Dental caries and bone mineral density: a cross sectional study


ABSTRACT. Aim The relationship between bone mineral density (BMD), age and dental caries has been studied. Quantitative ultrasonography (QUS) is an economic, non invasive, and reproducible method for measuring both bone mineral density and bone elasticity in growing subjects in large populations. Methods This study evaluated the relationship between BMD and prevalence of dental caries (Decayed Missing Filled Tooth - DMFT) in 540 healthy adolescent with mean age 12.3 years, age range 10 to 15 years, resident in two provinces in south Italy. BMD was measured using QUS by calculating the speed of sound (m/s) on the last four fingers of the non dominant hand, with the estimate thus obtained being defined as the AD-SoS (Amplitude-Dependent Speed of Sound and categorised as AD-SoS≤1900m/s and AD-SoS>1900m/s). Occurrence of dental caries was defined using the DMFT index (DMFT=0 and DMFT>0). Results The results of the multifactorial analysis, carried out with logistic model, confirms the expected statistically significant association between response (DMFT) and explicative variables - AD-SoS (P<0.006) and Age (P<0.004). Conclusion Greater bone mineralisation (AD-SoS>1900m/s) and younger age (Age ≤12 years) are dental caries prevention factors: the probability to have caries for the subjects in such conditions is 0.34, about the half of that recorded in the subjects with lower bone mineralisation and older age (0.62).

KEYWORDS: Dental caries, DMFT, Bone mineral density, Quantitative Ultrasound, Amplitude-dependent speed of sound, AD-SoS.

Introduction

Studies carried out in recent decades demonstrate that bone mineral density (BMD) changes with age, and the diagnostic importance of this variation is now universally recognised [National Osteoporosis Foundation, 1998]. BMD increases from infancy until peak at the age of 18-20. After this age, bone mass in the various skeletal sites stabilises and then progressively declines in both sexes from the third or fourth decade of life, with the decline in women increasing after menopause [Boot, 1997].

Insufficient bone mass during skeletal development in addition to predisposition to senile osteoporosis, is a risk factor for other hard tissue pathologies such as osteopenie (osteomalacia, post-menopausal osteoporosis), traumatic fracture, and dental diseases such as tooth loss and periodontal disease [WHO, 2003]. Other factors such as race, sex, nutrition, health, physical activity and lifestyles all correlate with BMD [Xu et al., 1997]. Regarding oral pathologies mainly the association between BMD and osteoporosis and periodontal disease in elders has been studied, describing related physiopathological mechanisms [Mohammad et al., 2003; Persson et al., 2001; Von Wowern, 2001; Reddy, 2002].

The hypothesis of a a correlation between bone mineralisation and dental caries was rarely, if ever, investigated [Dorozhkin and Epple, 2002; Giannini et al., 2000; Mosca et al., 2000].

Authors agree about the cause of senile osteoporosis [National Osteoporosis Foundation, 2003], with some authors defining it as a "paediatric pathology" [Baroncelli et al., 2003]. There is no scientific evidence correlating dental caries with BMD, however an indirect association can be inferred, whereas
several variables correlated to both the pathologies: the nutritional state [Alvarez, 1995]; the intake of trace elements - fluorine [Fabiani et al., 1999; Phips, 1998], calcium, vitamin D [Abrams et al., 1999; Krall et al., 2001; Pettifor and Moodley, 1997], silicon, aluminium, magnesium, zinc, gallium, copper, iodium [Touger-Decker and Mobley, 2003], phosphates [Macfarlane and Swart, 1989], -, lifetimes - smoking [Hildebolt et al., 2000; Johnson and Bain, 2000], - and lastly genetic factors not yet completely known influencing the speed of growth and the exfoliation of teeth. In addition, an excess of energy nutrients in the diet, namely proteins [Heaney, 1998], carbohydrates [MacKeown et al., 2000], and lipids [Eliakim et al., 2001], can cause alterations in hard tissues.

There are two main reasons for measuring BMD in children [Gilsanz, 1998]. Firstly, with regard to the diagnostic value of the parameter for diseases that cause osteopenia: above all osteoporosis, but less frequently rickets, and lastly congenital diseases (osteogenesis imperfecta, cystinuria, galactosemia, chondrodysplasias, and Menkes’ syndrome). The second reason is to improve the knowledge of pathologies of the elderly such as osteoporosis, in a life course approach [Ben-Sholmo and Kuh, 2002].

Quantitative ultrasonography (QUS) has recently been made available. It is economic, simple, safe, and free from ionizing radiation. This means both the BMD and the bone elasticity of the growing subject can be measured in large populations in a non-invasive manner. This contrasts to the more expensive and invasive conventional techniques such as dual energy x-ray absorption (DEXA) and quantitative computed tomography (QCT) [National Osteoporosis Foundation, 2003; Gilsanz, 1998; Moris et al., 1995]. The palmar QUS is a diagnostic means useful to appraise the BMD and therefore to analyze the relationship between anthropometric parameters, age and presence of dental caries.

This study aims to use the osteosonography to examine the relationship between bone mineral density and dental caries in a population of adolescent.

**Subjects and method**

Between 1999 and 2000 a cross-sectional study was carried out on a healthy population of adolescent residents in two cities in the south of Italy. All subjects in the 10 days of sampling were attending eight lower-middle schools (7-10 grade) in the two cities. In order to obtain informed signed consent before sampling, a form was administered to all pupil parents and returned if they agreed to the epidemiological study.

The subjects had to fill a food diary, with reference to the three days before clinical examination, in addition to a questionnaire about fluoride prophylaxis, and the occurrence of previous, elapsing or chronic disease.

Information regarding the presence of dental caries and bone mineral density was gathered from dental visits and from osteosonographic examinations carried out in the school first aid post by specialised personnel whose agreement in clinical observations was documented [Bolin et al., 1995]. In agreement with WHO guidelines [1997], the dental visit included evaluation of both dental formula and the dental caries experience index. The response variable is the prevalence of dental caries in permanent teeth, which is measured using the DMFT index. This is the sum of the number of permanent teeth (T), decayed (D), filled (F), and missing (M) due to caries, in which according to WHO guidelines [1997] a carious lesion is defined as a visible grade 3 and 4 defect. Being a discrete variable, the binary system can be used to describe it: DMFT index = 0 (healthy) and DMFT>0 (diseased).

QUS is a device for measuring the speed of ultrasound based on the transmission of sound through the distal extremity of the first phalanx in proximity to the articular condylus of the last four fingers of the non dominant hand. The distal condylus is an easy to find anatomical site, and the probe can be applied easily, an essential prerequisite for reproducible measurement, and, therefore, reliability across observations (stability and accuracy). The distal extremity of the proximal phalanx contains both cortical and trabecular bone and a small medullary canal. Each transmitter, emitter and receiver probe, is placed on the lateral and medial surface of each phalanx, where contact with the skin is ensured by using standard ultrasound gel [Baroncelli et al., 2003].

The DMS-Sonic 2000 device (Igea, Modena, Italy) was used to measure the speed of the ultrasound.

Bone mineral density measured using osteosonographic examination is the explicative variable considered. It calculates the speed of sound (SoS) through the distal extremity of the first phalanx, it is expressed in meters per second (m/s) and is calibrated for a minimal amplitude so that the estimated speed of the ultrasound is AD-SoS (amplitude-dependent speed of sound). The final result of measurement is the average AD-SoS measured in the last four fingers of the non dominant.
The equipment automatically correct the interferences derived from the soft tissues by evaluating the soft tissue reference speed of the subject, obtained at the beginning of the session by applying the probe in the first interdigital space. Two classes of distinct observations were considered: AD-SoS ≤ 1900 m/s (exposed) and AD-SoS > 1900 m/s (not exposed).

Being the age a possible confusing factor in the relationship between presence of dental caries and BMD, as a greater age influences positively both the variable, was necessary to run back logistic multifactorial models where the age as explanatory binary variable was considered (age < 12 and age ≥ 12). Wald’s test was used to evaluate the significance of the model and of the contrast between levels of factors and of the two-order interaction between age and AD-SoS, respectively. A significance level of 0.05 was considered.

Food habits and fluoride prophylaxis, as recorded by questionnaires, in addition to age, sex and residence were considered in the model as explaining variables, but they were not significant.

### Results

The sample analysed was composed of 596 subjects of which 56 (9.4%) have been excluded because they were absent at the time of the sampling (dental visit or osteosonographic examination). Informed consent was given in all cases.

Table 1 reports the characteristics of the 540 subjects examined. The percentage of subjects free from dental caries (DMFT=0) was 55.9%. The average number of permanent teeth is 24.7±4.2.

The results of the analysis carried out with a logistic model are reported in the Table 2.

The probability of dental caries presence (DMFT>0) according to AD-SoS and age classes is shown in Table 3.

The interaction of second order between age and AD-SoS was not significant.

### Discussion

This paper firstly shows the results of the relationship between BMD and dental caries on a wide sample of children aged from 10.09 to 15.15.

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**Table 1 - Characteristics of the sample.**

<table>
<thead>
<tr>
<th>Sex</th>
<th>No</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>287</td>
<td>53.2</td>
</tr>
<tr>
<td>F</td>
<td>253</td>
<td>46.8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>No</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;12</td>
<td>239</td>
<td>44.3</td>
</tr>
<tr>
<td>≥12</td>
<td>301</td>
<td>55.7</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Means age (SD)</th>
<th>No</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.3 (0.94)</td>
<td>540</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>AD-SoS (m/s)</th>
<th>No</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤1900</td>
<td>103</td>
<td>19.1</td>
</tr>
<tr>
<td>&gt; 1900</td>
<td>437</td>
<td>80.9</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Means AD-SoS (SD)</th>
<th>No</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1953.5 (0.5)</td>
<td>540</td>
<td></td>
</tr>
</tbody>
</table>

**Table 2 - Logistic model for the anova analysis of variance for presence of dental caries (DMFT >0); explanatory variables Age and AD-SoS. Odds ratio (OR) and its lower confidence interval (IC) and significance level (P<).**

<table>
<thead>
<tr>
<th>Mean</th>
<th>OR</th>
<th>Lower IC (95%)</th>
<th>P&lt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>AD-SoS*</td>
<td>1.869</td>
<td>1.199</td>
<td>0.006</td>
</tr>
<tr>
<td>Age°</td>
<td>1.961</td>
<td>1.186</td>
<td>0.004</td>
</tr>
</tbody>
</table>

*Contrast (AD-SoS≤1900) vs (AD-SoS>1900); °Contrast (age≥12) vs (age<12)
The percentage of caries free subjects is markedly greater (55.9% at 12 years of age) than the data published by the WHO (36.6%) [2003], recorded in Milan [1996], and in a previous study carried out by the authors for the whole of Italy [Fabiani et al., 1998].

Furthermore, the data observed are in line with the objectives of the WHO [WHO, 1997] both for 2000 and for 2010. The trend observed in the sample analysed for the explanatory variable AD-SoS with age is similar to that observed by other authors [National Osteoporosis Foundation, 1998; Baroncelli et al., 2003]. It is difficult to find conclusive evidence of the inverse relationship between the two variables (DMFT and AD-SoS) as it can also be masked by both small differences in age, and anthropometric parameters linked to age. Another problem arose from the analysis between DMFT and AD-SoS is due to the age as confounding factor, and to the not linear relationship. In our paper, this difficulty was overcome by transforming the original data in binary variables.

Beside the age, other possible confounding factors are lifestyles, food habits, mineral content of drinking water; these factors, considered in our logistic multifactorial model, can be fully controlled in a prospective cohort study, where perhaps the protective effect of a greater BMD could emerge better.

Adjusting for the age, the above mentioned relationship appears significant and, keeping constant the age, lower level of bone density almost double the risk of dental caries.

Indeed the multifactorial analysis using a logistical model (Table 2) confirms the expected statistically significant association between response variables (DMFT) and the explicative variables of AD-SoS (P=0.006) and age (P=0.004). Greater bone mineralisation (AD-SoS>1900m/s) at a younger age (age ≤12 years) corresponds to a lowest probability (0.34) of caries (DMFT>0) (Table 3).

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>AD-SoS (m/s) ≤12</th>
<th>≥12</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤1900</td>
<td>49</td>
<td>62</td>
</tr>
<tr>
<td>&gt;1900</td>
<td>34</td>
<td>46</td>
</tr>
</tbody>
</table>

**Table 3 - Probability (%) of carious disease in the AD-SoS groups and Age groups.**

**Conclusion**

In conclusion the BMD reached in the first adolescence would be checked because the level attained do not only contribute to the prevention of tooth decay, but also allows to anticipate different diseases in adulthood.

Tooth decay is a multifactorial disease whose causes includes the degree of hard tissues resistance (enamel and dentin), which is a parameter correlated with bone mineral density (AD-SoS value). This represents one of the biological factors involved. Other local predisposition or resistance factors are resident bacterial flora, eating habits, oral hygiene and saliva, in addition to general factors (age, sex, race, socio-economic state, etc).

If the predictive value of the osteosonographic examination were confirmed by a wider study, it could be adopted as an investigative instrument capable of selecting children and adolescents at greater risk from caries so that dental check up would be carried out more frequently.

Osteosonographic evaluation is even more significant in triggering intervention to promote optimal bone mineralisation through nutritional changes and adjustments of lifestyle which can reduce the risk of osteoporosis and oral pathologies, including dental caries.

QUS represents a tool means for primary and/or secondary prevention of most osteopenie, since it allows the evaluation of the bone mineral density during growth.

The National Osteoporosis Foundation [2003] described four factors that act synergistically in preventing osteoporosis: balanced diet rich in calcium and vitamin D; body weight control with physical activity; healthy lifestyle (free from tobacco and alcohol abuse); later treatment and prevention using BMD tests and pharmacological drugs.

Dental caries is a chronic-degenerative pathology in which primary preventive intervention in the natural history of the disease (fluorine in water and milk, sealing of dental pits, diet and oral hygiene, periodic visits) carried out in association with secondary interventions, screening (salivary test), and osteosonographic examination, can slow down tooth loss thanks to early diagnosis and reduced exposure to risk factors.

Key-points are the following.

- An indirect association between dental caries and BMD is known: susceptibility to dental caries as the level of BMD are both linked to genetic factors, feeding, fluoride intake, socio-economic factors, etc. A direct (causal) association has not
been studied adequately.
- The availability of ultrasound device that measure the BMD as ultrasound velocity through the finger’s bone (ADSoS; m/sec) allow epidemiological studies, also on children and teenagers, in schools.
- The present multifactorial analysis shows that the inverse relationship between BMD and DMFT is significant (p=0.006) in a quite large sample (540) of healthy teenagers (average DMFT = 1.2).
- Greater bone mineralisation and younger age are factors of prevention for the dental caries: the probability to have caries is 0.34 for subjects < 12 years old and with a BMD level ≥ 1900 m/s, whereas it is 0.62 for subjects > 12 y old and with a ADSoS of < 1900 m/s.

References
Abrams SA, Copeland KC, Gunn SK, Stuff JE, Clarke LL, Ellis KJ. Calcium absorption and kinetics are similar in 7-and 8-years-old mexican-american and causasian girls despite hormonal differences. J Nutr 1999;129:666-71.


