EXPERIMENTAL STUDY

The role of oxidative stress and antioxidants in older individuals with osteoporotic hip fractures

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ABSTRACT

BACKGROUND: Osteoporosis is characteristically defined as a decrease in bone density and mass, accompanied by the deterioration of bone structure, which increases bone fragility and the risk of fractures. Osteoporosis frequently develops with age. In high-risk populations, oxidative damage is a common pathological condition. Oxidative stress plays a critical role in the development of osteoporosis and the formation of osteoporosis-related fractures. This study aimed to investigate the role of oxidative stress and antioxidants in bone tissue metabolism among elderly individuals with osteoporotic hip fractures, specifically intertrochanteric femur fractures and femoral neck fractures, who presented to our department.

METHODS: Based on power analysis, 24 patients over the age of 65 who presented with hip pain following a fall, were diagnosed with hip fractures (intertrochanteric or femoral neck fractures) on X-ray, were hospitalized in the Orthopedics and Traumatology Department, and underwent surgery were included in the study. A control group consisting of 24 healthy individuals matched for age and gender, with no history of fractures and meeting the same exclusion criteria, was also included. Levels of oxidative stress and antioxidant parameters, including total antioxidant status (TAS), total oxidant status (TOS), oxidative stress index (OSI), and paraoxonase-1 (PON-1), were measured in serum samples using spectrophotometric methods.

RESULTS: The TAS (p=0.189) and OSI (p=0.110) levels in the patient group were significantly lower compared to the control group. Conversely, the TOS (p=0.002) and PON-1 (p=0.013) levels in the patient group were significantly higher than those in the control group.

CONCLUSION: The data indicate that oxidative balance is disrupted due to increased oxidative load and the resulting antioxidant deficiency. A better understanding of the pathophysiology of the disease, along with the development of alternative treatment approaches and disease markers, will contribute to the literature.

Keywords: Antioxidants; osteoporotic hip fractures; oxidative stress.

INTRODUCTION

Osteoporosis is defined as the weakening and fragility of bones due to a decline in bone mineral density and low bone mass. It is one of the most common systemic skeletal diseases globally.[1-3] Hip fractures caused by osteoporosis represent a significant health problem, contributing to high rates of mortality, morbidity, and socioeconomic burden in the elderly population. With advancing age, physical activity tends to decrease due to physiological and biological changes. A direct relationship has been established between reduced physical activity in aging and an increased prevalence of metabolic diseases, cardiovascular diseases, osteoporosis, infectious diseases, and cancers.[4] Many factors contribute to the etiology of osteoporosis, with estrogen deficiency and aging being the most prominent. Additional risk factors include late menarche, early

Cite this article as: Aydın M, Avcı E. The role of oxidative stress and antioxidants in older individuals with osteoporotic hip fractures. Ulus Travma Acil Cerrahi Derg 2025;31:9-14.

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Ulus Travma Acil Cerrahi Derg 2025;31(1):9-14 DOI: 10.14744/tjtes.2024.89335
Submitted: 08.08.2024 Revised: 05.12.2024 Accepted: 06.12.2024 Published: 03.01.2025

menopause, advanced age, low body weight, and weight loss.[5] As with other chronic diseases, osteoporosis negatively impacts quality of life due to systemic deficiencies. Studies have reported that pain, loss of functionality, inability to perform daily living activities, and physical inactivity are among the factors that reduce the quality of life in individuals with osteoporosis. Falls, which are the most feared complications of osteoporosis, and the resulting fractures, particularly those of the hip and femoral neck, diminish quality of life and impose restriction in various aspects of daily living.[6]

Oxidative stress is a condition characterized by a disruption of the oxidant balance, defined by an imbalance between reactive oxygen radicals and antioxidant defense mechanisms in favor of the radicals. It serves as a risk factor for numerous chronic diseases, including metabolic diseases, cancer, respiratory diseases, and cardiovascular diseases.[7,8] It exerts its effects by damaging macromolecules such as lipids, proteins, carbohydrates, and DNA.[9]

Reactive oxygen species play a critical role in bone formation and remodeling processes by acting as second messengers that regulate and activate signal transduction pathways involved in various biochemical and physiological processes, particularly apoptosis in metabolism. They are also important for maintaining the balance between osteoblastogenesis and osteoclastogenesis in the context of oxidant balance. While reactive oxygen production and oxidant balance processes in osteoclasts facilitate bone destruction and restructuring, antioxidant systems in osteoblasts are crucial for eliminating reactive oxygen species (ROS) released into the environment.[10-12] If oxidative stress is not mitigated or oxidant balance is not restored, it contributes to bone mass loss in the metabolic process, ultimately leading to osteoporosis. Specifically, excessive production of reactive radicals during oxidative stress stimulates osteoclastogenesis, resulting in its increase, while simultaneously reducing osteoblast activity. This process may ultimately result in bone loss.[13,14]

This study aims to examine the role of oxidative stress and antioxidants, as well as their pathological impact on bone tissue metabolism, in elderly individuals with osteoporotic hip fractures, including intertrochanteric femur fractures and femoral neck fractures, admitted to the emergency department.

MATERIALS AND METHODS

Sample

Based on power analysis, the study included patients over 65 years of age who presented to Gülhane Training and Research Hospital with hip pain following a fall. Hip fractures, specifically intertrochanteric fractures or femoral neck fractures, were confirmed via direct radiographs. These patients were admitted to the Orthopedics and Traumatology Service and underwent surgery. The study group consisted of 24 patients, while the control group comprised 24 healthy individuals. Ethical approval for the study was obtained from the Gulhane Training and Research Hospital, University of Health Sciences Ethics Committee of the University of Health Sciences (Date: 26.06.2024, Decision No: 2024-366).

The control group consisted of healthy individuals matched to the patient group in terms of age and gender, meeting the same exclusion criteria, and with no history of fractures. Oxidative stress and antioxidant levels were determined using serum samples that remained and were discarded after preoperative examinations conducted for diagnosis and surgery preparation when individuals were admitted to the hospital for treatment.

The age, gender, disease duration, initial clinical presentations, and final clinical outcomes of the patients were recorded. Additionally, hemogram results, routine biochemical data, and imaging findings were retrieved from patient records for analysis. Blood samples from all individuals in the study were centrifuged at 4000 g for 5 minutes to separate the serum, which was then stored at –80° until the analyses were conducted.

Determination of Total Antioxidant Status (TAS)

Serum TAS levels were determined spectrophotometrically using commercially available diagnostic kits (Rel Assay, Gaziantep, Türkiye). The data were measured spectrophotometrically, the results were calculated as mmol Trolox eq./L.[15]

Determination of Total Oxidant Status (TOS)

Serum TOS levels were analyzed using commercially available diagnostic kits (Rel Assay, Gaziantep, Türkiye). The results were calculated as μmol H_2O_2 equivalent/L.[16]

Determination of Oxidative Stress Index (OSI)

The oxidative stress index, an indicator of oxidative stress, was expressed as the percentage ratio of TOS levels to TAS levels. The OSI was calculated using the formula: OSI(AU)=((TOS μmol/L)/(TAS μmol/L))x100.[17-19]

Determination of Paraoxonase-1 (PON-1)

PON-1 activity, a lipophilic and hydrophobic antioxidant enzyme bound to high-density lipoprotein (HDL) cholesterol, was measured using the commercial Rel Assay brand kit. The absorbance of the product was monitored in kinetic mode at 412 nm, and the enzyme activity was expressed as U/L.

Statistical Methods

All data were reported as mean ± standard deviation (SD). Statistical analyses were performed using the SPSS version 22.0 software package (IBM SPSS Inc., USA). Data distribution was tested for normality using the Shapiro-Wilk test. Analyses included Analysis of Variance (ANOVA), Mann-Whitney U test, Levene's test, and t-tests to assess the equality of means for independent groups. A significance level of $p<0.05$ was considered statistically significant.

Table 1. Biochemical parameters in older healthy individuals and individuals with osteoporotic hip fractures

Parameters	Mean±SD	CIM	Mean±SD	CIM
Patient Group			Control Group	
Age	78.65±1.84	74.79-82.50	79.95±7.38	69.0-79.95
HB	11.43±0.55	10.27-12.59	12.27±1.46	11.59-12.95
HTC	34.11±2.18	29.95-39.11	35.62±6.58	32.54-38.70
Na	137.75±0.72	136.75-139.27	140.4±1.75	139.57-141.22
K	4.45±0.12	4.19-4.71	4.32±0.26	4.20-4.44
Ca	8.43±0.12	8.16-8.69	9.02±0.43	8.81-9.22
LDH	291.30±22.04	245.16-337.43	217.55±29.67	203.66-231.43
Urea	55.75±5.90	43.38-68.11	31.9±7.74	28.27-35.52
Creatinine	1.15±0.15	0.79-1.15	0.88±0.18	0.79-0.97
Total Protein	4.39±0.58	3.17-5.60	6.45±0.45	6.23-6.66
Albumin	3.58±0.18	3.19-3.97	3.25±0.55	2.99-3.51

SD: Standard Deviation; CIM: 95% Confidence Interval for the Mean.

RESULTS

Care was taken to ensure that the mean ages of the individuals in the patient and control groups in our study were comparable (78.65±1.84 and 79.95±7.38, respectively). Upon evaluation of biochemical parameters, no statistically significant differences were observed in hemoglobin (HB), hematocrit (HTC), sodium (Na), potassium (K), or calcium (Ca) levels (Table 1).

However, lactate dehydrogenase (LDH), urea, creatinine, and albumin levels were higher in the patient group, while total protein levels were lower compared to the control group (Table 1).

Determination of Total Antioxidant Status

Statistical evaluation indicated that TAS values were lower in the patient group compared to the control group. However, the difference was not statistically significant (p=0.189, p>0.05) (Table 2, Fig. 2).

Determination of Total Oxidant Status

The TOS values in the patient group were statistically significantly higher than those in the control group (p=0.002, p<0.05) (Table 2, Fig. 2).

Determination of Oxidative Stress Index

An increase in OSI values was observed due to increased TOS levels and decreased TAS levels following hip fractures. OSI values were lower in the control group compared to the patient group, but the difference was not statistically significant (p=0.110, p>0.05) (Table 2, Fig. 3).

Determination of Paraoxonase-1

PON-1 levels in the patient group were significantly higher than those in the control group (p=0.013, p<0.05) (Table 2, Fig. 4).

DISCUSSION

Osteoporosis has become an increasingly significant health concern in modern times due to the extension of human life

Table 2. Oxidative stress parameters in older healthy individuals and individuals with osteoporotic hip fractures

Parameters	Mean±SD	CIM	Mean±SD	CIM
Control Group			Patient Group	
TAS	1.96±0.048	1.86-2.06	1.88±0.17	1.80-1.96
TOS	9.53±2.28	4.76-14.30	12.65±2.71	11.38-13.92
OSI	0.50±0.12	0.24-0.75	0.63±0.49	0.40-0.86
PON-1	209.08±36.44	132.81-285.35	292.13±59.39	264.33-319.93

SD: Standard Deviation; CIM: 95% Confidence Interval for the Mean.

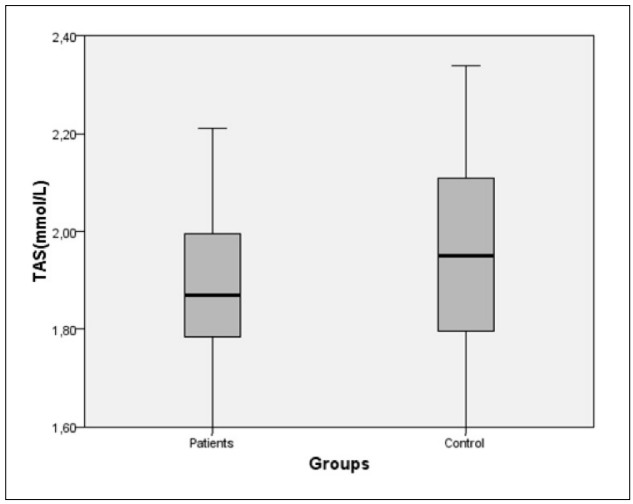

Figure 1. TAS levels of in older healthy and individuals with osteoporotic hip fractures.

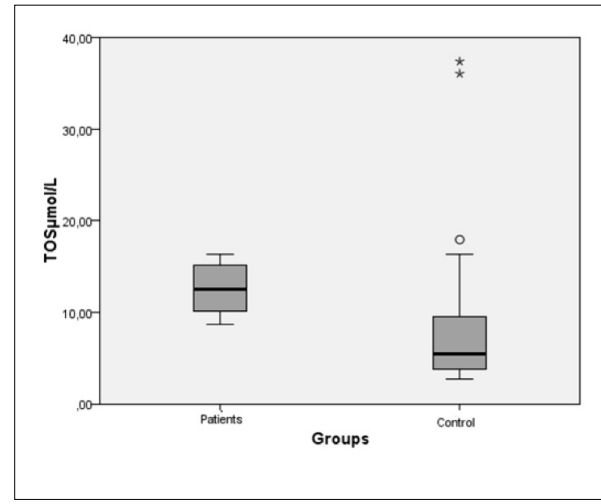

Figure 2. TOS levels of in older healthy and individuals with osteoporotic hip fractures.

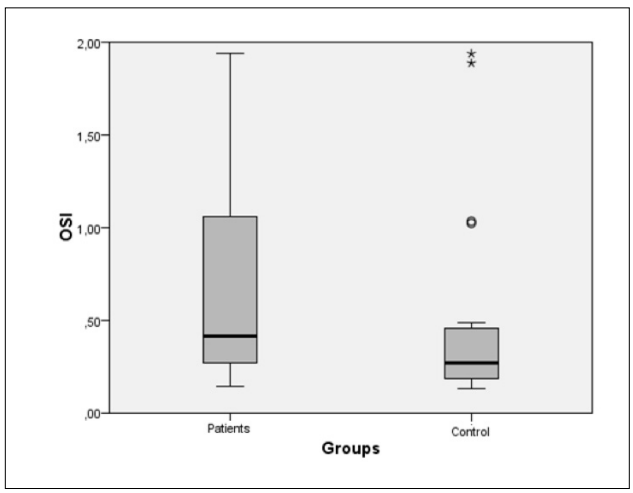

Figure 3. OSI levels of in older healthy and individuals with osteoporotic hip fractures.

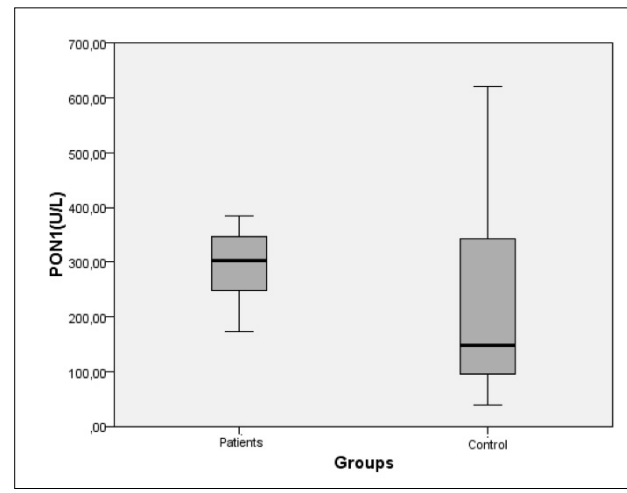

Figure 3. PON-1 levels of in older healthy and individuals with osteoporotic hip fractures.

expectancy and the aging population.[20] Osteoporosis is often referred to as a silent disease until a bone fracture occurs. Fractures often occur with minimal trauma or, in some cases, without any trauma. Osteoporosis can be diagnosed before fractures occur, and with appropriate precautions and treatments, serious health problems resulting from fractures can be prevented.[21]

In the diagnosis of osteoporosis, biochemical analyses are often performed alongside radiological methods to provide additional diagnostic support. Various biochemical indicators, including proteins, enzymes, and metabolites in serum or urine, play a crucial role in monitoring changes related to bone transformation, destruction, and formation.[22,23]

In modern times, the elderly population is increasing rapidly globally. Consequently, the annual number of fractures in this age group rises significantly with advancing age.[24] Bone fractures resulting from osteoporosis are associated with high rates of morbidity and mortality, most commonly occurring as a result of falls.[24,25] In this study, patients aged 65 and older were evaluated.

Antioxidants play an important role in metabolic processes and in mitigating oxidative damage, making them particularly important for patients with osteoporosis. Identifying the oxidant load is essential for guiding the management of osteoporosis and post-fracture treatment approaches.[26] Increased stress, resulting from a disruption of the oxidant balance during the osteoporosis process, leads to apoptosis of osteoblasts and osteocytes, which subsequently causes abnormal bone formation around the damaged area.[27] Studies indicate that excessive osteocyte apoptosis is associated with a disruption in oxidant balance, favoring osteoclastogenesis.[28-30]

In this study, important indicators of oxidative stress were examined to evaluate the oxidant state during the disease process. The findings indicate increased total oxidant activ-

ity in patients compared to the control group. It was also observed that total antioxidant levels began to rise as a compensatory response, while the oxidative stress index increased in favor of oxidants. Studies have demonstrated that antioxidants contribute to the activation of osteoblast differentiation, the mineralization process, and the reduction of osteoclast activity by neutralizing the effects of reactive oxygen species during the osteoclast process.[3,31,32]

Studies have also explored the role of antioxidants in the treatment of osteoporosis. The use of antioxidants is recommended for numerous disorders associated with oxidative stress. Research has shown that oxidative stress levels in osteoporosis are negatively correlated with bone mineral density, and consequently, antioxidant levels are often reduced.[33,34]

Paraoxonase-1 regulates the metabolism of reactive oxygen and nitrogen derivatives, increasing nitric oxide production, and reducing macrophage foam cell formation.[35] Studies indicate that PON-1 possesses antioxidant properties by mitigating the effects of free radicals in oxidative stress balance, and as a result, it may influence the progression of osteoporosis.[36-39]

Aging, menopause, obesity, and various chronic diseases are known to contribute to the development of osteoporosis. During this process, significant bone loss occurs, and complications lead to an irreversible reduction in bone mass. During this period, individuals require appropriate preventive treatment. However, the primary changes underlying osteoporosis in these populations differ. Oxidative stress is a common pathological condition associated with this process. In a study by Altındağ et al.,[39] involving 39 patients with osteoporosis and 26 healthy controls, TAS, TOS, and OSI values were investigated. The findings revealed that TOS and OSI values were significantly higher in patients compared to healthy controls, while TAS levels were observed to be lower. Similarly, a review by Zhao et al.[40] analyzed 36 studies examining 16 parameters related to osteoporosis and oxidative stress. Consistent with our study, these investigations demonstrated increased oxidative stress and a reduced antioxidant response during the osteoporosis process. These studies demonstrated that significant oxidant damage occurs during the osteoporosis process. This damage is a critical factor contributing to the development of fractures in individuals with osteoporosis.

Limitations of Our Study

A significant limitation of this study is that the level of imbalance in the observed oxidative stress parameters before the fracture is unknown. As a result, it is unclear whether there is increased oxidative stress in the body after the fracture. Further studies are necessary to clarify this relationship.

CONCLUSION

The most effective approach to addressing oxidative stress in individuals diagnosed with osteoporosis is to prevent bone loss by strengthening the antioxidant system. Antioxidant treatments have the potential to reverse the adverse effects of oxidative stress on bone in high-risk individuals. A key strategy for enhancing the antioxidant system involves maintaining proper nutrition to mitigate the risk of osteoporosis. For individuals at high risk, adopting a vitamin-rich diet or utilizing antioxidant supplements may be beneficial. Antioxidant supplements containing vitamins and minerals will become increasingly popular as a practical approach to maintaining optimal bone health.

Ethics Committee Approval: This study was approved by the Gulhane Training and Research Hospital, University of Health Sciences Ethics Committee (Date: 28.06.2024, Decision No: 2024-366).

Peer-review: Externally peer-reviewed.

Authorship Contributions: Concept: M.A., E.A.; Design: M.A., E.A.; Supervision: M.A., E.A.; Materials: M.A., E.A.; Data collection and/or processing: M.A., E.A.; Analysis and/or interpretation: M.A., E.A.; Literature review: M.A., E.A.; Writing: M.A., E.A.; Critical review: M.A., E.A.

Conflict of Interest: None declared.

Financial Disclosure: The author declared that this study has received no financial support.

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DENEYSEL ÇALIŞMA - *ÖZ*

Osteoporotik kalça kırığı olan yaşlı bireylerde oksidatif stres ve antioksidanların rolü

AMAÇ: Osteoporoz, karakteristik olarak kemik yoğunluğu kütlesinin azalması ve kemik yapısının bozulması olarak tanımlanır, bu da kemik kırılganlığını ve kırık riskini artırır. Osteoporoz ayrıca yaşla birlikte sıklıkla gelişir. Yüksek riskli osteoporoz popülasyonunda, oksidatif hasar yaygın bir patolojik durumdur. Dahası, oksidatif stres osteoporoz ve osteoporozla ilişkili kırık oluşumunda önemlidir. Bu çalışma, servisimize başvuran osteoporotik kalça kırıkları (intertrokanterik femur ve femur boyun kırıkları) olan yaşlı bireylerde kemik dokusu metabolizmasında oksidatif stres ve antioksidanların rolünü araştırmayı amaçlamıştır.

GEREÇ VE YÖNTEM: Güç analizine göre, düşme sonrası kalça ağrısı ile başvuran, röntgende kalça kırıkları (intertrokanterik kırıklar, femur boyun kırıkları) tespit edilen ve ortopedi ve travmatoloji kliniğine yatırılarak ameliyat edilen 65 yaş üstü 24 hasta ve kontrol grubu olarak 24 sağlıklı birey çalışmamıza dahil edildi. Kontrol grubu, yaş ve cinsiyet açısından hasta grubuyla aynı olan, aynı dışlama kriterlerini karşılayan ve kırık öyküsü olmayan sağlıklı bireylerden oluşturuldu. Çalışmada serum örneklerinde oksidatif stres ve antioksidan parametrelerin (TAS, TOS, OSI ve PON-1 biyobelirteçleri) düzeyleri spektrofotometrik yöntemlerle belirlendi.

BULGULAR: Hasta grubunda TAS (p=0.189) ve OSI (p=0.110) değerlerinin kontrol grubuna göre istatistiksel olarak anlamlı derecede düşük olduğu bulundu. Hasta grubunda TOS (p=0.002) ve PON1 (p=0.013) değerlerinin kontrol grubuna göre istatistiksel olarak anlamlı derecede yüksek olduğu bulundu.

SONUÇ: Elde edilen veriler ışığında, oksidatif yükün artması ve bunun sonucunda oluşan antioksidan eksikliği nedeniyle oksidan dengenin bozulduğu görülmektedir. Hastalığın patofizyolojisinin daha iyi aydınlatılması ve alternatif tedavi süreçlerinin ve hastalık belirteçlerinin geliştirilmesi literatüre katkı sağlayacaktır.

Anahtar sözcükler: Antioksidanlar; oksidatif stres; osteoporotik kalça kırığı.

Ulus Travma Acil Cerrahi Derg 2025;31(1):9-14 DOI: 10.14744/tjtes.2024.89335