COMPARATIVE EVALUATION OF BITE PRESSURE AND ELECTROMYOGRAPHIC ACTIVITY OF TEMPORALIS AND MASSETER MUSCLES BETWEEN OSTEOPOROTIC AND NON-OSTEOPOROTIC PATIENTS AFTER PROSTHETIC REHABILITATION

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ABSTRACT

INTRODUCTION: Should screening for osteoporosis be essential before rehabilitating edentulous patients with complete dentures?

OBJECTIVES: The aim of the present study was to investigate the effect of low bone mineral density (osteoporosis) on bite pressure and electromyographic activity (EMG) of masseter and temporalis muscles in edentulous patients after rehabilitation with complete dentures.

MATERIAL AND METHODS: Eighty (44 non-osteoporotic and 36 osteoporotic) edentulous subjects, aged 50-70 years, visiting the department for complete dentures rehabilitation were recruited based on selection criteria. All subjects were rehabilitated with maxillary and mandibular complete dentures. After 1 month of adjustment period, evaluation of EMG of masseter and temporalis muscles and bite pressure was done. Data were obtained, statistically analyzed, and compared for osteoporotic and normal bone mineral density groups using SPSS (Statistical Package for Social Sciences, Chicago, IL, USA) version 24.0 statistical analysis software.

RESULTS: Maximum and average bite pressure was significantly lower for osteoporotic subjects. Mean maximum bite pressure applied in complete denture wearing osteoporotic patients was 25.21 MPa, and for normal bone mineral density subjects, it was 29.94 MPa. Surface EMG activity amplitude for masseter ($p = 0.005$) and temporalis ($p = 0.03$) muscles was also found to be significantly lower in osteoporotic patients.

CONCLUSIONS: Osteoporosis has significant adverse effects on masticatory functions of complete denture wearers, such as neuromuscular and chewing pressure components.

KEY WORDS: bite pressure, bone mineral density, electromyography, masseter, osteoporosis, temporalis.

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INTRODUCTION

Complete denture prosthodontics is the body of knowledge and skills related to rehabilitation of the edentulous arch with removable prosthesis [1]. Since many years, dentists and prosthodontists have been committed to the task of restoring chewing ability and masticatory efficiency in edentulous individuals. Although there is no consensus whether conventional complete dentures improve the quality of life, studies do suggest a positive association between the two [2-5]. In developing countries, where a huge part of the population lies outside the affordability bracket for an implant-supported fixed prosthesis, it becomes prudent to provide good quality conventional dentures for edentulous patients to improve their general health and well-being. Most of these edentulous patients constitute the elderly population, who are plagued with yet another chronic ailment: osteoporosis. Osteoporosis is a common chronic metabolic bone disease, which is characterized by loss of bone mass, increased bone fragility, and susceptibility to bone fracture [6, 7]. Increasing age and hormonal changes, such as menopause are common risk factors for this disorder. The International Osteoporosis Foundation has predicted that every 1 person in 3 women and 5 men over the age of 50 will experience osteoporotic fractures globally [6]. To assess the fracture risk and screen for osteoporosis, bone mineral density (BMD) is evaluated based on a standardized score introduced by the World Health Organization (WHO) [8]. Diagnostic categories are: normal (T-score, –1.0 and above); low bone mass, referred to as osteopenia (T-score, between –1.0 and –2.5); osteoporosis (T-score, –2.5 and below); severe osteoporosis (T-score, –2.5 and below with a history of fracture). Dual-energy X-ray absorptiometry (DXA) is the gold-standard for diagnosing osteoporosis and monitoring BMD changes [9-11]. BMD assessed by this method can be interpreted using the WHO T-score definition given above.

Sufficient data have already been published that show systemic osteoporosis aggravates bone loss in facial skeleton, especially in regard to an acceleration of residual ridge reduction [12-16]. This effect may possibly lead to dysfunction of the masticatory system, lesser masticatory muscle strength, and diminution in bite force in patients with osteoporosis [17-20]. Edentulous individuals rehabilitated with complete dentures have also been found to exhibit less masticatory pressure in comparison with dentate subjects during clenching and mastication [21-25]. The probable reasons behind this are presumed to be multivariate [26, 27]. It is important, therefore, to examine whether lowered bone mineral density in the edentulous maxilla and mandible can cause an alteration of function (mastication), which in turn may affect health and quality of life of complete denture wearers.

Electromyography (EMG) is an important tool to assess functioning of head and neck muscles that include muscles of mastication. EMG has been undertaken to investigate myofunctional abnormalities and their effect on stomatognathic activities, such as mastication, swallowing, speech, etc. [26, 28]. Patients with complete dentures present with lower EMG activity of muscles of mastication (masseter and temporalis) than their dentate counterparts [29, 30]. This may be attributed to the absence of periodontal mechano-receptors in edentulous patients, with mucosal mechano-receptors that have a high activation threshold, performing the primary feedback mechanism for masticatory muscle activity [29, 31]. Alteration of muscle function has also been demonstrated in osteoporotic individuals [19, 32].

Significant correlation has been shown between bite force and EMG activity of masticatory muscles. However, data is lacking on the effect of osteoporosis on bite pressure and EMG activity of muscles in complete denture wearers. It is important to determine how this disease may affect masticatory function in the already compromised edentulous condition. This study was therefore undertaken to investigate the influence of osteoporosis on bite pressure.

OBJECTIVES

The aim of this study was to compare bite pressure and electromyographic activity in edentulous osteoporotic and normal BMD subjects post-conventional complete dentures rehabilitation. The null hypothesis of this study was that there will be no difference in bite pressure and EMG masticatory muscle activity between osteoporotic and normal BMD complete denture patients.

MATERIAL AND METHODS

This prospective cohort study was carried out in the Department of Prosthodontics of our institute, among edentulous male and female patients, aged 50-70 years, visiting for fabrication of conventional complete dentures. Following selection criteria were used for enrolment after obtaining ethical clearance (Ref. code: 76th ECM II-B-Th./ P25).

Inclusion criteria: Completely edentulous subjects, aged between 50 and 70 years, and graded class II as per American College of Prosthodontics classification [33]. Subjects should have been edentulous for more than 6 months (rate of residual ridge resorption was maximum within first 6 months of extraction) [34, 35], with no reported metabolic, endocrine, or skeletal diseases. Patients should not be previous denture wearers (previous denture wearers may have trained musculature than those without a history of prosthetic rehabilitation), and have a favorable attitude according to MM House classification [36].

Exclusion criteria: Subjects having diseases that compromise the masticatory system, including but

not restricted to neurological disorders, cerebral palsy, temporomandibular joint (TMJ) disorders, and myofascial pain syndrome. Subject taking medication that interfere with muscular activity, such as anti-histaminic, sedatives, or depressants of the central nervous system. Any treatment that directly or indirectly affects muscle activity, including speech therapy or otorhinolaryngological procedures. Patients having a history of smoking, alcoholism, or drug abuse [10]. However, no screening examination to exclude pain and tenderness in TMJ or masticatory muscles was performed.

As there was no previous data to extrapolate sample size, the study was designed as a pilot study with sample size based on study duration and patient availability. A total of 80 subjects were recruited, following informed consent process, over a study duration of 2 years and 3 months. Bone mineral density (BMD) assessment was done using dual-energy X-ray absorptiometry. Based on findings, 2 groups were formed: NORM group, comprising of 44 non-osteoporotic patients, and OSP group, including 36 osteoporotic subjects. Osteopenic subjects were excluded at this stage.

Fabrication of maxillary and mandibular complete dentures was performed for all subjects [37]. Quality of fabrication was standardized and validated by two investigators (PC and DA). Evaluation of EMG of masseter and temporalis muscles, and bite pressure was done simultaneously 1 month after the final denture adjustment appointment.

EMG acquisition involved an 8-channel simultaneous recording with a common ground applied to all channels. The parameters were as follow: low-pass filter of 10 Hz to 10 kHz, channel input impedance of not more than 10 kΩ in differential mode, 3 bites of dynamic resolution range, an amplitude band of –100 mV to +100 mV, and a channel sampling frequency of 2 kHz. Nicolet EDX Synergy software was used for signal visualization and processing. Two silver-bromide surface differential active electrodes, 10 mm in diameter, kept at a 20 mm distance were utilized [38-40]. Regions of electrode placement were cleaned with alcohol and shaved, if required. Conductive paste was applied to that area. Silver bromide discs were positioned bilaterally over the belly of masseter muscles, and in anterior portion of temporalis muscles [38]. Electrode positions were determined by palpation and fixed with adhesive tape, ensuring their orientation being parallel to the direction of muscle fibers. A circular 30 mm radius stainless steel electrode, taped to the frontal bone skin, served as the reference or ground electrode.

Patients were kept in a quiet and peaceful room, sitting with arms and legs relaxed, head unsupported and back straight, and Frankfurt horizontal plane parallel to the ground. Masseter and temporalis muscles recordings were made only during maximal clenching. For each subject, an average of three stable signal EMG values (mean of left and right muscle value to eliminate variation caused by muscle asymmetry), each recorded over a period of 5 seconds with 2-minute intervals, was obtained. To ensure subject comparability, raw data were normalized by the ratio of each surface EMG recording to maximal voluntary contraction activity.

Bite pressure was measured with Fujifilm pressure distribution mapping system for Pre-scale (FPD-8010E version 2.0) [41-43]. Dental Pre-scale is a pressure image system that scans the pressurization and converts it into pressure values. Patients were made to sit on a comfortable chair, with arms extended and hands on their thighs. After attaching the surface electrodes, Pre-scale film (Fuji Pre-scale Sensors, Fuji Photo Film Co., Tokyo, Japan) placed in Nupai bite holders (Nupai bite scan, India) [41, 42] was covered with disposable plastic sheets and positioned in patient's mouth between the maxillary and mandibular dentures. With the surface electrodes attached and the Pre-scale film secured in place, the patient was asked to bite hard (1 second) onto the sensor. Amplitude (microvolts) was recorded at the same time with the help of surface electrodes and software.

Statistical analysis was performed using SPSS (Statistical Package for Social Sciences, Chicago, IL, USA) version 24.0 software to compare bite pressure as well as masseter and temporalis muscles EMG activity, for the osteoporotic and normal BMD groups. Shapiro-Wilk test was done to evaluate normality of distribution. Descriptive tests used included mean, standard deviation, range, chi-square, and independent sample t-test, with p-values < 0.05 considered statistically significant.

RESULTS

Fifty-five percent of the subjects belonged to the normal BMD group. While comparing BMD in the three age groups, i.e., 50-56 years ($n = 20$), 57-63 years ($n = 25$), and 64-70 years ($n = 35$), osteoporotic subjects were significantly higher (51.43%) in the 64-70 years age group, and normal BMD subjects were significantly higher (65%) in the 50-56 years age group (Table 1).

Both the maximum and average bite pressure evaluation (Table 2) showed lower values for osteoporotic subjects, which were statistically significant ($p = 0.04$ and $p = 0.01$, respectively). The EMG amplitude value comparison for masseter and temporalis muscles (Table 3) was also significantly lower in osteoporotic than normal patients ($p = 0.005$ and $p = 0.03$, respectively). The mean amplitude for masseter activity was 177.33 microvolts and 279.70 microvolts for osteoporotic and normal patients, respectively. The mean value for temporalis muscle activity was 182.85 microvolts for the OSP group, and 277.78 microvolts for the NORM group subjects.

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TABLE 1. Comparison of osteoporotic and normal BMD groups with age

Factor	OSP group		NORM group		Total	
	n	%	*n*	%	*n*	%
Age (years)						
50-56 years	7	35.00	13	65.00	20	25.00
57-63 years	11	44.00	14	56.00	25	31.25
64-70 years	18	51.43	17	48.57	35	43.75
Total	36	45.00	44	55.00	80	100.00

$\chi^2 = 25.900 \ (df = 4), \ p < 0.05$

TABLE 2. Comparison of bite pressure (MPa) between OSP and NORM groups

Group	*n*	Mean (MPa)	Standard deviation (SD)	*p*-value
Maximum pressure				
OSP	36	25.21	2.53	0.04*
NORM	44	29.94	2.54	
Average pressure				
OSP	36	8.99	1.20	0.01*
NORM	44	11.05	1.39	

TABLE 3. Comparison of EMG amplitude (microvolts) between OSP and NORM groups

Group	*n*	Mean (SD) (microvolts)	Range	*p*-value
Masseter				
OSP	36	177.33 (131.94)	88.70-602.65	0.005*
NORM	44	279.70 (128.25)	41.95-476.85	
Temporalis				
OSP	36	182.85 (118.77)	88.30-607.05	0.03*
NORM	44	277.78 (92.51)	23.30-370.05	

DISCUSSION

Osteoporosis has become a major global public health problem, and is increasingly prevalent in the ageing population. Age and changes in hormonal levels represent the major cause of osteoporosis in the elderly. Furthermore, inadequate masticatory function has proven to be a potentially correctable cause of malnutrition in the older population. Studies have shown that loss of dentition results in avoiding selected foods based on consistency and texture [43]. Increasing age further impairs mastication because of diminished neuromuscular control. Nutrition has been found to play an important role in promoting and maintaining bone mass [44-47]. Therefore, the interplay of osteoporosis and impaired masticatory function and nutrition deserves further study.

After the selection of subjects and delivery of complete dentures, participants were re-called every week till the completion of dentures adjustment period. Bite pressure and EMG activity tests were performed 1 month after final denture adjustment, and compared for osteoporotic and normal BMD groups. This adjustment period allowed new memory patterns for mastication to be established for masticatory muscles [48].

Dental Pre-scale is a computerized occlusal analysis system that can be utilized to obtain masticatory pressure in dentate and denture-wearing individuals. The sensor film consists of a dye, which is released on application of pressure, and releases red color corresponding to the area of occlusal contacts. The more the exerted pressure, the more intense the color. A color image scanner determines the area of contact and occlusal pressure by measuring the area and density data. The pressure image software digitally converts the area of contact to pressure values obtained as bite pressure per mm² of the occlusal contact area [49].

Masticatory pressure is important to assess the condition of stomatognathic system. Edentulous individuals rehabilitated with complete dentures show a considerable reduction in masticatory pressure and efficiency (one-fifth to one-quarter of the maximal masticatory pressure recorded in individuals with healthy natural teeth) [16, 24, 29, 30, 50-53]. This could be due to atrophy of the muscles of mastication and loss of muscle training.

In the present study, osteoporotic subjects showed lower maximum and average masticatory pressure than normal subjects, which was in conformance with previous work, where positive association of osteoporosis was observed with reduced muscle mass, strength, and function. Muscle mass decrease may be due to transformation into fat, leading to a decreased tissue elasticity and capacity for contraction [17, 19, 23, 54]. Bite pressure in edentulous individuals has been linked to non-physiological factors, such as facial osteoporosis [16]. Laudisio *et al.* [17] also derived that occlusal forces in subjects with high bone mineral density were significantly higher than those with low BMD. Since masticatory pressure directly influences masticatory efficiency, reduced pressure in complete dentures wearing subjects

afflicted by osteoporosis may further deplete nutritional acquisition and increase morbidity.

Reduction in bone mass due to poor nutrition in the ageing edentulous population when combined with osteoporosis may lead to further reduction in bone mass and muscles. The study showed lower EMG amplitude of masseter and temporalis muscles for the osteoporotic group (Table 3). Ageing has been reported to lead to a decrease in skeletal muscle mass, length and cross-sectional area, with a decrease in both muscle fibre size and number [55]. Lexell [56] showed a decrease in type 2 muscle fibers with aging. Another study showed individuals with osteoporosis having less activity during dental clenching. This possibly represents masticatory muscular dysfunction caused by depletion of the bone and muscle strength. Klemetti *et al.* [55] observed that masseteric muscle contraction is proportional to bone mineral density of the mandible. Therefore, it may be assumed that BMD and force exerted by muscles of mastication are inter-related.

Various receptor muscle spindles, periodontal and intra-dental press receptors, responsible for influencing activity of motor neurons are absent in edentulous patients [31]. As a result, sensory feedback is altered. Combined with decreased BMD (which leads to a decreased activity of muscles of mastication), this may further reduce EMG activity in the osteoporotic edentulous subjects.

The current study found the osteoporotic patients to have lower masticatory pressures, and electromyographic activity in the edentulous subjects. Considering that edentulism and osteoporosis are conditions common in the elderly, it is essential to look out for the latter, while rehabilitating the former. Completely edentulous patients should be routinely screened for their BMD status. This can be done with the help of proper history taking, paying attention to radiologic signs, and a definitive investigation, if there is a cause for suspicion [57]. Lack of dentition leads to improper mastication and digestion of proteins, which in turn affects calcium utilization [58, 59]. Protein deficiency leads to decreased muscle volume, which can affect bite pressure. Also, rapid ridge resorption in the edentulous may lead to negative calcium balance [58, 59] that is accentuated by improper intestinal calcium absorption. The result is a calcium-deficient condition that could contribute to osteoporosis [58, 59]. Timely management of osteoporosis would help reduce depletion of jawbone mass and volume as well as masticatory muscle function. This in turn would help maintain nutritional balance and requirements of the patient, and improve quality of life and systemic outcome.

Study limitations included a short post-insertion adjustment period before recording observations (1 month). Longer time duration before testing may have led to an improved pressure and EMG values due to better adaptation of dentures, muscle training, and nutritional supplementation. Factoring in the effect of possible con-

founders, such as gender, age, socio-economic status, and intra-oral morphology on bite pressure and electromyographic activity will help validate the study findings. Studies comparing objective and subjective masticatory efficiency and ability in addition to bite pressure and EMG activity, EMG examinations other than only in maximal clenching position, and prior examination of TMJ and masticatory muscles as an inclusion criterion, shall all enhance clinical relevance of this research.

CONCLUSIONS

Bite pressures generated (maximum and average) were significantly lower in osteoporotic complete denture wearers than in normal BMD complete denture wearers. EMG amplitude for masseter and temporalis muscles was significantly lower for osteoporotic than normal BMD edentulous subjects rehabilitated with complete dentures. Screening for osteoporosis is essential for edentulous patients in need of rehabilitation to improve mastication, nutritional intake, systemic health, and quality of life.

CONFLICT OF INTERESTS

The authors declare no potential conflicts of interest concerning the research, authorship, and/or publication of this article.

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