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Research Article

Radiologically Identified Morphologic Changes of Maxillary and Mandibular Bones among Diagnosed Cases of Skeletal Fluorosis in Ethiopia

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Abstract

In 1937, the chronic toxic effect of fluoride on skeletal fluorosis was demonstrated for the first time in history in the Indian state of Madras. Exposure to fluoride concentrations greater than eight ppm in water is reported to cause skeletal fluorosis. Skeletal fluorosis is a chronic metabolic bone disease resulting from prolonged ingestion of large amounts of fluoride. Bone knee syndrome, osteosclerosis, pathological fractures, calcification of ligaments, joint stiffness, immobility, muscle atrophy, and severe forms of neurological deficits are some of the consequences of skeletal fluorosis. Skeletal fluorosis, as such, is a highly morbid disease. Yet, the condition is overlooked, and, most importantly, little is known about its effects on the facial skeleton. This unique, investigative, cross-sectional study was initiated to evaluate the morphologic changes in the jawbone caused by skeletal fluorosis in adults diagnosed with skeletal fluorosis. A two-dimensional radiograph was used to evaluate the possible skeletal fluorosis-related morphological changes in the maxillary and mandibular bones. A total of 9 patients diagnosed with skeletal fluorosis underwent panoramic radiography of the mandibular and maxillary bones. Several skeletal fluorosis-related morphological changes were detected in the jaw bones of 6 study participants, including exostosis, osteosclerosis, thickened cortical bone, narrowed bone marrow, and periosteal plaques. According to studies, these morphological changes pose a serious threat to the healing process of the bone. Therefore, surgeons practicing in the Oro-craniofacial region must be alert to potential perioperative and postoperative complications when treating patients diagnosed with skeletal fluorosis.

Keywords: Maxilla; Mandible; Morphology; Radiology; Skeletal fluorosis

Abbreviations: ROM: Range of Motion; TMJ: Temporomandibular Joint; OPG: Orthopantomogram; IRB: Institutional Review Board; SPSS: Statistical Package for the Social Sciences; BMD: Mandibular Bone Mineral Density; DXA: Dual-Energy X-Ray Absorptiometry

Introduction

In human nutrition, fluorine plays a dual role: at a certain intake, it prevents dental caries and can cause severe damage to bone and tooth tissue [1]. Optimal fluoride levels reduce the incidence of dental caries and maintain the integrity of body tissues [2]. Clinical studies have shown that fluoride uptake rapidly reaches mineralized tissues such as bone and developing teeth. Accordingly, skeletal changes and stained enamel may occur if the fluoride content of drinking water exceeds two ppm [3]. It is generally accepted that

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fluoride ingestion has toxic effects. Still, the concentration that can cause harmful effects is controversial [4].

Skeletal fluorosis is a chronic metabolic bone disease that occurs when abnormally large amounts of fluoride accumulate in bone tissue [3]. Because bone growth and remodeling occur throughout a person's lifespan, skeletal fluorosis can gradually worsen with overexposure to high levels of fluoride [5]. Endemic skeletal fluorosis affects millions of people in nearly 25 countries, primarily in Asia and Africa. Men tend to be more affected by severe fluorosis than women; children can also be severely affected by the disease [6]. In these regions, fluoride toxicity most often results from groundwater consumption with high fluoride concentrations. According to studies, daily fluoride intake in endemic areas ranges from 10 to 35 mg and can be even higher during summer months [7]. This has several adverse effects, including dental fluorosis, skeletal fluorosis, and R.B.C. cell wall disruption [8]. The disease diffusely affects bone and connective tissue [4]. It is important to note that the duration of fluoride intoxication has a definite influence on the development of endemic fluorosis [4,9]. Several studies found that the incidence increases with age for a similar fluoride concentration [3,10]. Gender and occupation also have an impact on the development of endemic fluorosis.

In addition, the disease is more commonly seen in laborers and farmers who perform heavy physical labor and carry heavy loads on their heads. Symptoms of the disease range from mild joint pain to severe neurological manifestations [9]. In skeletal fluorosis, patients often complain of vague discomfort and paresthesias in the limbs and trunk; next, there is pain and stiffness in the back, especially in the lumbar region, followed by the dorsal and cervical spine. Restricted spinal motion is the earliest clinical sign of skeletal fluorosis [8] The stage at which skeletal fluorosis leads to crippling usually occurs between the ages of 30 and 50 in endemic regions [10].

Typical signs and symptoms include pain, limited joint motion, knock knees, leg flexion, and spinal curvature [8]. Recurrent joint pain, axial osteosclerosis, radiculomyelopathy, myelopathy, increased bone mineral density, and joint stiffness are the other clinical manifestations of skeletal fluorosis [7,11]. Skeletal fluorosis has been reported to cause bone deformities, joint pain, and neuralgia in the anatomical region of the face [12]. Stiffness of the temporomandibular joint, upper chamber exostoses, cranial bone osteosclerosis, narrowing of the medullary spaces in the temporomandibular bone (maxilla and mandible), and multifocal periarticular calcifications of the temporomandibular joint are some of the clinical manifestations in the facial region [8,13]. Cranial nerve palsies, mostly involving the eighth nerve, have been reported, leading to progressive high-frequency perceptual deafness due to nerve compression in the sclerosed ear canal [11].

Reportedly, more than 50 countries have high fluoride levels in drinking water [8,10]. The Rift Valley region in Ethiopia is one of them. Despite the high prevalence and morbidity, there is insufficient published scientific work on the effects of skeletal fluorosis on jaw bones [14]. Therefore, this study was initiated to investigate the morphological changes of jaw bones caused by skeletal fluorosis among adults in Ethiopia.

Methodology

This study aimed to evaluate the potential skeletal fluorosis-induced morphologic changes to the jaw bones (maxilla and mandible) in adults diagnosed with skeletal fluorosis. Accordingly, the methodology section focuses on the study's primary objective.

Research Design

A cross-sectional study was conducted to identify, describe, and characterize skeletal fluorosis-induced jawbone morphologic changes in adults in Ethiopia.

Study period and sample

The study was conducted between February 4, 2023, and March 20, 2023, in Addis Ababa, Ethiopia. Volunteer subjects diagnosed with skeletal fluorosis were included in the study. Their diagnosis was made based on the findings of epidemiological, physical, biological, and radiological investigations.

Method and instruments of data collection

The relevant radiological data were collected after ethical approval by the Addis Ababa Health Bureau. Further radiological examinations were performed to rule out possible morphological changes caused by skeletal fluorosis in the jaw bones of the study participants.

Radiologic orofacial assessment

An orthopantomogram (posteroanterior and lateral views) was used to investigate possible morphological changes in the oral-facial region caused by skeletal fluorosis, especially in the jaw bones. An independent radiologist interpreted the radiographs. It should also be noted that differential diagnoses such as myelofibrosis, osteoblastic metastases, renal osteodystrophy, ankylosing spondylitis, and Paget's disease were aforethought, and subjects presented with these conditions were excluded from the study.

Data management, analysis, and evaluation

Radiological findings were recorded and analyzed using SPSS statistical software.

Ethical considerations

Ethical assurance (approval number: A/A/H/8415/227) was provided by the Addis Ababa Health Bureau Institutional

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Review Board (I.R.B.), the ethics committee, after a review of the submitted study proposal. Study participants were adequately informed of the nature of the research project. In addition, verbal informed consent was obtained from each volunteer participant. The right of study participants to make decisions about themselves was respected. They were also free to interrupt or discontinue the study. The radiographs of the study participants and their respective interpretations were kept confidential.

Findings

Initially, 42 study participants were screened epidemiologically, biologically, clinically, and radiographically to be diagnosed with skeletal fluorosis. Of these, 9 were found to present skeletal fluorosis. All of them (three women and six men) underwent further radiographic investigation (O.P.G.) to rule out possible skeletal fluorosis-related morphological changes in the jaw bones. The age of the study participants ranged from 41 to 69 years. Radiographs of the 6 study participants (1 female and five males) showed various morphological changes (n=7). With the exception for a 49 years old female patient in whom both the maxilla and mandible were affected, the remaining five patients (males) had only a single morphologic change in either the maxilla or mandible. In general, buccal maxillary exostosis, buccal mandibular exostosis, osteosclerosis of the posterior mandible, cortical thickening of the maxilla, narrowed bone marrow in the mandible, increased mandibular cortical and trabecular bone volume, and mandibular periosteal plaques were identified as skeletal fluorosis-related morphologic changes of the jaw bones (Table 1).

Discussion

Fluoride can act on osteoblasts and osteoclasts in vivo and in vitro. It has been reported that an optimal fluoride concentration in the skeletal system stimulates osteoblasts [15,16]. This osteoblast activity of the chemical element can be used to increase bone density in patients with osteoporosis [17]. In contrast, a high fluoride concentration in the musculoskeletal system increases the incidence of various pathological bone lesions and the propensity for fractures [18]. Fluoride levels >1.4 mg/L have been found to cause classic radiographic features such as osteosclerosis with calcification of the ligamentous attachments, chalky bone appearance, and osteophyte formation [19]. In trabecular bone, fluoride causes an increase in bone volume and trabecular thickness without a concomitant increase in trabecular connectivity [7,20]. This lack of trabecular connectivity reduces bone quality despite the increase in bone mass [15].

High systemic fluoride exposure can generally lead to skeletal fluorosis, a condition characterized by osteosclerosis, ligamentous calcifications, and often accompanying osteoporosis, osteomalacia, or osteopenia [21]. Bone changes are most common in the axial skeleton, and the earliest and most severe radiological changes are seen in the cervical spine and pelvis [8]. However, there are also studies, albeit limited in number, that report severe forms of radiological changes in the jaw caused by skeletal fluorosis. For example, according to Cooper et al. [19] and Monjo et al. [18], there is increased osteoblastic differentiation and interfacial bone formation at low local concentrations, as occurs after fluoride modification of dental implants associated with increased expression of osteogenic markers at the implant site. In 2012, Buyukkaplan and Guldag [22] investigated the effects of high fluoride intake on mandibular Bone Mineral Density (BMD). Their case-control study measured BMD using Dual-Energy X-Ray Absorptiometry (DXA). The results of the study showed that fluoride intake higher than the optimal value increased mandibular BMD. Gupta et al. [23] showed that high fluoride intake affected skeletal scintigraphy results, including the calvaria and mandible, which showed increased active bone formation. In a study that investigated fluoridation and settling of a fluoride profile in the alveolar bone of rats, the parts of the ridge (the middle, apical part of the alveolar bone and the body of the mandible), the upper parts of the alveolar bone and the part of the alveolar ridge had the highest resorption rates due to settling of the fluoride [24]. Similarly, the current study's radiological evaluation of O.P.G. images revealed various skeletal fluorosis-related morphological changes, including exostosis, osteosclerosis, thickened cortical bone, narrowed bone marrow, and periosteal plaques in the jaw bones of six study participants.

Table 1: Skeletal fluorosis-related morphological changes of the jaw bones (maxilla and mandible).

Study participants who exhibited morphological changes in the jaw bone	Morphological changes	Jawbone	Radiography used
Female (n=1)	Exostosis (2×)	Upper jaw and lower jaw	O.P.G.
Males (n=5)	Constricted bone marrow	Lower jaw	O.P.G.
	Osteosclerosis	Lower jaw	
	Increased cortical and trabecular bone volume	Lower jaw	
	Periosteal plaques	Upper jaw	
	Cortical thickening of the maxillary bone	Upper jaw	

Conclusion

The bone mineral density of the jaws seems important for predicting surgical outcomes in the oro-craniofacial region. This study found that chronic toxicity of fluoride affects the density of jaw bones. On the other hand, it is apparent that excessive intake of fluoride leads to crippling skeletal fluorosis

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and increases the risk of bone fracture. Therefore, clinicians, including oro-craniofacial surgeons, should practice due diligence to provide the best possible treatment and avoid potential complications when treating cases presenting with skeletal fluorosis. Radiologists also should be familiar with maxillofacial orthopantomogram (O.P.G.), computed tomography (C.T.), and magnetic resonance imaging (MRI) findings of chronic conditions such as skeletal fluorosis to provide the best possible medical care in orocraniofacial surgery. Furthermore, skeletal fluorosis must be included in the lists of differential diagnoses of craniofacial lesions. Indeed, in the long term, defluoridation and the provision of systemic fluoride treatment must be considered.

Conflict of Interest

The author declares no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

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