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Review Article

Evaluation and appraisal of osteopenia on jaws: An update

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Abstract

The aim of the present work is to review data of the OSTEODENT project, whose purpose was to compare dental X-rays with DXA results in order to determine the possibility of diagnosing osteopenia and osteoporosis, in advance. OSTEODENT project provided us with up-to-date data which are presented directly and briefly in this paper in order to compare techniques and methodologies that have been used by each research group. Researchers examined pre - existing dental panoramic and periapical X-rays on subjects of specific criteria, primarily women 45-70 of age. Measurements of bone density were calculated on these X-rays using pre-existing classifications, consequently they were compared to accurate bone density measurements according to DXA. Comparing the results, researchers were able to determine the accuracy, in question, of the methods used. These data have been processed by four university institutes in Europe, using pre-existing classifications, yet the aforementioned project provided the background for new merged clinical classifications as well as new documentation systems. All studies agree towards the direction that there is a larger need for further research on craniofacial imaging and metabolic bone diseases.

Keywords: Dental panoramic x-ray, OSTEODENT, Osteopenia, Osteoporosis

Introduction

Osteoporosis is a chronic bone metabolic disease that leads to a gradual decrease of bone mass and deterioration of the micro-architectural bone structure. In addition, to multiple clinical manifestations, the risk of fracture increases mainly in the cortical bones. It affects mostly people over 70 years old, with significant prevalence in postmenopausal women[1,2]. The densitometric diagnosis of osteoporosis relies solely, according to WHO, on Dual Energy X-ray Absorbiometry (DXA).

In many cases the patient fails to prevent severe outcomes, such as bone fractures, due to the lack of early diagnosis. DXA test requires the patient's access to a specialized diagnostic center referred by their treating physician. Any delay increases, in several cases of patients located far from urban centers, the progression of the disease considerably, causing significant impact on the quality of life. Early assessment could prevent such unfortunate storylines. If only it was possible, signs of the disease could be identified by more conventional and routine screening methods causing awareness and prevention.

Through this perspective the OSTEODENT[2] project was conducted, according to which the initial hypothesis was that simple panoramic imaging of the jaws "Dental Panoramic Radiograph" (DPR) can provide indications for further examination, or even an accurate diagnosis of osteopenia/osteoporosis[2]. The most common and abundant bone imaging are dental X-rays, justifying the reason they have

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been chosen. The project involved four European universities Athens (Greece), Manchester (Great Britain), Leuven (Belgium), Malmo (Sweden)[3], where data were collected from 671 postmenopausal women aged 45-70 years. Through the research program several imaging methods and pre-existing classifications of jaw bone density were used, since the idea was not original but had been studied in the past. However, the project revealed the necessity of new classification systems, combining methodologies. The results and the evaluation methods differ to some extent between university units.

The OSTEODENT project

Various parts of bone tissue were examined by DXA by conducting measurements for bone density determination (Bone Mineral Density (BMD)). In the present case there was a need for different methodological approach of bone density measurements and in particular, that of the lower jaw, which would emerge from the screening method of intra-oral dental X-ray (a qualitative imaging method), taking into account the two-dimensional form of the image. One such suggestion, which was used subsequently by many researchers, was that of Klemetti et al (1994)[4]. In particular, the different shades of bone screening (darker and lighter areas of the bone), indicate similar characteristics of bone architecture and this lead to the categorization of jaw imaging into three categories; a) C1: the intraosseous boundaries of the mandibular cortex are equal and distinct on both sides, b) C2: the intraosseous margins have crescent or cortical residues on one or both sides and c) C3: the intraosseous margins are visibly porous and bear strong residues of cortical bone in function of spongy bone.

This was in agreement with another study by Ledgerton et al. (1999), which introduced the definition of Mandibular Bone Mineral Density (MBMD), as well as it's relation to age[5]. In a subsequent study, Richy et al. (2003) examined the Osteoporosis Index of Risk Factor (OSIRIS) (resulting from the combination of the aforementioned measurements and the patient's medical history), establishing this factor as one of the most valid indicators of reduced bone density and consequently osteoporosis[6]. Noteworthy, few studies that preceded the OSTEODENT project, significantly influenced its conduct. In the work by Halling et al (2004)[7], a comparison was attempted with the suggested classification in the study of Klemmeti et al. (1994). Both studies concluded that the absence of imaging pathological findings on panoramic radiography can be considered as high prognostic factor for the absence of osteopenia/osteoporosis. These findings were cross-examined with the DXA method in paired subjects, supporting this conclusion. Similarly, Taguchi et al. (2004) suggested that panoramic X-rays can be used as a diagnostic tool, when combined with other assessment methods[8]. In particular, they compared the indicators of Osteoporosis Self-Assessment Tool (OST), the width and formation of cortex bone in two groups of post-menopausal women divided as; a) healthy (with no history of hysterectomy) and b) post-menopausal women with a history of hysterectomy, oophorectomy or under estrogen treatment, and concluded that in combination with a special questionnaire, reduced bone mass could be diagnosed with the supplemental careful examination of panoramic X-rays. The same conclusions reached a study by White et al. (2005) emphasizing that the dentist's contribution through his daily practice, could be crucial in the sense that it could refer a patient suspected for osteopenia to a specialist[9].

The first study from the OSTEODENT project was published in 2007 by Devlin et al. (2007) where the measurements of MBMD on panoramic radiographs were compared to measurements of DXA on hip and spine[2]. Furthermore, the measurement of the cortex thickness of the lower jaw, especially in the area of the second premolar, (Mandibular Cortical Width (MCW)) was considered. This study concluded that for Cortical Width (CW), with CW>4 mm there is considerably higher sensitivity for the accurate diagnosis of osteopenia and for CW<4 mm significantly higher specificity. This research team concluded that for subjects where the respective areas of cortical bone have thickness <3 mm, were in significant risk for osteoporosis.

Karayianni et al. (2007) compared the MCW measurements with the OSIRIS factor in dental panoramic radiographs and of course the validity of the results was validated with DXA, concluding that in comparison, the MCW measurement was more reliable[3]. Horner et al. (2007), on the same page, concluded that MBMD classification is not sufficient as the only indication method for osteopenia/osteoporosis[10]. On the other hand, Geraets et al. (2007) had a slightly different approach, as they selected four points of interest in DPRs but also included in the study two posterior alveolar radiographs[11]. Comparing dental X-rays with BMD of the subjects, including the age factor, they concluded that imaging of the upper jaw does not show significant clinical signs, but there is a statistical correlation between the study measurements from the lower jaw and BMD measurements. Overall, the aforementioned studies suggested that DXA, although the best standard for the estimation for osteoporosis and osteopenia, dental X-rays are very promising to be used after further research.

In 2008 a new set of data was published, concerning the OSTEODENT program, where Devlin et al. (2008) compared the MCW and OSIRIS methods[12]. From this comparison a new index emerged, the OSTEODENT index, which combined the two methods, giving better predictability significantly. In particular, the OSTEODENT index "is a predicted probability of osteoporosis derived from a combination of an automated analysis of a dental panoramic radiograph and clinical information. This index has been proposed as a suitable case-finding tool for identification of subjects with osteoporosis in primary dental care"; however, no data exist on the relationship between OSTEODENT index and fracture risk[13]. Further on, Lindh et al. (2008) expanded the study

Table 1. Summary of the OSTEODENT studies with respective publications.

Article	Number of subjects	Measurement method	Suggested categorization	Random founding	Co-existing diseases	Sensitivity	Specificity	Statistically or not important difference / Results
Devlin 2007 Diagnosing osteoporosis by using dental panoramic radiographs: The OSTEODENT project[2].	653 post – menopausal women aged 45-70	DXA, DPRs	MCI CI:1-3 MCW <4.5 mm Lower jaw T-score	Pre – existing DPRs	Excluded: Secondary osteoporosis, not controlled thyroiditis, hyperparathyroidism, liver disease, alcoholism.	CI<1, CW>4 71% CI=1, CW<4 10%	CI<1, CW>4 40% CI=1, CW<4 99%	Areas where cortical bone <3 mm, are considered risk indicators for osteoporosis
Karayianni 2007 Accuracy in osteoporosis diagnosis of a combination of mandibular cortical width measurement on dental panoramic radiographs and a clinical risk index (OSIRIS): The OSTEODENT project [3].	653 post – menopausal women aged 45-70	DXA, DPRs	MCW, ROC, OSIRIS <1	Pre – existing DPRs	Excluded: secondary osteoporosis, primary hyperparathyroidism, poorly controlled thyrotoxicosis, malabsorption, liver disease, alcoholism	OSIRIS 70,9% MCW>3 mm: 41-59,6% MCW>4,5 mm: 94,2-99,3%	OSIRIS 79,5% MCW>3 mm: 81,8-90,3% MCW>4,5 mm: 9,8-23,7%	MCW index, more valid than OSIRIS index
Horner 2007 The Mandibular Cortex on Radiographs as a Tool for Osteoporosis Risk Assessment: The OSTEODENT Project [10].	653 post – menopausal women aged 45-70	DXA, DPRs	MCI, OSIRIS	Pre – existing DPRs	Excluded: secondary osteoporosis, primary hyperparathyroidism, poorly controlled thyrotoxicosis, malabsorption, liver disease, alcoholism			MCI not sufficient
Geraets 2007 Prediction of bone mineral density with dental radiographs[11].	525 post – menopausal women aged 45-70	DXA, DPRs and two intraoral dental X-rays	4 areas of interest where chosen on the DPR, 2 intraoral dental X-rays both upper and lower jaw		Excluded: secondary osteoporosis, primary hyperparathyroidism, poorly controlled thyrotoxicosis, malabsorption, liver disease, alcoholism			There is an association between DPRs, and BMD, potentially of the same power.
Devlin 2008 The role of the dental surgeon in detecting osteoporosis: The OSTEODENT Project[12].	652 women aged 45-70	DXA, DPRs	MCW and OSIRIS strategies compared	Pre – existing DPRs		(95% CI=60.2 to 76.1):69%	(95% CI=87.1 - 92.5):90%	There was a significant improvement in the diagnostic ability of the combined OSIRIS and cortical width test, as compared to the individual tests (p<0.001).
Lindh 2008 The use of visual assessment of dental radiographs for identifying women at risk of having osteoporosis: The OSTEODENT project[14].	600 women aged 45-70	DXA, intraoral dental X-rays in the areas of second premolars, upper and lower jaw	Kappa index: 2+3, 3 indication for osteoporosis examination	Subjects with pre – existing DXA where included	Excluded: secondary osteoporosis, primary hyperparathyroidism, poorly controlled thyrotoxicosis, malabsorption, liver disease, alcoholism	Upper jaw: 28,2% Lower jaw: 28,2%	Upper jaw: 91,6% Lower jaw: 90,8%	The method is a sufficient indicator for osteoporosis.
Karayianni 2009 Tooth loss and osteoporosis: The OSTEODENT study[15].	651 women aged 45-70	BMD, number of teeth	Number of teeth of subjects with or without osteoporosis. Factors age and smoking are examined		Excluded: secondary osteoporosis, primary hyperparathyroidism, poorly controlled thyrotoxicosis, malabsorption, liver disease, alcoholism			p-value=0.016 for <6 teeth p-value=0.011 for <28 teeth
Horner 2010 The relationship between the OSTEODENT index and hip fracture risk assessment using FRAX[13].	339 women aged 55.3 average (through two institutes)	BMD, DPR	OSTEODENT index and FRAX compared					There are indications to suggest the association of the two parameters but further investigation is required for better results.
Devlin 2007 Diagnosing osteoporosis by using dental panoramic radiographs: The OSTEODENT project[2].	653 post – menopausal women aged 45-70	DXA, DPRs	MCI CI:1-3 MCW<4.5 mm Lower jaw T-score	Pre – existing DPRs	Excluded: Secondary osteoporosis, not controlled thyroiditis, hyperparathyroidism, liver disease, alcoholism.	CI<1, CW>4 71% CI=1, CW<4 10%	CI<1, CW>4 40% CI=1, CW<4 99%	Areas where cortical bone <3 mm, are considered risk indicators for osteoporosis

by introducing the Kappa Index (KI) method[14]. In their study, posterior radiographs of the upper and lower jaws were also included and added to the examination algorithm. The KI is composed by three classifications (C1, C2, C3) based on bone porosity, were the combination of C2 and C3 as well as C3 alone, indicate the possibility of osteopenia/osteoporosis.

In the study by Karayianni et al. (2009), based on existing data, they examined possible correlation between the number of teeth and diagnosed osteoporosis[15]. Age and smoking were considered also as factors. The co-existence of periodontal disease despite the high rate of tooth loss as a symptom, was not taken into consideration in this study, nevertheless the discussion revolved around it. The presence of less than six and less than 28 teeth were considered significant respectively, suggesting no correlation between the diagnosed osteoporosis and the number of teeth. On the contrary, in 2013, an observational study was published on a sample of postmenopausal women aged 45-70 years by Darcey et al. (2013), which examined osteoporosis in correlation with periodontal disease, in which no significant statistical difference was observed between the two[16-18]. Finally, Horner et al. (2010) compared the OSTEODENT index and the Fracture Risk Assessment Tool (the FRAX index), aiming to associate the OSTEODENT project to the possibility of a bone fracture due to osteoporosis, concluding that there is clear evidence for a correlation between the two, but, a more extensive study is required to present valid results[13].

Devlin et al. (2015) published a review of the OSTEODENT project analyzing the indices used, the jaw imaging methods, the electronic systems used to classify bone porosity and the possible task of re-examining the high-risk thresholds of the measurements. In conclusion, they stressed that dental panoramic radiographs can be evaluated for indications of osteopenia/osteoporosis under specific conditions, regarding the observer, the equipment and the so far knowledge, but it is not yet considered as a diagnostic tool of the disease. An interesting study by Bollen et al. (2000), preceding OSTEODENT, examined a sample of 394 subjects with traumatic or absent hip fractures and 93 subjects with osteoporosis-related hip fractures, as well as the subject's dental panoramic radiographs[19]. In their study, the dental images which indicated osteopenia/osteoporosis tend to match subjects diagnosed with osteoporosis.

In order to assist towards the comprehension of the OSTEODENT study, we have summarized the findings of this study in the following table (Table 1).

Discussion

Through the OSTEODENT project, a wealth of information has been selected according to the utilization of X-rays regarding the bone mineral density. Dental panoramic X-ray is an examination performed, if not at various stages of a person's life, at least once. In cases where more than one panoramic images are at hand during a person's lifetime, it is suggested that by using appropriate processing of the images, their comparison should confer to the accumulation of further information. The dentist's contribution to the initial diagnosis of osteopenia/osteoporosis could be life-changing in many cases of patients unsuspicious for the existence or progression of their disease. The OSTEODENT project revealed differences between the classifications and the selected measurements between the studies, although it raised the clear conclusion that further research can lead to a holistic approach of simple observation and examination of dental radiography, regarding the osteoporotic disease. The dental community is trained for the detection of various diseases and illnesses either local or systemic, but so far not for the presence of osteopenia/osteoporosis. It is obvious that an important step has been taken towards this direction due to the OSTEODENT project, as well as by other research groups not mentioned in the present review. Yet, it is also necessary, in order to include this diagnostic tool in everyday day dental clinical practice, for the centralization of all the information and the conduction of additional research on the subject, in order to consequently transmit the knowledge and educate the dental community.

Previous studies have highlighted the use and importance of the OSTEODENT index and approach. In particular, it has been found that classification methods manifested the ability of the proposed algorithm to to "predict patient management decisions" and in particular, this comparison was made to the FRAX tool. Thus, the OSTEODENT index consists of a combination between clinical and radiographic data, whereas FRAX is derived from clinical data alone, despite the fact that FRAX considers more clinical data, as compared to the OSTEODENT index[2,10,12,13]. Furthermore, it has been reported that information provided by OSTEODENT, could probably provide insight to the BMD status, a fact compensating for the smaller number of clinical data items included. Thus, it is evident that the OSTEODENT tool can be used for the diagnosis of osteopenia. Although, several limitations have been reported, the OSTEODENT index has potential as a "case-finding tool for osteoporosis and as an indicator of hip fracture risk". Its main advantage is that it can be used in the daily primary care, which is the dental healthcare. Yet, further investigations are required in order for the algorithm to strengthen its position and diagnostic efficacy.

Conclusions

The primary conclusions that emerge from this article can be summarized to four main points. In the area of the second premolars of the lower jaw, for bone marrow thickness CW<3 mm, there is a clear indication for referral of the patient to be examined for osteopenia/osteoporosis. The MCW index outperforms the OSIRIS index in terms of the indication of the disease. The MBMD method alone is not sufficient for the assessment of osteopenia and finally, comparing different

two-dimensional dental X-rays from different areas of the oral system, the panoramic dental X-ray shows a significant advantage in comparison to the intraoral dental X-ray, providing the most valid information.

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