Available online at http://www.journalijdr.com

International Journal of
DEVELOPMENT RESEARCH

ISSN: 2230-9926

International Journal of Development Research
Vol. 5, Issue, 02, pp. 3502-3507, February, 2015

Full Length Research Article

THE INNOVATIVE TECHNIQUE OF UTILIZING PANORAMIC RADIOGRAPHY FOR PREDICTION OF OSTEOPOROSIS: INVENTION TO RECENT ADVANCEMENT

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ARTICLE INFO

Article History:

Received 28th November, 2014
Received in revised form
31st December, 2014
Accepted 20th January, 2015
Published online 27th February, 2015

Key words:

Panoramic radiography,
Radiomorphometric indices,
Orthopantomographs,
Skeletal osteoporosis,
Mandible.

ABSTRACT

Dental panoramic radiographs or orthopantomographs, have received overwhelming attention from clinical researchers and dental practioners worldwide in the recent years. The credit for this interest is attributed to the potential use of orthopantomographs in the prediction of skeletal osteoporosis. Numerous radiomorphometric indices of the mandible bone and other radiographic parameters, devised by authors all over the globe have successfully correlated mandibular bone mass with bone mineral densities of skeletal sites important for diagnosis of osteoporosis, computed through the current gold standard techniques. This unique and innovative technique of utilization of panoramic radiography in estimation of osteoporosis, has been modified and refined continuously over the years by a variety of researches conducted across the world. This review attempts to summarize the origins of the technique, contributions of prominent authors towards its improvement, inventions of eminent researchers leading to further sophistication in the field, recent advances and the current focus of contemporary research. The shortcomings in the technique and the potential aspects of future research directed towards their improvement, have also been explored in this review.

INTRODUCTION

Orthopantomographs are panoramically scanned dental X-rays of the upper and lower jaw. They show a two-dimensional view of a half-circle from ear to ear. Panoramic radiography is a form of tomography; thus, images of multiple planes are taken to make up the composite panoramic image, where the maxilla and mandible bones are in the focal trough. These radiographs permit visualization of the entire dentition, alveolar bone, cortical bone, trabecular bone and other contiguous structures on a single extraoral film (Whaites, 2007). These are routinely used in dental clinics on a large section of adult population for dental treatments, implants, cosmetic and reconstructive surgeries, etc. In the recent years, the successful correlation of mandibular bone mass with that of bone mineral densities of skeletal sites traditionally associated with diagnosis of osteoporosis i.e. lumbar spine and neck of femur, has led the practioners across the whole world to explore the utilty of orthopantomographs in detection of osteoporosis (Von Wowern *et al*., 1994; Horner *et al*., 1996; Klemetti *et al*., 1993; Taguchi *et al*., 1996 a).

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The potential benefits of dental panoramic radiographs in comparison to the current gold standard techniques of diagnosing osteoporosis, for example- easy availability, cost-effectiveness and safety resulting from minimal radiation exposure, etc. has prompted the dentists to research this technique from every angle possible (White, 2002) . This review article attempts to present the contribution of the most prominent of the numerous researches undertaken worldwide over the years, in the development of this technique of utilizing panoramic radiography for prediction of osteoporosis; in a summarized form, based on the existing literature.

Panoramic radiography and osteoporosis: A long association

A lot of radiomorphometric indices of the mandible have been developed over the years by various authors to establish the correlation between altered mandibular morphological characters and osteoporosis (Devlin and Horner, 2002). Among the devised indices, the most prominent ones are those associated with the qualitative and quantitative estimation of the mandibular cortical bone, for example, the panoramic mandibular index, mental index, gonial index and the antegonial index. Whereas, the parameters developed for the analysis of alveolar bone include mandibular total height, basal bone height and trabecular fractal analysis (White, 2002). Taking the next step in this direction, successive research teams have included multi-racial populations in their studies to determine and enhance the sensitivity, specificity and reproducibility of these radiographic indices/parameters in identification of osteoporosis. The variety of techniques employed for the purpose included the use of out-patient questionnaire tools, association with biochemical markers of metabolic bone loss and direct or indirect comparisons with the current gold standard technique of diagnosing osteoporosis i.e. DEXA (Dual Energy X-ray Absorptiometry) scan (Devlin and Horner, 2002; Mahl *et al*., 2008; Morita *et al*., 2009; Taguchi., 2004). Few authors have also conducted studies directed towards the establishment of standard cut-off threshold values of the radiomorphometric indices for determination of osteoporosis (Devlin and Horner, 2002; Dutra *et al*., 2007; Devlin *et al*., 2007; Gulsahi *et al*., 2008) . A lot of contemporary studies have focused on the correlations between the various radiomorphometric indices and confounding variables like age, gender and dental status. The knowledge of these interactions has further highlighted the importance and augmented the utility of panoramic radiography in detection of osteoporosis.

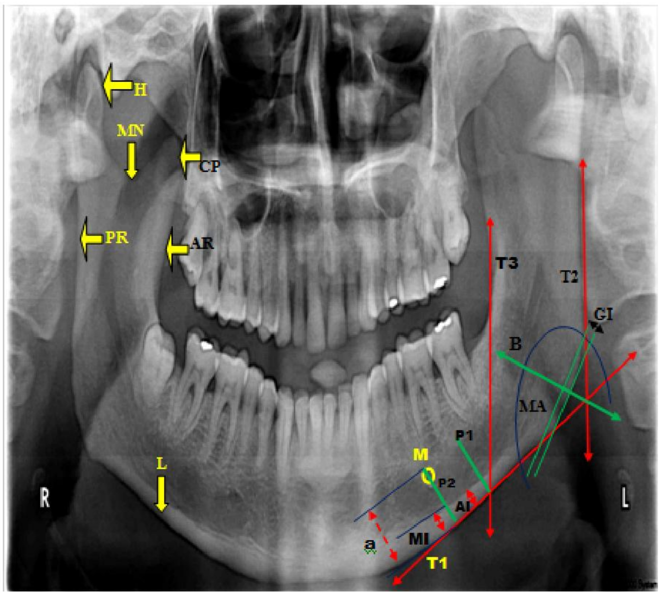

Fig. 1. Measurement of mandibular radiomorphometric indices on an orthopantomograph

T1-Line tangent to lower border of mandible (L). T2-Line tangent to posterior border of ramus (PR) of mandible. T3-Line tangent to anterior border of ramus (AR) of mandible. P1-Perpendicular to T1 passing through centre of mental foramen (M), P2-Perpendicular to T3 at its intersection with L. B-Bisectrix of angle formed between T1&T2 i.e. MA-Mandibular Angle. a-Distance between the superior margin of mental foramen and inferior mandibular border. Mental Index (MI)-Cortical thickness on P1. Panoramic Mandibular Index (PMI)-MI/a. Antegonial Index (AI)-Cortical thickness on P2. Gonial Index (GI)-cortical thickness on B. CP-Coronoid Process, H-Head of mandible, MN-Mandibular notch.

The prominent global studies: A summarized review

Wical *et al*., 1974 devised a method of estimating the severity of mandibular bone resorption by using the mental foramen and the inferior border of the mandible, as they appear in panoramic radiographs, as reference points. This method of measurement formed the basis of many other radiomorphometric indices (to evaluate mandibular bone loss on panoramic radiographs). A larger alveolar bone loss of mandible has been reported to be associated with lower skeletal bone mineral density or osteoporosis in post menopausal women. Mandibular Total Bone Height (TBH) and Basal Bone Height (BBH) at the site of mental foramen (i.e. height from the centre of mental foramen to the inferior border of the mandible) are used to calculate the mean TBH/BBH ratio. Low TBH/BBH ratio has been reported to indicate high alveolar bone loss of the mandible. The structure of trabecular bone has been analyzed in relation to osteoporosis with fractal analysis. Such textural analysis measures the pattern of trabeculae and includes determining the thickness of trabeculae, spacing between trabeculae and the measures of trabecular connectivity. This analysis can be made on dental radiographs manually or by morphodigital studies using specially developed software for this procedure. There is evidence in literature that the trabecular pattern of the jaws is altered in subjects with osteoporosis.

Bras *et al*., 1982 first devised the gonial index; defined as the thickness of the mandibular angular cortex at the gonion (fig.1) and measured it on panoramic radiographs of 180 normal persons. They reported that before the fifteenth year, a distinct cortical layer was missing. After the fifteenth year, the thickness of the mandibular angular cortex was relatively constant (average: 1.56mm ± 0.26mm); except in post-menopausal women of 60 years and older, where the cortical thickness was distinctly thinner (average: 0.84mm). Kribbs *et al*., 1990 reported the cortical thickness at gonion (Gonial Index) in 50 normal women between the ages of 20 and 90 and that the cortical thickness at gonion decreased with age and was related to skeletal bone mass. Kribbs, 1990 compared the cortical thickness at the gonion in normal older women with age matched osteoporotic women. The thickness was significantly greater in normal group (mean 1.04mm) than in the osteoporotic group (mean 0.89mm). The author concluded that osteoporosis adversely affects mandibular bone with a thinned cortex at the gonion.

Benson *et al*., 1991 first defined the panoramic mandibular index (PMI), a quantitative radiomorphometric index of mandibular cortical bone mass. The differences in this index in a population of 353 adult subjects equally divided by sex, age from 30 to 79 years and racial groups (Black, Hispanic and White) were evaluated. They reported that Blacks were found to have a greater mean PMI than Hispanics or Whites. Age related changes comparing younger and older age groups within each sex and racial group indicated a significant decrease in mean PMI with increasing age in black and Hispanic women. The mean PMI in white men increased with advancing age.In the technique devised by Benson *et al*., 1991, PMI was calculated as the ratio of mandibular cortical thickness divided by the distance between the superior margin of mental foramen to the inferior border of the mandible. Hence it is synonymously termed as SPMI or Superior Panoramic Mandibular Index (fig.1). IPMI or Inferior Panoramic Mandibular Index is another variant of PMI, described by Ledgerton *et al*., 1997 which uses the distance between the inferior margin of mental foramen to the inferior border of the mandible as the denominator instead. SPMI is usually preferred over IPMI since it has shown better results in many studies. Gungor *et al* reported the precision of the panoramic mandibular index and reported the precision values to the sufficient (0.002-0.005). The precision figures of the superior panoramic mandibular index were almost two-fold better than those of the inferior panoramic mandibular index, implying presence of more consistency in its measurements. Ledgerton *et al*., 1997 devised a study designed to evaluate the intra-observer repeatability and inter-observer repeatability of the measurements used in deriving the panoramic mandibular index. For the cortical width, strong positive intra- and inter-observer measurement correlations were demonstrated in all cases on both the left and right sides. Mean differences in all compared measurements were small. Precision figures appeared more consistent for both inter- and intra- observer comparisons for superior and inferior foraminal distances, when compared to those for cortical width. The precision figures for superior foraminal distance measurements appear to demonstrate better consistency than those for the inferior distance and left sided precision figures were better than those for the right.

Klemetti *et al*., 1994 were first to describe the widely used classification of Mandibular Cortical Index (MCI). Subjects were classified into 3 groups (C1-C3) according to the following criteria: C1 (Normal). The endosteal margin of the cortex was even and sharp on both sides, C2 (Osteopenia). The endosteal margin of cortex showed semi-lunar defects (lacunar resorption) or seemed to form endosteal cortical residues (one to three) layers on one or both sides, C3 (Osteoporosis). The cortical layer formed heavy endosteal cortical residues and was clearly porous. The severity of the changes in the mandibular cortex (C1-C3) was significantly dependent on the mineral status of the skeleton, which was based on the normal value tables for bone mineral densities of the lumbar vertebrae and femoral neck. Taguchi *et al*., 1996 b reported high accuracy using the status of the mandibular inferior cortex on panoramic radiographs. They reported significant correlations between mandibular cortical width, mandibular cortical index classification and the total bone mineral density of L3 vertebrae. A study done by Zlataric *et al*., 2003 reported that MCI (Mandibular Cortical Index) assessment is related to BMD (bone mineral densities) values of both cortical and trabecular bone or cortical bone alone and therefore may be helpful for the assessment of local quality of mandibular bone structure. Uysal *et al*., 2007 reported that MCI was affected by gender and age. When the effects of age and gender were evaluated together, older woman had more porous mandibular cortex (higher MCI values).

Horner *et al*., 1996 conducted a study to investigate the relationship between mandibular bone mineral density (BMD) and that of other skeletal sites and to assess the validity of mandibular BMD in these other sites; in 40 edenteluous females (44-79 years of age). To derive data for mandibular bone mineral density (BMD), manual analysis was performed using rectangular customized regions of interest (ROI's) placed over three areas: the ramus, the body and the symphysis. Significant correlations were observed between BMD in the mandibular body, ramus and symphysis and all the other skeletal sites ($p \leq 0.02$). The authors concluded that the mandibular BMD assessed by dual-energy x-ray absorptiometry (i.e. DEXA-Scan) correlates significantly with BMD measurements of other important skeletal sites. They also reported that validation of mandibular radiographs as a means of detecting individuals who are at increased risk of osteoporotic fracture. They suggested that the body of the mandible may be the most appropriate site for any planned assessment of the validity of mandibular measurements as a predictor of general bone mass (Masud *et al*., 1996).

The measurement of the thickness of the cortical bone of lower border of mandible in the region of mental foramen (fig.1), was independently termed as the Mental Index (MI) by Ledgerton *et al*., 1997. Dutra *et al*., 2007 compared the inferior mandibular cortical thickness recorded using a digital caliper with the measurements on panoramic radiographs. The authors concluded that the bone status reports, based on measuring cortical thickness of the lower border of the mandible in the mental foramen region based on panoramic radiographs, i.e. the mental index, are accurate.[38] Devlin *et al*., 2007 reported in their study named "The Osteodent Project" that the cortical indices and cortical width are indicators of osteoporosis. The authors also concluded that when evaluating panoramic radiographs, only those patients with the thinnest mandibular cortices (i.e <3mm) should be referred for further osteoporosis investigation. Their study included six hundred seventy one post-menopausal women, aged 45 to 70 years of age; who underwent Dual Energy X-ray Absorptiometry (DEXA) scans of the left hip and lumbar spine (L1 to L4) and dental panoramic radiographic examinations of the teeth and jaws.

Hastar *et al*., 2011 reported in their research work done on Turkish population that while mean mandibular cortical width values (Normal value: ≥ 3mm as suggested by Devlin *et al*., 2007) and panoramic mandibular index values (Normal value: ≥ 0.3 as suggested by Benson *et al*., 1991) were normal in men over 60 years, the mean mandibular cortical width values and panoramic index values decreased significantly in women of the same age group. The authors also reported significant difference in the categories of Mandibular Cortical Index (MCI) between men and women, based on the appearance of inferior mandibular cortical border. Category C1 was more frequently seen in men, Category C2 was more frequently seen in women and Category C3 was observed only in women. Gulsahi *et al*., 2008 have reported that persons with Mental Index (MI) < 3 mm, Panoramic Mandibular Index (PMI) < 0.30 may be seen as high risk patients for osteoporosis. They also concluded that Mandibular Cortical Index (MCI) was significantly associated with age, MI and PMI. As age increased, the likelihood of being in the C3 category (age above 70 yrs) also increased. The likelihood of being in C3 category (age above 70 years) for patients with an MI < 3mm was 14.86 times higher than in patients with an MI ≥ 3mm. The likelihood of C3 category patients with PMI < 0.30 was 9.78 times higher than in patients with a PMI ≥ 0.30. Mudda *et al*., 2010 in their study on South Indian population have demonstrated significant differences between the pre menopausal and post menopausal groups for Mental Index (MI) and Panoramic Mandibular Index (PMI). Age was found to be correlated with MI and PMI in both patient groups. MI showed a negative correlation with age but PMI was positively correlated. A negative correlation was seen with age after the age of 60 years in the post menopausal group. Rao *et al*., 2011 conducted a study in the South Indian population in which analysis of bone mass of 100 healthy adults (50 males, 50 females) aged 30-60 years; using Panoramic Mandibular Index (PMI) was carried out along with comparison of the bone mass between both the genders and different age groups. The mean PMI for the selected population was 0.275. As the age advanced, the values of the mean PMI decreased, thus indicating that there was decrease in bone mass with age. The mean PMI in females was almost equal to that of the male mean PMI suggesting that there was no difference in the bone mass between the genders. The mean PMI of males within each age group showed a gradual decline in values, supporting the general consensus that bone mass decreases with increasing age. The mean PMI of females within age group showed gradual decrease in the values after the age of 50. The non-menstruating women had mean PMI values less than that of the menstruating, thus displaying the fact that the bone mass in post-menopausal women is less than compared to pre-menopausal women. Beatriz *et al*., 2011 evaluated the mental index and gonial index in 1287 digital panoramic radiographic images of Brazilian population that were grouped into five groups (17-70 years of age). Results for both the indices measurements showed significant differences among patient age groups of both the sexes, considering that the older age groups (56-70 years) presented lower values for the cortical width of both indices. Their study supported the role of sex and age related changes in mandibular radiomorphometric indices in identifying skeletal osteopenia. Raghdaa *et al*., 2011 in their study conducted on Egyptian subjects concluded that age had a significant influence on both the Panoramic Mandibular Index (PMI) and Mental Index (MI), but only MI was significantly influenced by gender. Both the indices remained independent of the dental status. Kalinoswki *et al*., 2011 have reported in their recent studies carried out on Polish patients that both age and gender had a significant influence on the Mental Index (MI), but the effect of age was more profound in comparison to gender.

Ledgerton *et al*., 1999 invented another radiomorphometric index of the mandible on panoramic radiographs, the Antegonial Index (AI)- measurement of cortical thickness of inferior mandibular border in the deepest concavity of the antegonial notch (fig. 1). Four other indices (mental index, gonial index, panoramic mandibular index, and mandibular cortical index) were also evaluated in this study. All the quantitative indices showed significant, negative correlation with age, i.e. all of them decreased with increasing age. They concluded that age-related changes in mandibular radiomorphometric indices and their variation within each age-band lend support to their potential use in identification of skeletal osteopenia. Knezovic *et al*., 2002 reported that mental index, panoramic mandibular index, antegonial index and gonial index showed a general downward trend with age for both sexes until 75 years of age when the mean values of gonial index, antegonial index and mental index begun to fall down sharply for females compared to males. The difference was significant between age groups and both sexes for gonial index and antegonial index. Only two categories (C2 (age 65-75 yrs) and C3 (age more than 75 yrs)) of mandibular cortical index were recognized in this study sample, due to relatively old age groups of patients with removable dentures. However, significantly higher incidence of C3 existed in the older group of females. Devlin and Horner, 2002 after comparing the cortical thickness at the mental foramen (Mental Index, MI), at the antegonion (Antegonial Index, AI) and at the gonion regions (Gonial Index, GI); concluded that only mental index contributed significantly to a diagnosis of low skeletal bone mineral density. The results of their study indicated that a diagnostic threshold for mental index of 3 mm (or less) was the most appropriate threshold for referral for bone densitometry. Dutra *et al*., 2005 have reported continuous remodeling in the mandibular cortex with age and this was influenced by dental status and gender. Gender was significantly associated with the antegonial index, and a significant interaction between gender and age was reported. The antegonial index among older females was significantly smaller; whereas it was greater for older males. The relationship of the mental index was significantly different for males and females. This index was smaller among older females whereas it was greater among older males. The same authors have observed in yet another study of theirs, that the mental index and antegonial index values decrease with increase in age (Dutra *et al*., 2006).

Mahl *et al*., 2008 compared various radiomorphometric indices (i.e. panoramic mandibular, mental, gonial, antegonial and mandibular cortical indices) calculated based on dental panoramic radiographs of post-menopausal women, with the bone densitometry results. The panoramic mandibular and mental indices presented the highest sensitivity in the detection of osteopenia/osteoporosis. All the indices evaluated could identify low bone density, but only the panoramic mandibular and mental indices could differentiate between the patients affected by osteoporosis and those affected by osteopenia. Dagistan *et al*., 2010 concluded in their study that the radiomorphometric indices - Mental Index, Panoramic Mandibular Index and Antegonial Index, were found to be smaller among male patients with osteoporosis, compared with the normal patients. However the values of Mandibular Cortical Index showed no significant difference. The authors suggested that the above mentioned indices, used as an ancillary method in the diagnosis of osteoporosis mostly in women, could also be useful for male patients. Kim *et al*., 2010 have recorded significant correlations between age and all the five linear radiomorphometric indices, i.e. Panoramic Mandibular Index (PMI), Mental Index (MI), Gonial Index (GI), Antegonial Index (AI) and Mandibular Cortical Index (MCI) in the Korean population. But significant association with gender was found only for PMI, MI and GI.

Conclusions and recommendations

Analysis of the available literature concludes that majority of the research work has focused on highlighting the role of panoramic radiographic parameters in identification of osteoporosis. But, very limited number of studies have been designed to establish the cut-off threshold values for the various radiomorphometric indices, which would escalate their status from being mere predictors of osteoporosis to standardized screening tests for the disease. There is scarcity in literature with respect to the evaluation and comparisons of the influence of age, gender and dental status on all the oral radiographic parameters in different ethnic populations and races. Therefore, future research is recommended with the objective of improving the deficiencies in existing literature.

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