



CLINICAL ARTICLE

Efficiency of Zoledronic Acid in Inhibiting Accelerated Periprosthetic Bone Loss After Cementless Total Hip Arthroplasty in Osteoporotic Patients: A Prospective, Cohort Study

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Objective: To investigate the influence of preoperative osteopenia/osteoporosis on periprosthetic bone loss after total hip arthroplasty (THA) and the efficiency of zoledronate (ZOL) treatment in periprosthetic bone preservation.

Methods: This multicenter, prospective cohort study was conducted in four centers between April 2015 and October 2017. Patients were assigned to Normal BMD, Osteopenia, and Osteoporosis+ZOL groups. Patients with osteopenia received daily oral calcium (600 mg/d) and vitamin D (0.5 µg/d), while patients in the Osteoporosis+ZOL group received additional ZOL annually (5 mg/year). Periprosthetic bone mineral density (BMD) in seven Gruen zones, radiographic parameters, Harris hip score, EuroQol 5-Dimensions (EQ-5D) score, and BMD in hip and spine were measured within 7 days, 3 months, 12 months postoperation and annually thereafter.

Results: A total of 266 patients were enrolled, while 81 patients that completed the first year follow-up were involved in the statistical analysis. The mean follow-up time was 1.3 years. There were significant decreases of mean BMD in total Gruen zones (-4.55% , $P < 0.05$) and Gruen zone 1 (-10.22% , $P < 0.01$) in patients with osteopenia during the first postoperative year. Patients in the Osteoporosis+ZOL group experienced a marked increase in BMD in Gruen zone 1 (+16%) at the first postoperative year, which had a significant difference when compared with the Normal BMD group ($P < 0.05$) and the Osteopenia Group ($P < 0.001$). Low preoperative BMD in hip and spine was predictive of bone loss in Gruen zone 1 at 12 months after THA in patients with normal BMD ($R^2 = 0.40$, $P < 0.05$).

Conclusions: Patients with osteopenia are prone to higher bone loss in the proximal femur after cementless total hip arthroplasty (THA). ZOL, not solely calcium and vitamin D, could prevent the accelerated periprosthetic bone loss after THA in patients with osteopenia and osteoporosis.

Key words: bone mineral density; periprosthetic bone remodeling; total hip arthroplasty; zoledronate

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Disclosure: Guang-tao Fu, Li-jun Lin, Pu-yi Sheng, Chang-chuan Li, Jin-xin Zhang, Jun Shen, Sheng Liu, Yun-lian Xue, Si-peng Lin, Kun Wang, Qiu-jian Zheng, and Yue Ding declare that they have no financial or personal relationships with other people or organizations that could inappropriately influence our work. There is no professional or other personal interest of any nature or kind in any product, service, and/or company that could be construed as influencing the position presented in, or the review of, the manuscript.

Received 5 April 2019; accepted 10 July 2019

Introduction

Total hip arthroplasty (THA) is the most effective and widely used therapy for end-stage hip disease. From 2000 and 2010, over 310 000 total hip replacements were performed among inpatients aged 45 and over in the USA annually¹. With the improvement in surgical technique and implant design, it has been proposed that the demand for THA in 2030 will grow by 134% from the level in 2012². However, the long-term functional outcome of THA is greatly limited by aseptic loosening. The aseptic loosening rate was reported to be 2.3%–7.4% at 10 years postoperation^{3–5} and approximately 16% at 20 years postoperation⁶. Total hip revision (THR) is the only established surgical treatment for aseptic loosening to date. However, it has been reported that the re-revision rate was approximately 14% at 5 years after the primary THR⁷. As the average age of patients undergoing primary THA is 53.5 to 63 years old⁸, substantial numbers of patients experience several THR, which is associated with not only high medical cost and surgical risk but also unsatisfactory functional outcome. Further exploration of the pathophysiology of aseptic loosening and the development of new treatment strategies are needed.

It has been proposed that patient-related factors are closely related to aseptic loosening⁹. Patients being patients and specific genetic backgrounds were closely related to enhanced periprosthetic bone loss^{10,11}. Osteoporosis is one of the most common disorders in patients undergoing THA; individuals with osteopenia and osteoporosis make up nearly 60% of patients¹². It was recently reported that low bone mineral density (BMD) contributed to advanced implant migration in the early stage after THA, accompanied with worse initial stability and delayed osseointegration^{13,14}. However, whether patients with osteopenia or osteoporosis would experience accelerated postoperative periprosthetic bone loss and have a higher risk of aseptic loosening is still unclear. The efficiency of zoledronate (ZOL), the most widely used anti-osteoporosis agent, in the prevention of postoperative periprosthetic bone loss also remains unclear. Thus, the aim of the present study was to investigate the influence of preoperative osteopenia/osteoporosis on postoperative periprosthetic bone remodeling and the efficiency of ZOL treatment in periprosthetic bone preservation in osteoporotic patients after THA.

Materials and Methods

Study Design and Setting

Patients aged 40–75 years old undergoing unilateral primary cementless THA due to femoral neck fracture, hip osteoarthritis, femoral head necrosis or developmental dysplasia of the hip between April 2015 and October 2017 were considered for enrollment. We excluded those patients with: (i) malnutrition (MNA-SF score ≤ 11)¹⁵; (ii) secondary osteoporosis; (iii) previous surgical history of the operated femur; (iv) history of anti-osteoporosis agents administration; (v) severe cardiopulmonary and renal function impairment;

(vi) inflammatory arthritis; and (vii) known sensitivity to bisphosphonates.

This multicenter, prospective cohort study was conducted in the Orthopedic Department of Sun Yat-sen Memorial Hospital, Sun Yat-sen University in collaboration with the Orthopedic Department of the Third Affiliated Hospital of Sun Yat-sen University, Guangdong Provincial People's Hospital, and Zhujiang Hospital of Southern Medical University. The study was conducted in accordance with the ethical principles of the Declaration of Helsinki and was approved by the institutional review board of Sun Yat-sen Memorial Hospital, Sun Yat-sen University. The study has been registered in the Chinese Clinical Trial Registry Center (ChiCTR-IPR-15006922). Signed informed consent was obtained from all study patients.

Patients enrolled were assigned to Normal BMD, Osteopenia, and Osteoporosis+ZOL groups according to the T value in hip and spine measured by dual-energy X-ray absorptiometry (DEXA, LUNAR DPXMD#5966, Madison, WI, USA) 1 week before the surgery. A patient was classified as osteopenic with a T value between -1 and -2.5 in any of the aforementioned sites. Correspondingly, a patient with a T value less than -2.5 or with a history of fragility fracture was classified as osteoporotic. For men less than 50 years old and premenopausal women, osteopenia was defined as when the Z-value was less than -2.0 . No intervention was given to patients with normal BMD. Patients with osteopenia received daily oral Caltrate D 600 (600 mg, Pfizer Pharma, USA) and Rocaltrol (0.25 μg , Roche Pharma, Switzerland) during the follow up, while patients in the Osteoporosis+ZOL group received additional Aclasta (5 mg/year, intravenous infusion, Novartis Pharma, Switzerland)¹⁶. The first time administration of ZOL was performed 1 week after the surgery. Thereafter, patients were requested to return to the clinic and received ZOL administration annually. Drug compliance of oral calcium and vitamin D was measured *via* telephone follow up by a qualified staff member from our department. Periprosthetic BMD in seven Gruen zones and radiographic parameters were measured within 7 days, 3 months, and 12 months postoperation, and annually thereafter. To assess functional disability, Harris hip score, EuroQol 5-Dimensions (EQ-5D) score, and BMD in hip and spine were also recorded at each visit. The study protocol is shown in Fig. 1.

Surgery

All operations were performed by one of the four experienced arthroplasty surgeons (YD, QJZ, LJL, or KW). A standard posterolateral surgical approach was used. The femoral prosthesis used in the present study included the Ribbed Stem (Waldemar Link GmbH, Germany), the Summit Stem (Johnson & Johnson, USA), and the Novation Stem (Exactech, USA). The acetabular and femoral component were inserted using a press-fit technique. Partial weight bearing was required 1 week after THA, and full weight bearing was allowed 2 weeks after THA.

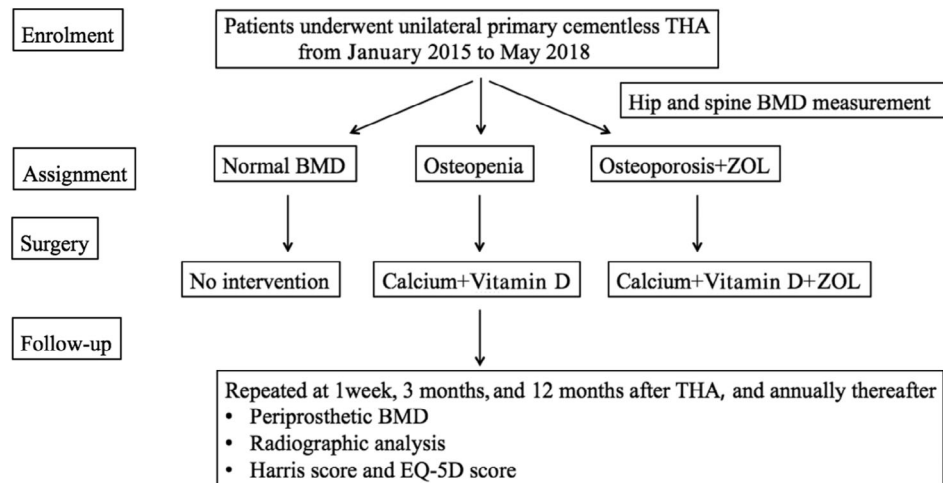


Fig. 1 Study design diagram.

Dual-energy X-ray Absorptiometry Measurements

Systematic BMD was measured by dual-energy X-ray absorptiometry (DEXA, LUNAR DPXMD#5966, Madison, WI, USA) at the lumbar spine (from L₁ to L₄) and proximal femurs. Periprosthetic BMD of the seven femoral region Gruen zones were analyzed by DEXA and associated software according to the analysis protocol recommended by Gruen¹⁷. Briefly, periprosthetic BMD was divided into seven regions of interest and BMD of zones 1 to 7 were also combined to form a mean total periprosthetic BMD (total Gruen

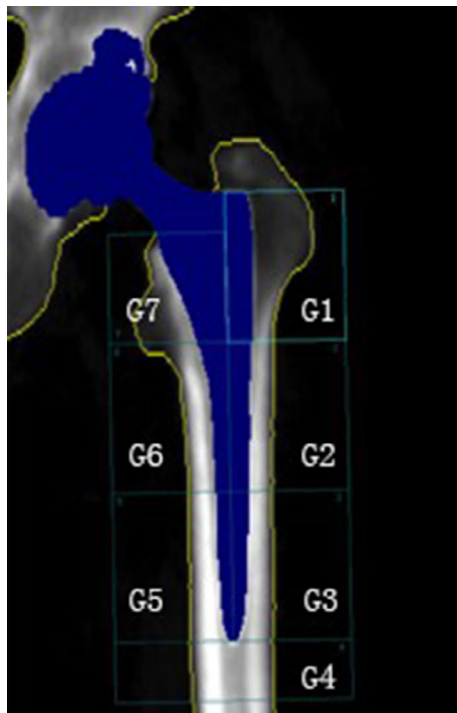


Fig. 2 Gruen zones used in dual-energy X-ray absorptiometry (DEXA) analysis of periprosthetic bone mineral density (BMD).

zone) (Fig. 2). During successive DEXA scans, the patient's leg was positioned in a standard neutral rotation using a supporting device. In the present study, the mean least significant change (LSC) of hip, spine, and periprosthetic Gruen zones is $0.017 \pm 0.013 \text{ g/cm}^2$, $0.007 \pm 0.005 \text{ g/cm}^2$, and $0.012 \pm 0.015 \text{ g/cm}^2$, respectively.

Radiographic Evaluation of Acetabular and Femoral Component Migration

Cup Inclination and Anteversion

The orientation of the acetabular component is defined in terms of cup inclination and anteversion, which ultimately influence the clinical outcomes, such as stability, impingement, and implant survival. Cup inclination was measured as the angle subtended by the face of the cup and by the inter-teardrop line. Cup anteversion was determined using the method recommended by Pradhan¹⁸.

Horizontal and Vertical Distance of the Hip Center

Migration of the cup component is measured by the changes of horizontal and vertical distance of the hip center during the follow up, which is the risk factor of aseptic loosening. The horizontal and vertical distance of the hip center was determined using the radiographic technique described by Harris¹⁹.

Inferior Displacement of the Femoral Stem

Migration of the femoral component is defined as the inferior displacement of the femoral stem; namely, the change in the distance between the tip of the greater trochanter and the inter-teardrop line during the follow-up²⁰. An anteroposterior radiograph of the pelvis with both hips in neutral rotation and 0° abduction was taken for radiographic analysis.

Statistics Analysis

All quantitative data were presented as mean \pm standard deviation (SD). Multiple comparisons of changes in periprosthetic BMD between different time points were analyzed using analysis of variance for repeated measurements with Bonferroni's correction. One-way analysis of variance (ANOVA) was used for the comparisons of mean change from baseline of periprosthetic BMD and radiographic parameters among Normal BMD, Osteopenia, and Osteoporosis+ZOL groups. Fisher's protected least significant difference test was used for *post hoc* comparison. The difference between ratios was analyzed *via* Pearson nonparametric χ^2 -test and Fisher exact test. The lowest preoperative BMD in hip and spine were analyzed for the value as a predictor for BMD changes of Gruen zone 1 in the first postoperative year by using a linear model with the calculation of the coefficients of determination (R^2) in patients with normal BMD. Subgroup analyses were performed for age, sex, and femoral stem design. A *P*-value of <0.05 was considered to be significant. SPSS 20.0 (SPSS Headquarters, Chicago, IL, USA) and SAS 9.4 (SAS Institute Cary, NC, USA) were used to carry out the statistical analysis.

Results

Demographic Data

A total of 266 patients (93 male and 173 female) were enrolled between April 2015 and October 2017. Cases were not included in the statistical analysis until the integrity of the data and drug compliance were confirmed. After excluding unqualified cases, 81 patients (37 male and 44 female) completed the first year follow up at the time that the manuscript was drafted and the mean follow-up time was 1.3 years. No patient was lost to the follow up. According to the preoperative hip and spine BMD measurement, 21 patients were classified into the Normal BMD group

(13 male and 8 female, with a mean age of 52.8 years) and 43 patients (19 male and 24 female, with a mean age of 60.2 years) into the Osteopenia group, while the remaining 17 patients (5 males and 12 females, with a mean age of 63.9 years) were defined included in the Osteoporosis+ZOL group. There was no significant difference in sex, height, weight, BMI, and type of femoral stem among the three groups. Patients in the Osteoporosis+ZOL group had significantly higher mean age than those in the other two groups. Demographic data are given in Table 1.

Clinical Outcome

No wound complications, periprosthetic infection, or periprosthetic fracture was observed during the follow up. None of the patients showed radiographic signs of component loosening or periprosthetic osteolysis. There was no significant change of the BMD in hip and spine during the follow-up in all three groups (Fig. 3A,B). All the patients experienced significant improvement in Harris score and EQ-5D score at 12 months after THA (Fig. 3C,D). No fragility fracture was observed in patients with normal BMD or osteopenia during the follow-up.

Changes of the Periprosthetic Bone Mineral Density

There were significant decreases in mean BMD in total Gruen zones (-4.55% , $P < 0.05$, Fig. 4H) and Gruen zone 1 (-10.22% , $P < 0.01$, Fig. 4A) in patients with osteopenia during the first postoperative year, while no significant difference was found in the Normal BMD and Osteoporosis+ZOL groups (Fig. 4). In regard to the comparisons of mean change from baseline, patients with osteopenia showed a greater bone loss in Gruen zone 1 than patients with normal systemic BMD at 12 months after THA (-10.22% *vs* -2.38%), without reaching a significant level. Patients in the Osteoporosis+ZOL group experienced a marked increase of BMD in Gruen zone 1 at the first postoperative year ($+16\%$),

TABLE 1 Demographic data (mean \pm SD)

| Patient characteristics | Normal BMD (N = 21) | Osteopenia (N = 43) | Osteoporosis + ZOL (N = 17) | P |
|--------------------------|---------------------|---------------------|-----------------------------|-------------|
| Sex | | | | |
| Male | 13 | 19 | 5 | NS |
| Female | 8 | 24 | 12 | |
| Age (years) | 52.8 \pm 12.1 | 60.2 \pm 11.4 | 63.9 \pm 12.12 | $P = 0.012$ |
| Weight (kg) | 64.86 \pm 11.28 | 65.16 \pm 12.49 | 62.88 \pm 7.44 | NS |
| Height (cm) | 165.95 \pm 7.28 | 166.95 \pm 9.55 | 162.41 \pm 6.94 | NS |
| BMI (kg/m ²) | 23.47 \pm 3.19 | 23.26 \pm 3.47 | 23.91 \pm 3.00 | NS |
| Femoral component design | | | | |
| Ribbed stem | 8 | 29 | 10 | NS |
| Novation stem | 4 | 4 | 4 | |
| Summit stem | 9 | 10 | 3 | |
| Diagnosis | | | | |
| Femoral head necrosis | 17 | 31 | 10 | / |
| Femoral neck fracture | 2 | 6 | 3 | |
| Hip joint osteoarthritis | 1 | 4 | 3 | |
| DDH | 1 | 2 | 1 | |

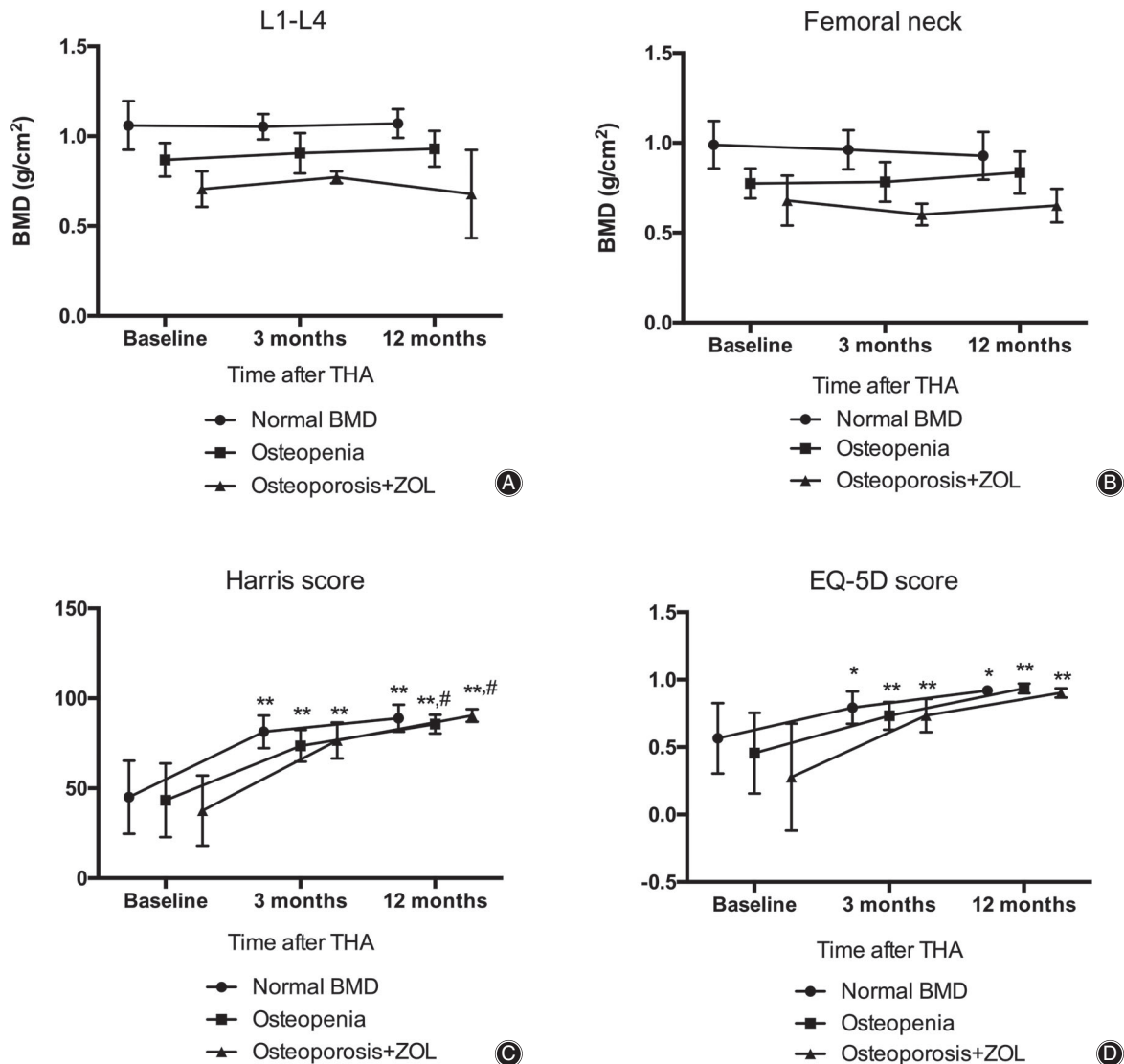


Fig. 3 (A, B) Comparison of the hip and spine bone mineral density (BMD), (C) Harris score, and (D) EuroQol 5-dimensions (EQ-5D) score during the follow-up in all three groups. * indicates $P < 0.05$ and ** indicates $P < 0.01$ when compared with the baseline. # indicates $P < 0.05$ when compared with the former time point.

which had significant difference when compared with the Normal BMD group ($P < 0.05$) and the Osteopenia Group ($P < 0.001$) (Fig. 5). Illustrated by subgroup analyses, female patients and those who used Novation Stem in the osteoporosis+ZOL group showed higher increase of BMD in Gruen zone 1 at the first postoperative year, but they did not reach significant difference (Fig. 6). Linear regression analysis illustrated that low preoperative BMD in hip and spine was predictive of bone loss in Gruen zone 1 at 12 months after THA in patients with normal BMD ($R^2 = 0.40$, $P < 0.05$, Fig. 7).

Changes of Radiographic Parameters

Significant changes of cup inclination (-10.87% , $P < 0.01$, Fig. 8B), horizontal distance of hip center (-10.85% , $P < 0.01$,

Fig. 8D), and vertical distance of hip center (-19.85% , $P < 0.001$, Fig. 8E) were observed in patients with osteopenia during the first postoperative year, while no significant difference was found in the Normal BMD and Osteoporosis+ZOL groups (Fig. 8). There was no significant difference of the cup anteversion and inferior displacement of the femoral stem during the follow up in all three groups (Fig. 8).

Discussion

The present study showed that there were significant decreases in total Gruen zones and Gruen zone 1 during the first 12 months after THA in patients with osteopenia, and low preoperative BMD in hip and spine was shown to be predictive of adverse postoperative bone loss in Gruen

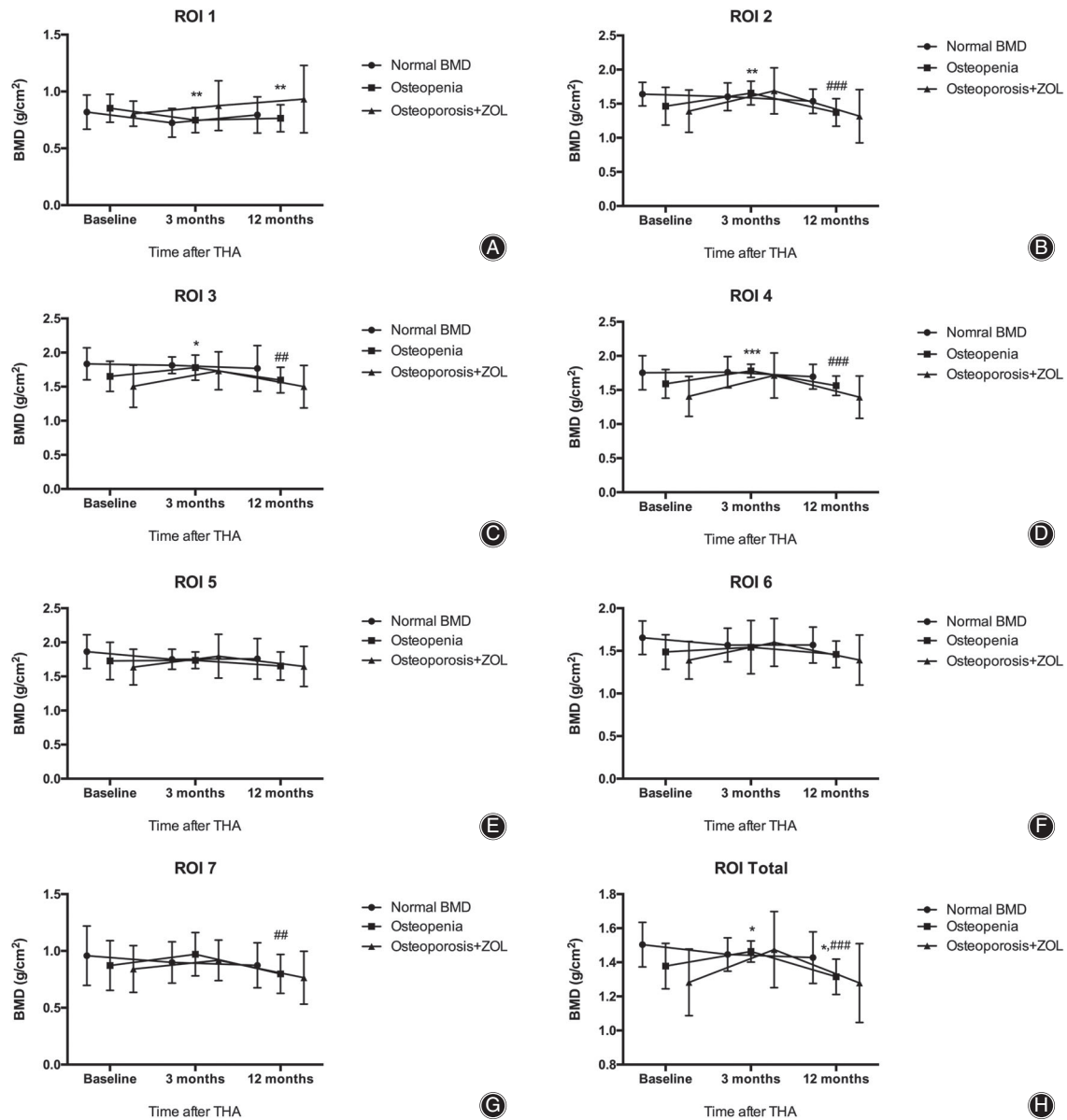


Fig. 4 (A–H) Comparison of the periprosthetic bone mineral density (BMD) in seven Gruen zones during the follow up in all three groups. * indicated $P < 0.05$, ** indicated $P < 0.01$, and *** indicated $P < 0.001$ when compared with the baseline. ## indicated $P < 0.01$ and ### indicated $P < 0.001$ when compared with the former time point.

zone 1 in patients with normal BMD ($R^2 = 0.4$). As the mean changes of BMD in total Gruen zones (-0.063 g/cm^2) and Gruen zone 1 (-0.087 g/cm^2) were larger than the LSC (0.012 g/cm^2), we believe that our results represent a real biological change²¹.

The few studies that have investigated the relationship between preoperative BMD in hip/spine and postoperative periprosthetic bone have obtained similar results to ours. Rahmy *et al.* found that preoperative spine, total hip, and total radius BMD were independent factors in predicting the

postoperative bone loss in Gruen zone 1²². It was also found that low preoperative systemic BMD was associated with higher bone loss in Gruen zone 7 ($R^2 = 0.15$, $P = 0.02$)²³. Patients with normal bone showed less bone loss than osteopenic patients in Gruen zone 1 without reaching a significant level (-5.4% vs -10.5%)²⁴. However, those aforementioned studies did not examine the changes in systematic BMD during the follow up, which we suggested to be one of their limitations. It was reported that systematic BMD decreases with age in both men and women after

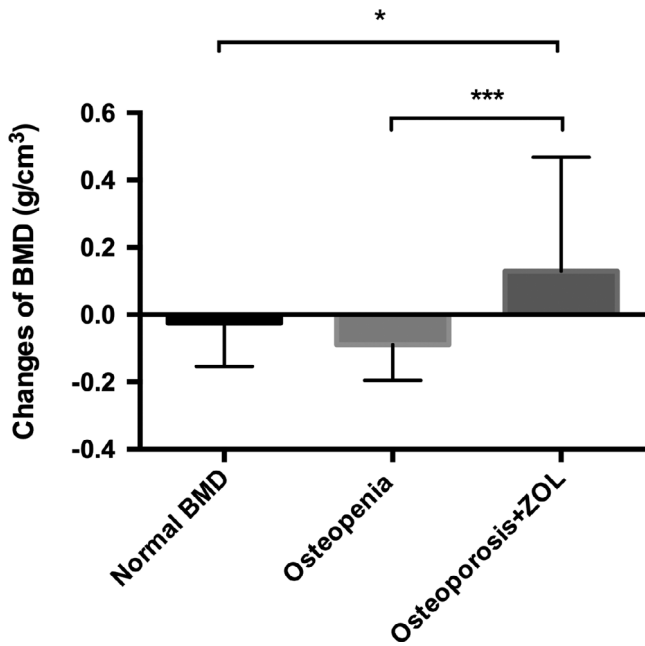


Fig. 5 Comparison of mean change from baseline in Gruen zone 1 among the three groups. * indicated $P < 0.05$ and *** indicated $P < 0.001$ when compared with the Osteoporosis+ ZOL group.

reaching the peak, with the largest decline rate of $-0.0038 \text{ g}\cdot\text{cm}^{-2}\cdot\text{year}^{25}$, which indicated that the influence of normal aging-related BMD changes on periprosthetic bone loss during the follow-up should not be underestimated. In the present study, changes of the BMD in hip and spine were minimal and no significant difference was found during the follow-up. Consequently, we proposed that the influence of aging-related bone change was limited in the present study. Taken together, we suggested that patients with osteopenia are prone to higher bone loss in the proximal femur in the early stage after cementless THA. Patients with low BMD in hip and spine but who have not yet been classified as having osteopenia or osteoporosis also need close follow up, as low preoperative BMD in hip and spine was a predictor of adverse postoperative bone loss in Gruen zone 1.

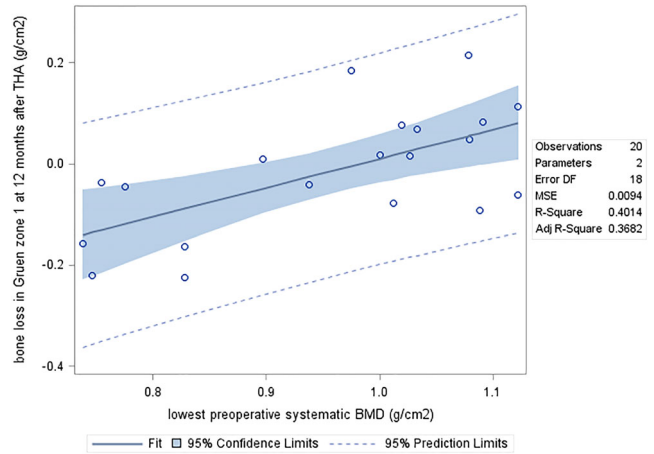


Fig. 7 Linear regression (with 95% confidence intervals) analysis in patients with normal systematic bone mineral density (BMD) ($n = 20$) demonstrated the significant association ($R^2 = 0.40$, $P < 0.05$) between the lowest preoperative systemic BMD and mean change from baseline in Gruen zone 1 at 12 months after total hip arthroplasty (THA).

Zoledronate is a widely used third-generation bisphosphonate, which has been proven to be a useful anti-resorptive agent for osteoporosis *via* the suppression of the activity of the osteoclasts^{26,27}. As osteoporotic patients are associated with high-risk fractures and calcium and vitamin D supplementation alone have been demonstrated to not effectively increase BMD in hips²⁸, creating an osteoporosis group with only calcium and vitamin D was rejected by the institutional review board of our hospital.

Oral bisphosphonates given daily or weekly for varying durations have been proven to have long-term effects in the preservation of periprosthetic BMD after joint arthroplasty²⁹. However, only two studies have investigated the efficiency of ZOL, the most widely used intravenous bisphosphonate, in patients with normal BMD on a small scale^{30,31}. Both studies obtained similar results and found that the administration of ZOL efficiently prevented periprosthetic bone loss, especially in proximal femurs (Gruen zone 1: +1.39% and + 3%) in the first year after THA^{30,31}. In accordance with previous studies, results of the present

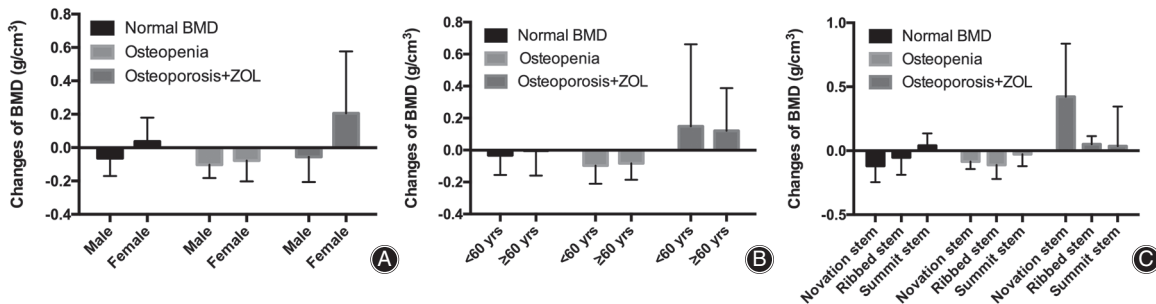


Fig. 6 Subgroup analyses performed for age, sex, and femoral stem design.

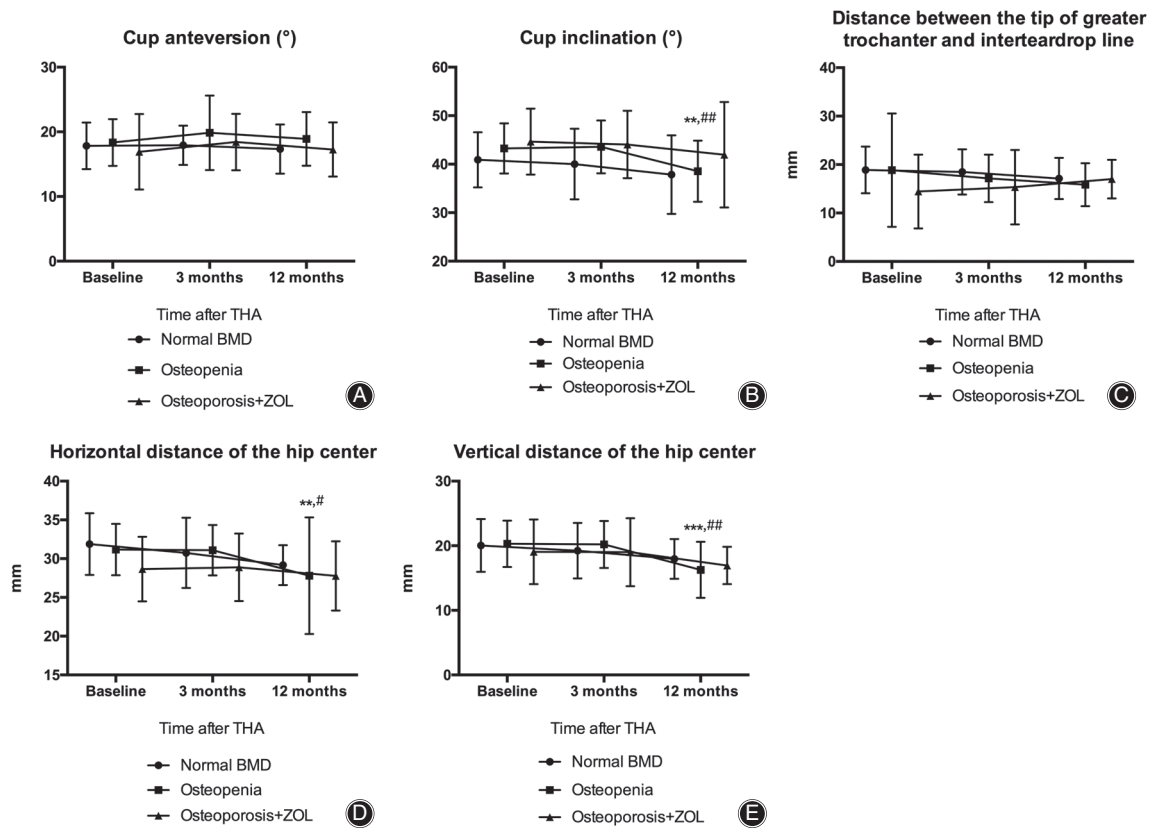


Fig. 8 Comparison of the radiographic findings at each visit in all three groups. ** indicated $P < 0.01$ and *** indicated $P < 0.001$ when compared with the baseline. # indicated $P < 0.05$ and ## indicated $P < 0.01$ when compared with the former time point.

study showed that patients in the Osteoporosis+ZOL group experienced a marked increase of BMD in Gruen zone 1 at the first postoperative year, which had a significant difference when compared with the Normal BMD group and the Osteopenia Group. In addition, it was reported that ZOL showed promise in improving initial fixation of cementless THA, with significantly decreased stem subsidence when compared to the placebo group³². Illustrated by subgroup analyses, female patients and those who used Novation stem in the osteoporosis+ZOL group seemed to benefit more from ZOL administration. However, further larger-scale studies are needed with to draw this conclusion.

As mentioned above, solely calcium and vitamin supplementation could not effectively prevent periprosthetic bone loss in Gruen zone 1 after THA in osteopenic patients. As the stress shielding and consequent bone remodeling is the dominant reason for early stage periprosthetic bone loss³³, we proposed that the effect of calcium and vitamin supplementation might be limited in implant-related bone loss. Taken together, we suggested that ZOL, not solely calcium and vitamin D, could prevent the accelerated periprosthetic bone loss after THA in patients with osteopenia and osteoporosis.

This study was subjected to some limitations. First, it includes a relatively short follow-up period. Nonetheless, the findings are compelling and consistent with previous reports. Shown by long-term longitudinal studies, there was a trend of continued decrease in periprosthetic BMD, but the bone loss was most evident in the first postoperative year and the change was minimal thereafter^{34,35}. It was also proposed that the changes in the first year were more clinically relevant, as the initial periprosthetic bone remodeling process was mainly completed in the first 12 postoperative months^{36,37}. Thus, 1–2 years is generally considered an adequate follow up for the evaluation of early-stage periprosthetic bone remodeling³⁰. However, we acknowledge that further studies with prolonged follow-up period are needed. Second, three different femoral implants were used in this study. It was reported that postoperative periprosthetic bone loss varies for different femoral stem designs³⁵. As there was no significant difference of proportion in the three femoral stems among all three groups, we proposed that the bias caused by different implant designs was limited in the present study. The potential bias caused by different diagnosis and BMI has not been discussed extensively in the present study, and stratified analysis with matched age, sex, BMI, diagnosis, and

implant will be performed in future studies. Third, some data for certain patients was missed during the follow up (shown in Appendix I), but the main outcome measures, namely, the periprosthetic BMD at baseline and at 12 months after THA, were complete.

Conclusions

Patients with osteopenia are prone to higher bone loss in the proximal femur in the early stage after cementless THA. Patients with low BMD in hip and spine but who have not yet been classified as having osteopenia or osteoporosis also need close follow up. ZOL, not solely calcium and

vitamin D, could prevent the accelerated periprosthetic bone loss after THA in patients with osteopenia and osteoporosis.

Acknowledgments

This work was supported by the National Natural Science Foundation of China (81672186), the Provincial Science and Technology Project of Science and Technology Department of Guangdong Province (2014B020212004), the Sun Yat-sen Clinical Research Cultivating Program (SYS-2015005), and the 5010 Program of Sun Yat-sen University (2018006).

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Appendix***Number of participants with complete data at each visit***

| Parameters | Baseline (n) | 3 months (n) | 12 months (n) | |
|--|------------------|--------------|---------------|----|
| Gruen zones | | | | |
| 1 | Normal BMD | 21 | 13 | 21 |
| | Osteopenia | 43 | 14 | 43 |
| | Osteoporosis+ZOL | 17 | 6 | 17 |
| 2 | Normal BMD | 21 | 13 | 21 |
| | Osteopenia | 43 | 14 | 43 |
| | Osteoporosis+ZOL | 17 | 6 | 17 |
| 3 | Normal BMD | 21 | 13 | 21 |
| | Osteopenia | 43 | 14 | 43 |
| | Osteoporosis+ZOL | 17 | 6 | 17 |
| 4 | Normal BMD | 21 | 13 | 21 |
| | Osteopenia | 43 | 14 | 43 |
| | Osteoporosis+ZOL | 17 | 6 | 17 |
| 5 | Normal BMD | 21 | 13 | 21 |
| | Osteopenia | 43 | 14 | 43 |
| | Osteoporosis+ZOL | 17 | 6 | 17 |
| 6 | Normal BMD | 21 | 13 | 21 |
| | Osteopenia | 43 | 14 | 43 |
| | Osteoporosis+ZOL | 17 | 6 | 17 |
| 7 | Normal BMD | 21 | 13 | 21 |
| | Osteopenia | 43 | 14 | 43 |
| | Osteoporosis+ZOL | 17 | 6 | 17 |
| Total | Normal BMD | 21 | 13 | 21 |
| | Osteopenia | 43 | 13 | 43 |
| | Osteoporosis+ZOL | 17 | 6 | 17 |
| PA spine BMD | | | | |
| | Normal BMD | 17 | 8 | 14 |
| | Osteopenia | 41 | 11 | 13 |
| | Osteoporosis+ZOL | 16 | 5 | 7 |
| Femoral neck BMD | | | | |
| | Normal BMD | 21 | 11 | 13 |
| | Osteopenia | 43 | 11 | 13 |
| | Osteoporosis+ZOL | 17 | 4 | 6 |
| Harris score | | | | |
| | Normal BMD | 21 | 20 | 14 |
| | Osteopenia | 43 | 39 | 14 |
| | Osteoporosis+ZOL | 17 | 16 | 7 |
| EQ-5D score | | | | |
| | Normal BMD | 12 | 11 | 5 |
| | Osteopenia | 33 | 30 | 5 |
| | Osteoporosis+ZOL | 14 | 13 | 4 |
| Cup anteversion | | | | |
| | Normal BMD | 15 | 13 | 13 |
| | Osteopenia | 13 | 14 | 14 |
| | Osteoporosis+ZOL | 7 | 6 | 7 |
| Cup inclination | | | | |
| | Normal BMD | 21 | 19 | 13 |
| | Osteopenia | 42 | 43 | 15 |
| | Osteoporosis+ZOL | 17 | 16 | 7 |
| Distance between the tip of greater trochanter and interteardrop line | | | | |
| | Normal BMD | 21 | 19 | 13 |
| | Osteopenia | 42 | 43 | 15 |
| | Osteoporosis+ZOL | 16 | 16 | 7 |
| Centre of rotation- horizontal | | | | |
| | Normal BMD | 21 | 19 | 13 |
| | Osteopenia | 42 | 43 | 15 |
| | Osteoporosis+ZOL | 17 | 16 | 7 |
| Centre of rotation- vertical | | | | |
| | Normal BMD | 21 | 19 | 13 |
| | Osteopenia | 42 | 43 | 15 |
| | Osteoporosis+ZOL | 17 | 16 | 7 |