reduction (p=0.0002). In the low-risk group (Group 1), EFF remained low (0.1%) but did not show a significant reduction.

Discussion

Early studies of HRA and registry data have identified greater age, female sex, dysplasia, osteonecrosis, and smaller implant size as risk factors for a higher failure rate (25, 37-41). Lower bone density, which is more prevalent among women and older adults, may partially explain the higher failure rate previously reported in these groups. We hypothesized that bone density is a principal determinant of EFF, but unlikely that it would influence other failure modes such as failure of bone in growth, loosening, infection, or wear failures. We further hypothesized that all failure modes would have different risk factors and would require different strategies to reduce their occurrence. Therefore, we investigated EFF separately. We decided to measure bone density preoperatively in all patients and then evaluate all available demographic factors in our database to determine what the risk factors might be. Our initial study demonstrated that BMI>29 and a decreasing T-score were the two factors that were significant. When bone density was measured, age and sex became dependent variables that were in themselves no longer important.

In addition, it has been hypothesized that technical factors such as varus stem position, an intraoperative notch in the femoral neck, or leaving reamed bone uncovered by the implant may be factors. The senior author has never created an intraoperative notch; therefore, its effect could not be assessed. Of the control group, 0.6% had varus stems, but none of these developed EFF, so the effect of a varus stem could also not be determined. The concept of leaving reamed bone uncovered is so vague and difficult to define that we could not evaluate it. It does seem logical that seating the femoral component too high on the head by either not resecting enough off of the apex or by leaving too much cement under the apex would be problematic and we recommend avoiding this. But we cannot provide evidence for this.

This study confirms that EFF in HRA can be significantly reduced through a targeted approach to bone density management. Our findings extend previous work, demonstrating effective risk reduction not only in high-risk patients but also in moderate-risk groups. By focusing on bone density and BMI, we have achieved an overall

reduction in the EFF rate from 1.5% to 0.2%, which is now below the early risk of periprosthetic fracture in

THR in our practice (0.5%) (21, 22).

Risk of EFF was significantly reduced for both high-risk groups (Groups 4 and 5) and intermediate-risk group

(Group 2). However, we were unable to show a statistically significant improvement for the moderate risk

group (Group 3) which had a BMI $\geq$ 30 and T-score > -1.5. Their risk of EFF dropped from 0.8% to 0.2%

(p=0.12), but this was not found to be statistically significant. This group received the same treatment the

intermediate-risk Group 2 for 6 months. Because we did not show statistically significant improvement, we will

no longer recommend alendronate in this group. Future steps to consider in minimizing EFF in this group could

include adding protected weight bearing for 10 weeks.

Although our risk of EFF in hip resurfacing is well below the risk of periprosthetic fracture in THR, we are still

looking to further reduce EFF using other strategies. Prolia seems to be another promising alternative for two

reasons. As soon as the 6-month injection is given, compliance is assured. Also, this drug does not cause reflux

or esophagitis as alendronate frequently does and it is a five-fold better antiresorptive drug. The problem is that

this drug costs nearly $2000 currently in the US and its use for preventing perioperative fracture is not covered

by most insurance companies.

This study has several notable limitations. The first is that this is a retrospective analysis of a single-surgeon

cohort, potentially limiting generalizability to all surgical settings. Further, this surgeon performs a high-volume

of resurfacing cases per year, further limiting reproducibility. Next, patient adherence to alendronate was not

independently verified. Lastly, as the femoral preservation protocol treatments were implemented

simultaneously, the contribution of each in the minimization of EFF cannot be identified from this study. A

randomized controlled trial would be needed to isolate which individual elements of the protocol contributed

most to these outcomes.

Conclusion

Our findings suggest EFFs in hip resurfacing is a treatable biological process. This includes acute FNFs within 6 months postoperative and progressive EHC occurring between 6 and 24 months postoperative. In the largest single-surgeon series to date, systematic DEXA-based risk stratification combined with targeted alendronate therapy and staged weight-bearing reduced EFFs from 1.5% to 0.2%. Importantly, when bone density was considered, neither female sex nor advanced age increased EFF risk. sex and age are dependent factors that do not influence the outcome – going against concerns that have historically limited access to HRA for these groups. Further, this study suggests low bone density also is not a reason for exclusion, if it is managed appropriately. In this cohort, HRA shows lower risk of periprosthetic fracture than registry-reported THR (41, 42) when a fracture prevention protocol incorporating antiresorptive medication and protect weight-bearing is implemented for at-risk groups. This data provides strong evidence that EFFs can be anticipated and mitigated, and that following a risk-stratification protocol can expand candidacy for HRA.

Abbreviations

1. MoM – metal-on-metal
2. HRA – hip resurfacing arthroplasty
3. THR – total hip replacement
4. FNF – femoral neck fracture
5. EHC – early femoral head collapse
6. EFF – early femoral failure
7. BMI – body mass index

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Conflicts of Interest

Funding

Data Availability

Data free of patient identifying information is available upon request from the corresponding author.

Tables

Table 1. Fracture Prevention Protocol

Group	Definition	Treatment
Group 1 (Low-risk)	Femoral neck (FN) T-score $\geq$ 0 and BMI < 30	No precautions
Group 2 (Intermediate-risk)	0 > FN T-score > -1.5, BMI < 30	Alendronate for 6 months
Group 3 (Moderate-risk)	BMI $\geq$ 30, T-score > -1.5	Alendronate for 6 months
Group 4 (High-risk)	T-score $\leq$ -1.5, BMI < 30	Protected weight-bearing for 10 weeks; alendronate for 12 months
Group 5 (Highest-risk)	T-score $\leq$ -1.5, BMI $\geq$ 30	Protected weight-bearing for 10 weeks; alendronate for 12 months

Table 2. Rate of EFF by Group

CONTROL	G1	G2	G3	G4	G5	OVERALL

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Total	115	141	236	31	5	528
%	21.8%	26.7%	44.7%	5.9%	0.9%	-
# EFF	0	3	2	3	1	8
% EFF	0.0%	2.1%	0.8%	9.7%	20.0%	1.5%
STUDY	**G1**	**G2**	**G3**	**G4**	**G5**	**OVERALL**
Total	1431	1830	1334	465	57	5117
%	28.0%	35.8%	26.1%	9.1%	1.1%	-
# EFF	1	4	3	1	1	9
% EFF	0.1%	0.2%	0.2%	0.2%	1.8%	0.2%
p-value	0.78	**0.0002***	0.12	**<0.0001***	**0.03***	**<0.0001***

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