Geriatrics, Gerontology and Aging

SCIENTIFIC JOURNAL OF Sociedade Brasileira de Geriatria e Gerontologia

OPEN ACCESS PEER-REVIEWED

ARTIGO DE REVISAO

Can be the cement augmentation an improvement method of preventing hip fractures in osteoporotic patients?

Pode ser a cimentoplastia um método aprimorado para a prevenção de fraturas do quadril em pacientes osteoporóticos?

Anderson Freitas[a]; George Neri[a]; Silvio Leite de Macedo Neto[a]; João Lindolfo Cunha Borges[b]; Ana Patrícia de Paula[c]

ABSTRACT

INTRODUCTION: The population around the world is aging. With this, there will be an increased incidence of fractures due to osteoporosis of the hip and this will be a serious global health problem. A World Health Organization (WHO) estimate suggests that the incidence of hip osteoporotic fractures worldwide will triple by 2050.

OBJECTIVE: To present, through a literature review, the main results of the femoral reinforcement, a technique described by scientific articles, with the potential to increase the proximal femoral load for the occurrence of fractures, whether using polymethylmethacrylate (PMMA), phosphate cement calcium (CPC), (j elastomers and metal implants.

METHODS: Through electronic search in databases PubMed, Latin American and Caribbean Center of Health Information Information (Bireme), Coordination for the Improvement of Higher Education Personnel (Capes), Scientific Electronic Library Online (SciELO), Google Scholar And Cochrane, using the terms cementoplasty and femororplasty, the studies were selected according to a specific inclusion criterion, describing the main findings of the biomechanical results, type of study and material used to perform the femoral reinforcement.

RESULTS: Of the 15 articles analyzed, 14 were experimental analyzes and one was a clinical trial,

seven studies used PMMA, two used CPC, four elastomers and two metal implants, 13 of them showed favorable Newton load (N) results for the fracture hip.
CONCLUSION: Most of the studies on femoral reinforcement is experimental, and mostly used the PMMA, presenting an increase in the load in N for fracture occurrence.

Keywords: polymethyl methacrylate; hip fractures; osteoporosis; hip.

RESUMO

INTRODUÇÃO: A população em todo o mundo está envelhecendo. Com isso, haverá aumento da incidência de fraturas por osteoporose do quadril e esse será um grave problema de saúde mundial. Uma previsão da Organização Mundial de Saúde (OMS) mostra que a incidência de fraturas osteoporóticas do quadril em todo o mundo triplicará até o ano 2050.
OBJETIVO: Apresentar por meio de revisão da literatura os principais resultados do reforço femoral, técnica descrita por artigos científicos, com potencial de incrementar a carga do fêmur proximal para a ocorrência de fraturas, seja com uso de polimetilmetacrilato (PMMA), cimento fosfato de cálcio (CPC), elastômeros ou implantes metálicos.
MÉTODOS: Por meio de busca eletrônica nas bases de dados PubMed, Latin American and Caribbean Center of Health Science Information (Bireme), Coordination for the Improvement of Higher Education Personnel (Capes), Scientific Electronic Library Online (SciELO), Google Scholar and Cochrane, utilizando os termos *Cementoplasty* e *femororplasty*, foram selecionados os trabalhos respeitando um critério de inclusão específico, descrevendo os principais achados dos resultados biomecânicos, o tipo de estudo e o material utilizado na realização do reforço femoral.
RESULTADOS: Dos 15 artigos analisados, 14 são análises experimentais e um é ensaio clínico, sete estudos utilizaram PMMA, dois usaram CPC, quatro elastômeros e dois implantes metálicos, 13 deles mostram resultados favoráveis na carga em Newton (N) para a ocorrência da fratura do quadril.
CONCLUSÃO: A maioria dos estudos sobre reforço femoral é experimental e em sua maioria utilizou o PMMA, apresentando incremento da carga em N para a ocorrência de fratura.

Palavras-chave: polimetil metacrilato; fraturas do quadril; osteoporose; quadril.

INTRODUCTION

Twenty-two million women and 5.5 million men in the European Union (EU) were diagnosed with osteoporosis in 2010. There were 3.5 million new fractures due to osteoporosis occurring that year, and 610,000 of them were fractures in the hip region.[1]

The World Health Organization (WHO) predicts that the incidence of osteoporotic fractures of the hip will triple by 2050.[1,2] In the population under 65 years old, the incidence of femoral neck fractures is two to four cases per 10,000 inhabitants. However, the incidence increases in the population above 70 years old, being of 28/10,000 in men and 64/10,000 in women. It is estimated that in 2050 there will occur 6.3 million fractures of the hip due to osteoporosis, a number three times greater than the current one, half of those fractures will happen only in Asia.[2]

This situation is very concerning, not just in the health point of view, but also economically, since the treatment of these fractures is a very expensive procedure, combining to antibiotics, analgesics and time of hospitalization, and still the mortality rates are very high. The annual cost in the United

States related to the treatment of osteoporotic fractures is US$ 20 billion, and the contribution of hip fractures in this cost is above 60%.[1-3]

About 1.5% of all hospital beds in Europe are occupied by patients being treated for osteoporotic fractures, and the cost for treating these fractures is € 37 billion, being expected to increase 25% by 2025.[1]

Mortality rate due to the fracture of the proximal femur out of osteoporosis reaches 30% in the first year after surgery. Patients with this type of fracture are at risk of up to 30% to suffer a new fracture in the contralateral hip within two years after the first fracture, and this rate may increase after five years.[4] In cases of non-simultaneous contralateral hip fracture, the mortality rate can reach 64% in men and 58% in women.[5]

Since the hip fracture is, of all osteoporotic fractures, the one with highest morbidity and mortality and the highest cost, we need to find associations, or even new methods to prevent with more efficiency this type of fracture.[1,3-5]

Several methods have been applied in order to reduce the risk of fracture of the proximal femoral end due to osteoporosis, such as home care, multidisciplinary treatments, and use of hip protectors, although the most frequent measure is the use of medicines.[1,6]

Care measures for patients with osteoporosis in the EU have had very significant results, with multidisciplinary techniques that are capable of reducing about 80% occurrences of new fractures. However, when we look at the effectiveness of these interventions in preventing new fractures in the hip region, the figure is approximately 40%. This same number is found regarding the use of medicines to prevent hip fractures, besides the undesirable consequences of its use, as significant side effects, adverse effects in long-term use, contraindications and high cost, happening in 50% of the patients.[3,6,7]

Analogous to vertebroplasty, cement-augmentation of the proximal femur, femoroplasty, can reinforce osteoporotic bones.[8] This procedure is still not yet very much used and stimulated by orthopedic society, but most of the studies about this method are *in vitro*, and there it has proven to reduce the risk of hip fractures, and should not be underestimated.

Cement augmentation is described in various ways, using several products, but the experimental uses of polymethylmethacrylate (PMMA) and calcium phosphate cement (CPC) have been most frequently studied.[8,9]

In consideration to the importance of this subject, the authors present a literature review related to prevention of the fractures of the hip, presenting data in order to encourage the possibility of better results with this scientific development and ensuring this big step in the change of the evolution of fractures of the proximal femur in elderly patients.

METHODS

Femoral augmentation is a surgical procedure, minimally invasive, performed percutaneously by an incision of about 1 cm in length in the lateral region of the patient's thigh. Through this incision, a metallic guide is inserted on the lateral cortex of the femur, in direction of the femoral head, through the femoral calcar, region in which the main forces of compression of the proximal femur are concentrated. This wire, introduced with fluoroscopy assistance, serves as a guide for introduction of the other instrumentals, like drills and cannulas. After the introduction of a drill, preparing the intraosseous space to be filled by "bone substitutes", a cannula is inserted through the same incision side, following the path of metallic wire and drill, by pressurizing with a syringe the prepared space which is refilled by femoral augmentation, replacing the bone portion with compromised quality by other substances and increasing the strength of the proximal femur.

The calcium phosphate based bone cements are ceramic materials, as the PMMA are acrylic materials, both having good biocompatibility due to their chemical composition similar to the bone and bioactivity, promoting osteoconduction. With these characteristics, the use of these materials as filling or bone implants is possible. The bone cements are materials consisting of a powder and a liquid which, upon mixing, form a paste that hardens spontaneously at room or body temperature.

All published articles, between the years 2004 and 2014, that were related to the prevention of osteoporotic fractures of the hip (femoral neck and intertrochanteric region) were selected from the following databases: PubMed, Latin American and Caribbean Center of Health Science Osteoporosis fracture. Can the cimentoplasty assist in prevention? Information (Bireme), Coordination for the Improvement of Higher Education Personnel (Capes), Scientific Electronic Library Online (SciELO), Google Scholar and Cochrane.

By using the words *cementoplasty* and *femoroplasty* in each of the databases, we selected all of the files and selected the papers according to the inclusion criteria.

To match the inclusion criteria, only the articles that reported or analyzed exclusively human bone reinforcement, without any focal pathology and whichever methodology or material that was used as augmentation, were selected.

After the selection of the articles included, we analyzed the specific data: study type, material used in the femoral reinforcement and the obtained results of the procedures.

RESULTS

The electronic database search showed 1,828 articles, but 1,813 of them were excluded of our study for not matching the inclusion criteria and the 15 remaining articles were selected for analysis (Table 1).

For the study type results, we found 14 experimental studies and only one clinical trial related to the subject in consideration.

The materials used in all experimental studies were cadaveric femurs with mineral density compatible with osteoporotic bones, and the augments were of many types: PMMA (seven studies),[10-16] CPC (two studies),[17,18] elastomers (four studies),[19-22] metal implants (two studies).[23,24] The metal implants were of two types, a titanium screw and a steel spiral shaped implant.

Two of the articles showed unsatisfactory results: it was used PMMA in both of them, the rise of temperature during the induration of the PMMA was indicated as a possibility of thermal injury to the bone tissue and possibly been the cause of the failure. Although one of these studies found an increase of resistance to the possibility of the fracture, using a mean volume of 36 mL,[15] the other one found no enhancement of mechanical strength, with a mean volume of 15 mL.[16]

The other papers, with favorable results, had PMMA, elastomers, CPC and metal implants as material for the femoral augmentation.

According to all the five studies using PMMA, it was proved an improvement in mechanical strength to the occurrence of the fractures. As the thought of the thermal injury occurring to the bone tissue in the indurating process, it was found that the optimization of the amount of volume of PMMA could reduce the rise of temperature and consequently shorten the possibility of a thermal lesion.[17-20] One of them even described the optimized volume, 6 mL, and the best positioning for the finite element use for the optimal mechanical result.[14]

The studies using elastomers showed an enhancement of the bone strength against the fracture occurrence. When it occurred, it happened with a minor deviation and no temperature rise was detected, avoiding consequent tissue damage.[22-24] The use of silicone showed equivalent result to the CPC group, with minimal deviation after fracture, preserving the "Caput-Collum-Diaphysis" angle.[25] In case of fracture occurrence, difficulties weren't found for elastomer removal neither treatment of the fracture with local osteosynthesis.

Using the CPC, brought a lower temperature rise in both studies, as they exposed as results the increase of mechanical resistance and a reduced possibility of thermal injury to the bone tissue.[21,23]

Both of the metal implants studies showed favorable results,[26,27] even though one of them was a clinical trial with short term follow up and with a small number of patients included, lowering its evidence value, putting in doubt its favorable result.[28]

DISCUSSION

Bone reinforcement for the hip is already present in literature descriptions for preventing fractures in focal neoplasia,[29,30] however its use in order to prevent osteoporotic fractures require clinical trials with good levels of evidence in order to validate its results, because, even with statistically validated proves of improvement in mechanical strength, most of the published articles are experimental studies.

The analysis of studies using PMMA for femoral reinforcement showed the necessity of an increased peak load to the occurrence of a fracture in values up to 33%, using augmentation volumes ranged from 6 to 40 mL. The authors using a lower volume of PMMA intended to decrease

the thermal lesion, but, in those cases, they determined an optimization of the augmentation location in the proximal femur. As negative possible outcomes, most of them described the possibility of thermal injury, a more difficult surgery for treatment in case of fracture occurrence and a chance of happening different patterns, more complex or unusual, of fracture due to the local density change.[15-20]

The results of studies using the CPC showed an increase in the peak loading to fracture occurrence in values ranging from 21 to 43%, but the augmentation volumes used of such substance weren't described, but observing the radiography images of their articles we noted that the one with best results showed a complete filling of the proximal femur, a questionable fact for its application *in vivo*. There was no significant rise of temperature during polymerization of this product, as it was not observed description of optimization in their positioning. It was not found a rise in difficulty for the treatment with osteosynthesis material in cases of fracture occurrence.[21,22]

The studies using elastomers described the need of cavity expanders for its intraosseous introduction, and there was no description of the volume used. However, observing the radiographs shown in the articles, there was a tendency to fill the entire proximal femur. There is also no description of temperature rise, since there was no polymerization in this process. The results showed no improvement of peak loading levels, although there was only minimized deviation of the fracture, comparing to the control group.[23-26]

The presentation of these results is very important to expose the need of information to develop future clinical trials, so that these results can be validated in experimental analysis.

CONCLUSION

The use of femoral reinforcement to prevent osteoporotic fractures has literary description, in most cases, exposed as experimental studies. They show a mechanical improvement of the bone for the occurrence of fractures, and this fact makes possible, and necessary, the realization of studies with better levels of evidence.

By the analysis of the most recent and subject related publications, the femoral augmentation is a successful method of preventing hip fractures in osteoporotic patients, and can be considered as a future improvement of this type of fracture prevention.

REFERENCES

1. Hernlund E, Svedbom A, Ivergård M, Compston J, Cooper C, Stenmark J, et al. Osteoporosis in the European Union: medical management, epidemiology and economic burden. Arch Osteoporos. 2013;8:136.

2. World Health Organization (WHO). Assessment of fracture risk and its application to screening for postmenopausal osteoporosis: report of a wHo study group. World Health Organ Tech Rep Ser. 1994;843:1-129.

3. Cummings SR, Melton LJ III. Epidemiology and outcomes of osteoporotic fractures. Lancet. 2002;359:1761-7.

4. Lawrence TM, Wenn R, Boulton CT, Moran CG. Age-specific incidence of first and second fractures of the hip. J Bone Joint Surg Br. 2010;92(2):258-61.

5. Ryg J, Rejnmark L, Overgaard S, Brixen K, Vestergaard P. Hip fracture patients at risk of second hip fracture: a nationwide population-based cohort study of 169,145 cases during 1977-2001. J Bone Miner Res. 2009;24(7):1299-307.

6. MacLean C, Newberry S, Maglione M, McMahon M, Ranganath V, Suttorp M, et al. Systematic review: comparative effectiveness of treatments to prevent fractures in men and women with low bone density or osteoporosis. Ann Intern Med. 2008;148(3):197-213.

7. Chevalley T, Guilley E, Herrmann FR, Hoffmeyer P, Rapin CH, Rizzoli R. Incidence of hip fracture over a 10-year period (1991-2000): reversal of a secular trend. Bone. 2007;40(5):1284-9.

8. Beckmann J, Ferguson SJ, Gebauer M, Luering C, Gasser B, Heini P Femoroplasty-augmentation of the proximal femur with a composite bone cement-feasibility, biomechanical properties and osteosynthesis potential. Med Eng Phys. 2007;29(7):755-64.

9. Basafa E, Murphy RJ, Otake Y, Kutzer MD, Belkoff SM, Mears SC, et al. Subject-specific planning of femoroplasty: an experimental verification study. J Biomech. 2015;48(1):59-64.

10. Rubenstein LZ. Falls in older people: epidemiology, risk factors and strategies for prevention. Age Ageing. 2006;35 Suppl 2:ii37-ii41.

11. Bliuc D, Alarkawi D, Nguyen TV, Eisman JA, Center JR. Risk of subsequent fractures and mortality in elderly women and men with fragility fractures with and without osteoporotic bone density: the Dubbo Osteoporosis Epidemiology Study. J Bone Miner Res. 2015;30(4):637-46.

12. Santesso N, Carrasco-Labra A, Brignardello-Petersen R. Hip protectors for preventing hip fractures in older people. The Cochrane Library. 2014 March 31 [cited April 3, 2016]. Available from: http://www.cochrane.org/CD001255/MUSKINJ_hip-protectors-for-preventing-hip-fractures-in-older-people

13. Fliri L, Sermon A, Wähnert D, Schmoelz W, Blauth M, Windolf M. Limited V-shaped cement augmentation of the proximal femur to prevent secondary hip fractures. J Biomater Appl. 2013;28(1):136-43.

14. Stern C. Hip protectors for preventing hip fractures in older people. Orthop Nurs. 2014;33(5):297.

15. Heini PF, Franz T, Fankhauser C, Gasser B, Ganz R. Femoroplasty-augmentation of mechanical properties in the osteoporotic proximal femur: a biomechanical investigation of PMMA reinforcement in cadaver bones. Clin Biomech (Bristol, Avon). 2004;19(5):506-12.

16. Sutter EG, Wall SJ, Mears SC, Belkoff SM. The effect of cement placement on augmentation of the osteoporotic proximal femur. Geriatr Orthop Surg Rehabil. 2010;1(1):22-6.

17. Beckmann J, Springorum R, Vettorazzi E, Bachmeier S, Lüring C, Tingart M, et al. Fracture prevention by femoroplasty: cement augmentation of the proximal femur. J Orthop Res. 2011;29(11):1753-8.

18. Fliri L, Sermon A, Wähnert D, Schmoelz W, Blauth M, Windolf M. Limited V-shaped cement augmentation of the proximal femur to prevent secondary hip fractures. J Biomater Appl. 2013;28(1):136-43.

19. Basafa E, Murphy RJ, Otake Y, Kutzer MD, Belkoff SM, Mears SC, et al. Subject-specific planning of femoroplasty: an experimental verification study. J Biomech. 2015;48(1):59-64.

20. Sutter EG, Mears SC, Belkoff SM. A biomechanical evaluation of femoroplasty under simulated fall conditions. J Orthop Trauma. 2010;24(2):95-9.

21. Strauss EJ, Pahk B, Kummer FJ, Egol K. Calcium phosphate cement augmentation of the femoral neck defect created after dynamic hip screw removal. J Orthop Trauma. 2007;21(5):295-300.

22. Beckmann J, Ferguson SJ, Gebauer M, Luering C, Gasser B, Heini P. Femoroplasty-augmentation of the proximal femur with a composite bone cement-feasibility, biomechanical properties and osteosynthesis potential. Med Eng Phys. 2007;29(7):755-64.

23. Lin PP, Kang HG, Kim YI, Kim JH, Kim HS. Minimally invasive surgery for femoral neck fractures using bone cement infusible hollow-perforated screw in high-risk patients with advanced cancer. Surg Oncol. 2015;24(3):226-31.

24. Kang HG, Roh YW, Kim HS. The treatment of metastasis to the femoral neck using percutaneous hollow perforated screws with cement augmentation. J Bone Joint Surg Br. 2009;91(8):1078-82.

25. Van der Steenhoven TJ, Schaasberg W, de Vries AC, Valstar ER, Nelissen RG. Cyclic loading of fractured cadaveric femurs after elastomer femoroplasty: an in vitro biomechanical study. Clin Biomech (Bristol, Avon). 2012;27(8):819-23.

26. Schaasberg W, van der Steenhoven TJ, van de Velde SK, Nelissen RG, Valstar ER. Feasibility of osteosynthesis of fractured cadaveric hips following preventive elastomer femoroplasty. Clin Biomech (Bristol, Avon). 2014;29(7):742-6.

27. Springorum HR, Gebauer M, Mehrl A, Stark O, Craiovan B, Püschel K, et al. Fracture prevention by prophylactic femoroplasty of the proximal femur-metallic compared with cemented augmentation. J Orthop Trauma. 2014;28(7):403-9.

28. Giannini S, Luciani D, Chiarello E, Cadossi M, Tedesco G, Hoque M. Osteosynthetic improvement of osteoporotic bone: prevention surgery. Clin Cases Miner Bone Metab. 2011;8(1):51-4.

29. van der Steenhoven TJ, Schaasberg W, de Vries AC, Valstar ER, Nelissen RG. Augmentation with silicone stabilizes proximal femur fractures: an in vitro biomechanical study. Clin Biomech (Bristol, Avon). 2009;24(3):286-90.

30. van der Steenhoven TJ, Schaasberg W, de Vries AC, Valstar ER, Nelissen RG. Elastomer femoroplasty prevents hip fracture displacement in vitro biomechanical study comparing two minimal invasive femoroplasty techniques. Clin Biomech (Bristol, Avon). 2011;26(5):464-9.

Received in September 30 2016.
Accepted em November 8 2016.