Bone mineral density and muscle mass in adults with developmental skeletal discrepancies

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Abstract

**Background:** It was aimed to investigate the musculoskeletal status in individuals diagnosed with skeletal discrepancies.

**Methods:** This case–control study was performed on 35 patients with developmental skeletal discrepancies listed for orthognathic surgery as a case group and 33 patients who were nominated for wisdom tooth removal as a control group. All participants were aged 18–40 years and the research was carried out in the period between May 2018 and May 2019. Dual X-ray absorptiometry (DEXA) was used to assess bone mass density at three bone sites: total hip, femoral neck, and the spinal lumbar vertebrae (L1-L4). The appendicular muscle mass index (ASMI) was measured based on the four limbs from the DEXA scan.

**Results:** Our data showed that 45.7% (16) of the case group were osteopenic or osteoporotic while in the control group only 21.2% (7) were osteopenic in at least one region (total hip, femoral neck, or lumbar) ($p$-value = 0.03).

Regarding muscle mass, there was significantly lower SMI in subjects with skeletal discrepancies (case group) compared with the control group (median (IQR) 5.9 (2.5) vs. 6.8 (2.9) (kg/m2), respectively, $p = 0.04$).

**Conclusions:** There is an essential need for more studies to understand the exact interrelationship between musculoskeletal status and skeletal jaw discrepancies.

**Keywords:** Osteoporosis, Muscle mass, Jaw deformity, Orthognathic surgery

Background

Osteoporosis and sarcopenia are two aging disorders whose economic impact matters to public health assessment. Both conditions are growing in intensity depending on lifestyle and life expectancy [1].

Sarcopenia is defined as a gradual drop in muscle mass [2]. In older adults, the quality and quantity of skeletal muscle are on a progressive decline, consequently reducing skeletal muscle strength and lowering metabolic function, and augmenting fatty connective tissues. Sarcopenic people are at risk of falls and osteoporotic bones remain at risk of fragility fractures. Osteosarcomenic patients suffer a remarkably higher mortality rate and pain with lower quality of life [3].

Osteoporosis is a disease that triggers alterations in bone density and structure, disrupting bone microarchitecture throughout life [1]. During the 2nd and 3rd decades of life, bone skeletal muscle mass shows the highest peak, although, from that age onwards, a progressive decline in bone and muscle mass is witnessed. Therefore, such phenomena are deemed as natural developments easy to diagnose and tackle at young ages, leading to a
slowdown in the osteoporosis and sarcopenia processes
[4].

The relationship between bone and muscle can be
described by the mechanistic hypothesis, which illus-
trates the stimulation of bone mass to effectual osteo-
genesis through muscle contracture [5]. Studies using
bone scans show that the bone density of any other part
of the body is subject to change [6–9]. It is well known
that mandibular shape can change by reducing skeletal
bone density [10]. The mandibular bone density in in-
dividuals with a jaw discrepancy is likely an indicator of
osteoporosis. Jaw discrepancies are, in fact, an imbalance
between the size, shape, or position of the jaws relative to
one other. The pathogenesis of a jaw discrepancy is not
completely clear, but genetic and environmental factors
seem to be involved in it. Recent studies have shown that
mandibular bone density in individuals with such a dis-
crepancy lacks adequate bone marrow quality, leading to
even worse intraoperatively fractures [11].

One of the serious intraoperative complications of
the bilateral sagittal split osteotomy (BSSO) in orthogn-
athic surgery is a bad split or unfavorable fracture due
to lower bone quality and bone marrow, especially in
elderly patients and osteoporotic individuals [12]. Practi-
cally speaking, by assuming that in patients with skeletal
discrepancies, the whole musculoskeletal status might
be affected in a way that is in favor of a higher incidence
of bad fractures, assessment of patients for diagnosis of
osteoporosis can be useful.

It is likely patients with skeletal jaw discrepancies are
at risk of alterations in musculoskeletal function. These
patients undergoing orthognathic surgery are usually in
the 2nd and 3rd decades of their lives, the best age to
detect any abnormalities in total bone mass to prevent
bone loss or muscle weakness.

The main purpose of this study was to investigate the
musculoskeletal status in individuals diagnosed with
skeletal discrepancies.

**Material and methods**

This was a matched case–control study designed by the
Tehran University of Medical Sciences. The participants
of this study were individuals aged 18–40 who were
enrolled from May 2018 to May 2019. As a case group,
35 patients were identified with developmental skeletal
discrepancies. They were thereby nominated for orthog-
nathic surgery and referred to the oral and maxillofacial
department at Shariati Hospital.

Our control group consisted of 33 individuals, who
were referred to Tehran University’s Dentistry Faculty,
and were candidates for a wisdom tooth removal.

The exclusion criteria were a history of maxillofacial
pathology, radiotherapy in the head and the neck region,
corticosteroid consumption beyond three months,
hyperparathyroidism, leukemia and multiple myeloma,
chronic renal and hepatic disorders, vertebral or non-
vertebral osteoporotic fractures, alcohol consumption,
medications affecting bone metabolism, metabolic bone
diseases, and bone metastases.

Demographic and clinical information including
age, sex, status, history of systemic diseases, using cal-
cium and vitamin D supplementations, sun exposure,
and physical activity were obtained by a questionnaire.
Nobody in the case and control groups had chronic
disorders.

For sun exposure, a questionnaire was completed
including 4 questions; time per day, day time, the aver-
age time of sun exposure, and using sunscreen during the
last three months. Sun exposure was classified based on
at least 10 min per day in the daytime (between 10 am to
3 pm).

For physical activity, the short format of the Interna-
tional Physical Activity Questionnaire (IPAQ) was used.
Following IPAQ’s guidelines, frequency and duration of
physical activity were converted to Metabolic Equivalent
of Tasks. Physical activity was classified into two levels:
inactive and active (moderate activity/health-enhancing
physical activity).

**Defined developmental skeletal discrepancies**

Based on the ANB angle, which is the most accurate and
relevant diagnostic tool, all participants were categorized
into three groups: Class I, Class II, and Class III [13].
Class I classification were recruited in the control group
which means they had a relatively normal maxilloman-
dibular relationship.

The basic radiographs were Panoramic, Lateral, and
posteroanterior cephalometry. Study casts were assessed
for the quantity of jaw discrepancy and asymmetry in the
case group. All participants in the case group who were
candidates for orthognathic surgery were classified as
having an ANB angle of class II or III.

**Bone status measurement**

Dual X-ray absorptiometry with a Lunar DPXMD densi-
tometer (Lunar 7164, GE, and Madison, WI) was used to
measure bone mass density and muscle volume at three
bone sites: total hip, femoral neck, and lumbar spine
vertebrae (L1-L4). Each person was categorized based
on the World Health Organization (WHO) osteopo-
rosis criteria: osteoporosis (T-score ≤-2.5), osteopenia
(-2.5 < T-score < -1), and normal (T-score ≥ -1).
Muscle mass measurement

Muscle mass was estimated by dual energy X-ray absorptiometry (DEXA). The appendicular muscle mass index (ASMI) was calculated by the following equation: skeletal muscle mass (kg) divided by the square of height (m²).

Statistical analysis

SPSS software (version 21) was used for data analysis. Nonparametric tests were used to compare variables between two groups; the Mann–Whitney U test for continuous variables and the Chi-square test or Fisher’s exact test for categorical data. Numerical variables were expressed as the median (IQR) and categorical variables were presented as percentages (number). A Spearman’s correlation was used to determine the correlation between bone density and muscle mass. A p-value less than 0.05 was considered statistically significant.

Results

Totally 68 patients were enrolled in the study; 35 in the case group and 33 in the control group. The two groups were not significantly different in terms of age (P-value = 0.1), sex (P-value = 0.3), and the body mass index (P-value = 0.5) (Table 1). There were not any significant differences in the prevalence of smoking, taking calcium and vitamin D supplementations, sun exposure, and physical activity (p-value > 0.05). The prevalence of obesity (> 30 kg/m²) was similar in the two groups; 5.7% in the case group and 6.1% in the control group (p = 0.9).

Bone and muscle mass status

The comparison of the BMD values, from the three regions (total Hip, femoral neck, and lumbar spine (L1-L4), showed no significant differences between the case and control groups (p-value > 0.05) (Table 1). While in terms of osteoporosis, the prevalence of osteopenia or osteoporosis (at least in one bone site) was higher in the case group compared with the control group (45.7% vs. 21.2%, respectively, p = 0.03).

Only one person in the case group had osteoporosis while there were no osteoporotic patients in the control group. In terms of muscle mass, the ASMI was lower in the case group compared with the control group; the median (IQR) 5.9 (2.5) vs. 6.8 (2.9) (kg/m²), respectively, p = 0.04. In the case group, there was a significant positive correlation between muscle mass (ASMI) and bone density in the hip site (BMD Hip: rho = 0.5, T-score hip: rho = 0.4, p < 0.01) in women while there was not any significant correlation between muscle mass and bone density in men (P > 0.05).

In the control group, there was a significant correlation between ASMI and total BMD (rho = 0.6, p = 0.02) but no other sites. In women, there was not any correlation between ASMI and total BMD or other specific sites (Hip, femoral neck, and lumbar sites) (p > 0.05).

Discussion

Our finding has shown that patients with skeletal discrepancies are at more risk of osteopenia and lower muscle mass compared with control people of the same age.

Table 1  Demographic characteristics and bone status in case and control group

|                          | Case group (N = 35) | Control group (N = 33) | P-value |
|--------------------------|---------------------|------------------------|---------|
| Age, year                | 27 (9)              | 29 (9)                 | 0.1     |
| Sex (Female)             | 71.4% (25)          | 60.6% (20)             | 0.3     |
| BMI, kg/m²               | 23.8 (4.3)          | 23.4 (5.4)             | 0.5     |
| Physical activity (activity) | 2 (5.7%)          | 5 (15%)                | 0.2     |
| Sun exposure at least 10 min (between 10AM-3PM) | 22 (62.8%) | 18 (54.4%) | 0.4 |
| Vitamin D and/or Calcium consumption | 0 (0) | 2 (6%) | 0.2* |
| Smoking                  | 0 (0)               | 1 (3%)                 | 0.4*    |
| Bone Status              |                     |                        |         |
| BMD total body (g/cm²)   | 1.06 (0.14)         | 1.09 (0.11)            | 0.6     |
| T-score total body       | -0.71 (1.50)        | -0.70 (1.10)           | 0.4     |
| BMD Hip (g/cm²)          | 0.90 (0.21)         | 0.97 (0.18)            | 0.2     |
| T-score Hip              | -0.20 (1.50)        | 0.00 (1.13)            | 0.2     |
| BMD Femoral Neck (g/cm²) | 0.81 (0.16)         | 0.82 (0.19)            | 0.4     |
| T-score Femoral Neck     | -0.70 (1.10)        | -0.30 (1.18)           | 0.5     |
| BMD Lumbar (L1-L4) (g/cm²) | 0.99 (0.16)   | 1.01 (0.08)            | 0.2     |
| T-score Lumbar (L1-L4)   | -0.85 (1.45)        | -0.20 (1.00)           | 0.1     |

Numerical variables were expressed as the median (IQR) and categorical variables were presented as percentages (number)

BMD Body Mass Density, BMI Body Mass Index, L Lumbar, N Number

*Fisher’s exact test
Although no study has comprehensively assessed the musculoskeletal status of the whole body and specific bone sites in patients with developmental skeletal jaw discrepancies, Konstantynowicz J et al. considered the total bone density and lumbar spine, hip, and head sites in the adolescence group. They reported that reduced total bone mineral density is associated with dental malocclusion in only men at 14–18 years old [14].

The case group of our population study was patients who were candidates for orthognathic surgery with a jaw discrepancy as well as dental malocclusion. Over 60% of them were in the second and third decays of their life and it is expected to have the maximum bone and muscle mass of their life.

However, these patients experience prompt weight loss during 4 weeks postoperative period because of the inability of mastication and intermaxillary fixation (IMF) [15]. It has been suggested weight loss in early adulthood can be a risk factor for lower bone mineral density (BMD) and an increase in osteoporosis in later life [16]. It is of importance for surgeons to consider these risk factors to improve the management of the patients specifically just following the surgery.

In the field of research, previous studies considered the relationship between maxillofacial morphology, bone characteristics, and bone metabolic markers in patients with jaw deformity [17]. Saito et al. (2015) showed a higher level of deoxypyridinoline as a collagen mature degradation marker and tartrate-resistant acid phosphatase isoform 5b (TRACP-5b) as an osteoclast marker in patients with skeletal discrepancy of Class III [18].

In another study, Taguchi et al. estimated bone status based on mandibular cortex erosion through evaluation of routine dental radiographs. The authors have reported the significant association between mandibular cortex erosion and bone turnover markers such as N-telopeptide (NTx), Cross-links of type I collagen, and alkaline phosphatase (ALP), which are increased in osteoporosis. As NTx is a bone marker of higher susceptibility when compared to ALP, it can serve as a useful indicator in detecting early stages of osteoporosis among postmenopausal women [19].

Higher levels of bone resorption markers have been found in lower BMD and deterioration of bone microstructure, which can be a prognostic factor for osteoporosis in the future. Furthermore, combining diagnostic tools of BMD measurement and bone resorption markers has proven to be more valuable in predicting the risk factors of osteoporosis in patients suffering from skeletal jaw discrepancies. In the current research, we didn’t measure circulating levels of bone markers or bone markers in bone tissue in our study population.

Bone mass density is regulated when the process of bone formation by osteoblasts is boosted while osteoclasts cause a decrease or degeneration. All concerns about assessing the dynamics of bone tissue during puberty are based on the fact that the stage plays a crucial role in optimizing skeleton strength and minimizing potential bone resorption [17]. Also, early-stage osteoporosis can be diagnosed in advance thus helping eliminate excessive osteoporosis-related medical costs and prevent pathologic fractures in patients with skeletal jaw discrepancies during orthognathic surgery or secondary during a lifetime.

Our data also showed there was a significant correlation between muscle mass and bone status in hip and femoral neck regions in women (not men) with a jaw discrepancy. The relationship between muscle mass and bone density is well established. Our findings suggest that young women with a jaw discrepancy are likely more at risk of both muscle weakness and osteoporosis before age of menopausal. Further studies need to be designed and consider this possibility.

In the present study, some limitations in our study are worth noting. Firstly, the design of our study is matched case control. So, we cannot explain the cause and effect relationship between low muscle mass and bone density, and skeletal jaw discrepancies. Designing large-scale studies need to evaluate the risk association between them.

Secondly, some lifestyle-related factors could have an impact on muscle mass and bone status. To minimize the effects of lifestyle, we considered smoking habits, sun exposure, physical activity, and vitamin D and calcium supplementations. There were not any significant differences between the two groups. Thirdly, we measured the bone density of three skeletal regions, the total hip, femoral neck, and the spinal lumbar vertebrae (L1-L4). Panoramic radiographs or other methods may help in considering the bone status of the jaw. Of note, we used DEXA as a gold standard for assessing bone and muscle mass.

Since no study in the literature has been reported to clarify the status of bone markers in patients with skeletal discrepancies, more efforts in this scope of research need to comprehend this interrelationship. Finally, it has been suggested that the muscle mass might be affected by tooth loss [20]. We did not collect data of dental problems including tooth loss, dental hygiene, etc.

In conclusion, our study suggests that patients with skeletal discrepancies are at risk of low muscle mass and bone density. Considering skeletal-muscle status in patients with skeletal discrepancies the early diagnosis of osteoporosis or muscle weakness can diminish the complications of severe osteoporosis in later life. Also, it is important to predict and prevention of unfavorable fractures in osteotomy sites of the mandible and very rarely in the maxilla during orthognathic surgery in patients with skeletal discrepancies.
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Authors’ contributions

ZM and MR performed conceptualization, project administration, investigation, formal analysis, and methodology. RSH and FN participated in sampling and data collection. YA interpreted in data curation and validation. ZM and SHK were major contributors in writing—original draft preparation. All authors read and approved the final manuscript.

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Availability of data and materials

The data that support the findings of this study are available from the Research Deputy of Tehran University of Medical Science but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are however available from the corresponding authors upon reasonable request and with permission of the Research Deputy of Tehran University of Medical Science.

Declarations

Ethical approval and consent to participate

All procedures performed in studies involving human participants with thereby the ethical standards of the national research ethics committee of Tehran University of Medical Sciences (Ethical reference code: IR.TUMS.VCR.REC.1395.900). All methods were carried out in accordance with relevant guidelines and regulations. The informed consent was obtained from all subjects.

Consent for publication

not applicable.

Competing interests

Sharif Reza, Sheida Kordi, Farhad Noravesh, Aghababaei Y, Ramezani M, and Maghbobi Z declare that they have no conflict of interest.

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