Dental Fluorosis and Lumbar Spine Bone Mineral Density in Adults, ages 20 to 49 years: Results from the 2003 to 2004 National Health and Nutrition Examination Survey

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Abstract

Purpose: Osteoporosis is an urgent public health concern. Many factors influence bone mineral density (BMD), a criterion used to diagnose osteoporosis. The purpose of this study was to determine if dental fluorosis may be a marker for osteoporosis. The association between dental fluorosis and BMD at the lumbar spine was examined.

Methods: Using a cross-sectional design with 1,805 adults, ages 20 to 49 years, from the 2003 to 2004 National Health and Nutrition Examination Survey, an analysis of the association between dental fluorosis and BMD was performed, using chi-square and multivariable logistic regression. Other variables included predisposing factors (gender, age and race/ethnicity), enabling factors (marital status, education, poverty status and health insurance) and life-style/behavioral factors (perceived health status, smoking, alcohol intake, physical activity and body mass index).

Results: Overall, 13.5% had fluorosis; 6.8% with fluorosis and 9.8% without fluorosis had low lumbar spine BMD. Multivariable analysis found there was not a statistically significant association between fluorosis and lumbar spine BMD (adjusted odds ratio=0.82; 95% CI (0.43. 1.56)).

Conclusion: Dental fluorosis and lumbar spine BMD were not found to be associated in a sample of adults.

Keywords: fluorosis, osteoporosis, osteopenia, lumbar spine, bone mineral density, NHANES

This study supports the NDHRA priority area, **Clinical Dental Hygiene Care:** Investigate the links between oral and systemic health.

Introduction

Osteoporosis, a systemic disease of reduced bone mineral density (BMD) and potential fractures, is responsible for $10 to $18 billion in annual U.S. fracture-related costs.[1] In 1994, the World Health Organization (WHO) provided criteria for osteoporosis in postmenopausal white women as BMD of 2.5 or more standard deviations below young average BMD.[2,3] A deviation of 2.5 standard deviations from the BMD of the average young white woman was significantly related to the future lifetime risk of any fractures, and was therefore used as the criteria.[4] The concern of low BMD is morbidity and mortality from spontaneous fractures or falls. A study of 163,979 participants showed that those with osteoporosis had a fracture risk ratio of 4.03 (95% CI 3.59, 4.53) and those with osteopenia (-1 to -2.5 standard deviations below young average BMD) had a fracture risk ratio of 1.80 (95% CI 1.49, 2.18) compared with those with normal BMD.[5] Similar results occurred when humerus, forearm and wrist fractures were considered.[6]

Biomarkers or other predictors would be beneficial in identifying those at risk for fracture to target them for early intervention. Periodontal disease was studied as an indicator, but at best was a weak factor.[7] Techniques, such as quantitative ultrasound, have also been proposed.[8] Recently, the use of dental panoramic radiography to evaluate inferior mandibular cortical BMD has been proposed for low BMD screening.[9,10]

Bone strength partially depends upon the hydroxyapatite crystal, the crystal also present in teeth. Its structure is modified by various metals (lead, arsenic) and halide anions such as fluoride. At therapeutic levels during development, small amounts of fluoride replace the hydroxyl-group and form fluorapatite, which is caries-resistant in teeth.[11] Although this pre-eruptive effect is now considered to be minor, compared to fluoride's topical effect, it led to the 1945 decision to fluoridate the water supply of Grand Rapids, Michigan.[12] The result, a reported (and later contested) 56% decrease in caries 15 years later, led to nationwide community water fluoridation (CWF) and dramatic reductions in caries.[12] CWF, one of the top 10 public health achievements of the twentieth century, was identified as the "most socially equitable way to prevent caries, [with the] greatest effect on the socially disadvantaged children who have the most decay."[13] CWF has been present in some sites for over 67 years.

Research involving fluoride as a medication to increase BMD was also conducted. A randomly controlled study of 202 postmenopausal women with osteoporosis and fracture history indicated that fluoride (75 mg/day) increased cancellous bone (lumbar spine, femoral neck, etc.) but decreased cortical BMD (radii).[14] The study showed no difference in spinal fractures, but identified an unexpected increase in non-spinal fractures.[14] Other studies showed no difference between the groups in fractures at either site.[15-17] A meta-analysis of 11 studies indicated an increase in lumbar spine BMD, with no significant difference in fractures.[18]

In developing children, excessive fluoride (greater than 1 mg/day or 1 ppm) will mottle teeth (dental fluorosis)[19] and may result in osteosclerosis, osteoporosis and osteomalacia, or a combination of the conditions.[11] Sources of excess fluoride include high naturally occurring levels of fluoride in wells, springs, etc., dietary fluoride supplements prescribed or taken inappropriately, and excessive ingestion of fluoride toothpaste and similar products. The American Academy of Pediatric Dentists recommends a smear of fluoridated toothpaste for children under age 2 years, and the American Dental Association recommends seeking dentist/physician advice for the use of fluoridated toothpaste for children under age 2 years. It is important for dental hygienists to know about community water fluoridation, and other sources of an individual patient's potential fluoride exposure and educate patients with young children about current recommendations.

The purpose of this study was to determine if dental fluorosis is associated (co-occurs) with low BMD in an adult sample. The conceptual framework was the Ecosocial Theory,[20] that there are many predisposing, enabling, health risk factors involved in the development of diseases and conditions, such as low BMD.

Methods and Materials

This study analyzed data from the National Health and Nutrition Examination Survey (NHANES) for years 2003 to 2004. The NHANES protocols are presented in detail elsewhere.[21] In summary, the NHANES is a U.S. federal, on-going program in which the nation's health and nutrition status are evaluated with questionnaires, clinical examinations and laboratory tests of participating non-institutionalized civilian adults and children. The survey follows epidemiological principles in selecting participants in which selections are multistage, probabilistic and stratified based on counties, blocks, households and individuals within the households. To provide for race/ethnicity analyses, the survey is designed to oversample non-Hispanic Blacks and Mexican Americans.

The study included adults who participated in BMD analysis and fluorosis evaluation, ages 20 to 49 years. Skeletal mass and BMD become consistent after bone growth stops. Children, having the potential of inconsistent BMD, were excluded to age 20 based upon the Centers for Disease Control's stature-for-age charts which indicate growth in stature continues from birth to age 20 years.[22] Fluorosis data were only available to age 49 years. Participants were excluded if there were missing data on fluorosis, or had highly variable imputed lumbar spine BMD data.

BMD data were collected using dual-energy x-ray absorptiometry with a Hologic QDR-4500A fan-beam densitometer (Hologic, Inc., Bedford, Mass.). Participants were excluded from the BMD examination if they were pregnant, if they self-reported having had radiographic contrast medium within the previous 7 days, a nuclear medicine study within the previous 3 days and if their physical size could not be handled by the instrumentation (a height over 6'5" or a weight above 300 pounds).

The lumbar spine BMD values were chosen based on previous research. The most clinically relevant site for younger patients to assess is the lumbar spine as epidemiologic evidence indicates the greatest risk of any fracture in women in the first 15 to 20 post-menopausal years are vertebral fractures.[4] Secondly, sensitivity and specificity for osteoporosis and osteopenia at other sites have been calculated assuming a low t-score at the spine or femoral neck as the criterion for a correct diagnosis.[23] Thirdly, spinal fractures are associated with increased mortality, therefore prevention of the first such fracture is important.[24] Originally, the definitions of osteoporosis (a BMD t-score below -2.5) and of osteopenia (a BMD t-scores between -1.0 and -2.5) were intended for epidemiological purposes.[3,4,25] Using the definition of osteopenia as the definition of low BMD, the lumbar spine BMD was dichotomized into a normal category and low BMD category using a t-score cutpoint of 1 standard deviation of the normal mean (≤0.880 g/cm2) as used in previous resesearch.[3,25] There were 38,280 participants, 1,440 missing/excluded/highly imputed values, 5,280 with imputed values and 31,175 with no imputed values.

Dental fluorosis data were collected for participants aged 6 to 49 years using the Dean's Index.[21] A score of 0 indicated a normal tooth, 1 indicated very mild fluorosis, 2 indicated mild fluorosis, 3 indicated moderate fluorosis, 4 indicated severe fluorosis and 5 indicated questionable fluorosis. For an evaluation of fluorosis, the contralateral tooth also had to have a fluorosis diagnosis. If a tooth were crowned, missing, not fully erupted, or if one-half or more of the visible enamel was replaced with a restoration, or covered with an orthodontic band, or destroyed by caries, the tooth was evaluated as "cannot be assessed."[21] Fluorosis was categorized into 3 categories: no/questionable fluorosis, the presence of fluorosis (Dean Indices of 1 to 4) and cannot be assessed.[21] The person level score was determined by the NHANES definition in which the score for the 2 teeth most affected by fluorosis are determined and if they are not equivalent, the lesser score is used.[21] The no/questionable and presence of fluorosis categories were based upon previous research using similar cutpoints (dichotomized presence of fluorosis/no fluorosis) although the other studies used the Thylstrup and Fejerskov Index[26,27] or Tooth Surface Index of Fluorosis.[28] There were 8,847 participants with dental evaluations. Trained, licensed dentists and trained recorders conducted the evaluations in mobile examination centers. They underwent intense training, monitoring and calibration. Interrater correlation was expected to be high, otherwise retraining of examiners occurred.[21]

The sample size with both available BMD and fluorosis values was 1,805. An economic model recommends using a WHO intervention algorithim when low BMD occurs with advancing age, low femoral neck BMD, low body mass index (BMI), personal history of prior fragility fracture, rheumatoid arthritis, other putative causes of secondary osteoporosis (such as inflammatory bowel disease), parental history of hip fracture, 3 months or more systemic corticosteroid use, 3 or more ounces of alcohol daily, and cigarette smoking.[29] As a result of the recommendation, predisposing factors (age, gender, race/ethnicity); enabling factors (education, poverty status, health insurance, marital status) and life-style/behavioral factors (perceived health status, smoking status, alcohol intake, physical activity, body mass index) were included in the analyses.

Bivariate association between fluorosis and low BMD were tested using the chi-square test. Logistic regression models were used to evaluate the association between fluorosis and lumbar spine BMD using 4 model specifications. The first model contained only the fluorosis variable. The second model additionally included predisposing factors of gender, race/ethnicity and age in years. The third multivariable model added the enabling factors of marital status, education, poverty status and health insurance. The fourth multivariable model included self-reported health status, alcohol use, smoking status, moderate exercise and BMI.

Valid data decreased with age as there were more pacemakers, stents, hip replacements and obesity with age.[21] Therefore, the missing data could not be treated as a random subset of the data file.[21] NHANES resolved the problem of bias due to non-random invalid and missing data with multiple imputations so that the use of the data sets would provide complete data and ensure an accurate standard error of the estimate.[21] The imputations were based on critical weight and waist circumference data. A subset of highly imputed values was created if weight and waist circumference were not available. The data in this study did not include the subset of highly imputed values.

Imputed BMD data had 5 imputed values for each individual. We analyzed the data with several combinations of the imputed values. The analyses were consistent across all 5 imputed values. The results presented are from 1 of the analyses.

Results

Table I presents the characteristics of participants. The study population was 51.4% male, predominantly Non-Hispanic White (69.1%), educated at above high school (58.7%), and between 40 and 49 years (37.6%). Most participants were moderate users of alcohol (35.5%), non-smokers (51.9%) and were married (61.6%). There were 74.8% who had health insurance and 61.8% who exercised moderately. There was an equal distribution of normal/underweight, overweight and obese participants. There were 90.4% with normal lumbar spine BMD and 13.5% had fluorosis.

Table I summarizes the characteristics of adult participants with low lumbar spine BMD. For ease of reading, the table does not include adult participants with normal lumbar spine BMD. Overall, there was not a statistical difference between those with fluorosis and those who did not have fluorosis who also had low lumbar spine BMD (6.8% and 9.8%, respectively).

Statistically significant group differences in low lumber spine BMD were noted by gender, age, education, health status, race/ethnicity and exercise. A higher percentage of men (12.5%) than women (6.6%) had low lumbar spine BMD. There were 15.3% of Mexican Americans, 9.6% of Non-Hispanic Whites and 4.4% of Non-Hispanic Blacks who had low lumbar spine BMD.

Table II presents 4 logistic regression models with

Table I: Description of Sample Characteristics and Number and Weighted Percent with Low Lumbar Spine Bone Mineral Density National Health and Nutrition Examination Survey, 2003 to 2004

	Total		With Low BMD		Significance
	n	wt%	n	wt%	
All	1,805	100.0	181	9.6	
Fluorosis					0.253
• Fluorosis	259	13.5	18	6.8	
• Normal	564	33.2	55	9.8	
• Cannot be assessed	982	53.3	108	10.2	
Gender					0.001
• Women	839	48.6	55	6.6	
• Men	966	51.4	126	12.5	
Race/Ethnicity					0.031
• Non-Hispanic White	878	69.1	84	9.6	
• Non-Hispanic Black	423	11.8	20	4.4	
• Hispanic	351	9.4	59	15.3	
• Other	153	9.7	18	10.1	
Age in years					0.010
20 to 29	606	29.8	41	6.7	
30 to 39	568	32.6	56	9.2	
40 to 49	631	37.6	84	12.2	
Marital status					0.522
• Married	1,034	61.6	108	10	
• Not married	769	38.4	72	8.7	
Education					0.008
• Less than High School	378	14.6	65	15.3	
• High School	483	26.7	40	9.0	
• Above High School	944	58.7	76	8.4	
Poverty Status					0.486
• Poor	476	20.9	60	12.0	
• Low Income	305	14.2	30	8.4	
• Middle Income	486	30.8	46	8.7	
• High Income	451	34.0	39	10.1	
Health Insurance					0.582
• Insured	1,228	74.8	123	9.7	
• Not insured	558	25.2	57	9.4	

either odds ratios (OR) or adjusted odds ratios (AOR) and corresponding 95% confidence intervals (CI) of low lumbar spine BMD. Model 1 included the single variable fluorosis and model 2 included predisposing variables (gender, race/ethnicity, and age). Enabling variables were added in model 3 (education, poverty status, health insurance and marital status), and lifestyle/behavioral variables were added in model 4 (self-perceived health status, alcohol use, smoking status, moderate exercise, BMI). There was no statistically significant association between fluorosis and low lumbar spine BMD in any of the models.

The odds ratio for fluorosis and low lumbar spine bone mineral density was 0.65 in the unadjusted model. The adjusted odds ratio for low lumbar mineral density became 0.68, 0.71 and 0.69 with the addition of predisposing variables, enabling variables and lifestyle/behavioral variables, respectively. In evaluating a type of non-response analysis, we considered the participants whose teeth could not be assessed due to missing teeth, crowns, partial eruption of teeth, restorations obscuring one-half or more of the visible enamel, coverage with an orthodontic band, or destroyed by caries. In these analyses, there was no significant difference in lumbar spine BMD with the reference group in any of the models.

Discussion

The findings on overall prevalence of fluorosis (13.5%) are consistent with existing studies. There is a wide range of values reported in other stud-

Table I: Description of Sample Characteristics and Number and Weighted Percent with Low Lumbar Spine Bone Mineral Density National Health and Nutrition Examination Survey, 2003 to 2004 (continued)

	Total		With Low BMD		Significance
	n	wt%	n	wt%	
All	1,805	100.0	181	9.6	
Health Status					
• Excellent	226	14.2	16	7.1	0.015
• Very good	589	38.3	37	7.1	
• Good	643	35.3	77	11.5	
• Fair/Poor	274	12.2	41	12.8	
Alcohol Use					
• Heavy	622	34.0	66	9.4	0.119
• Moderate	580	35.5	49	8.7	
• None	430	21.5	41	8.6	
• Missing	173	9.0	25	16.2	
Smoking Status					
• Current Smoker	573	31.4	64	11.4	0.233
• Former Smoker	272	16.7	31	10.3	
• Never Smoker	960	51.9	86	8.3	
Exercise					
• Yes	1,028	61.8	81	8.3	0.004
• No	777	38.2	100	11.7	
Body mass index					
• Underweight/Normal	647	37.3	75	10.7	0.091
• Overweight	584	32.5	63	9.9	
• Obese	564	30.2	41	7.6	

Based on 1,805 non-institutionalized civilian men and not-pregnant women aged between 20-49 years, who had fluorosis and bone mineral density screenings. Weighted percentages were obtained to control for complex sample design, therefore division of individual cell sizes by the total sample will not reflect weighted percentages. Significant group differences were tested by Chi-square statistics.
***$p<0.001$; **$0.001 \le p<0.01$; *$0.01 \le p<0.05$
Wt %: weighted percent; N: number of participants

ies for fluorosis. One study of persons aged 6 to 39, reported fluorosis prevalence at 23%.[30] Another, for children from Kindergarten to grade 5, reported fluorosis at 44%.[31] One study reported fluorosis at 23.0% for maxillary central incisors when fluoride intake was 0.04 to 0.06 mg F/kg.[32] Finally, another reported fluorosis at 51% with CWF fluoridated at 1 ppm.[33] A literature review indicated that although the 1945 fluorosis prevalence estimate for Grand Rapids was 10%, 10 to 17 years later, the prevalence was 7 to 16%, and has been increasing with increasing availability of multiple sources of fluoride (toothpaste, mouth rinses, prescribed fluoride)--ranging from 7.7% to 69% in areas of CWF and from 2.9% to 42% in non-fluoridated communities.[19]

In this study, no significant association of fluorosis and low lumbar spine BMD were found. Though not at a statistically significant level, fluorosis had a protective effect (AOR 0.78 in model 1 and 0.81 in model 2 and 0.82 in model 3). While therapeutic levels of fluoride have drastically reduced caries, increasing amounts of fluoride ingestion has become a public health concern in terms of dental fluorosis, resulting in the Health and Human Services 2011 recommendation to lower CWF to 0.7ppm.[34]

There are many individuals in the public who remain skeptical about fluoride and its systemic effects. Fluoride exposure has been a controversial national discussion and requires scientific examination to inform the debate. The first wave of the U.S. population potentially exposed to a lifetime of community water fluoridation is approaching middle age and older, and life-time effects may be examined. This study adds to the literature in that we found no association of dental fluorosis and lumbar spine BMD.

This study has several strengths. It uses data from a large, nationally representative study with laboratory measures of BMD, clinical evaluations of fluorosis, and availability of comprehensive information on many variables that can affect presence of osteoporosis. There were some limitations present in the study. As a cross sectional study, causal statements cannot be inferred. Highly imputed lumbar spine data were not used, and this study used self-reported indicators potentiating selection bias and non-differential misclassification bias. Missing teeth, crowned or veneered teeth, not fully erupted teeth, or teeth with more than one-half or more of the visible enamel replaced with a restoration, or covered with an orthodontic band, or destroyed by caries had to be evaluated as cannot be assessed, which resulted in a large category of participants. Nevertheless, their BMD was not significantly different from the referent. Despite these limitations, our study was able to examine the association between fluorosis and low lumbar spine BMD. This study did not reveal a statistically significant association between fluorosis and lumbar spine BMD, was not present in the sample of adults aged 20 to 49.

Table II: Odds Ratios and Adjusted Odds Ratios for Fluorosis from Logistic Regression on Low Lumbar Spine Bone Mineral Density National Health and Nutrition Examination Survey, 2003 to 2004

	Odds Ratio	95% Confidence Interval	Significance
MODEL 1			
Fluorosis			
• Yes	0.65	[0.37 , 1.15]	0.2737
• Cannot be assessed	1.09	[0.77 , 1.54]	0.4640
• No (Reference Group)	-	-	-
	Adusted Odds Ratio	95% Confidence Interval	Significance
MODEL 2			
Fluorosis			
• Yes	0.68	[0.36 , 1.30]	0.4240
• Cannot be assessed	0.98	[0.70 , 1.38]	0.8707
• No (Reference Group)	-	-	-
MODEL 3			
Fluorosis			
• Yes	0.71	[0.37 , 1.36]	0.5114
• Cannot be assessed	0.93	[0.66 , 1.32]	0.8568
• No (Reference Group)	-	-	-
MODEL 4			
Fluorosis			
• Yes	0.69	[0.35 , 1.37]	0.5127
• Cannot be assessed	0.88	[0.61 , 1.28]	0.7113
• No (Reference Group)	-	-	-

1,805 non-institutionalized civilian men and not-pregnant women aged 20 to 49 years.
Model 2 adjusted for fluorosis (present, absent), gender (male, female), race/ethnicity (Non-Hispanic Whites, Non-Hispanic Blacks, Mexican Americans, others), and age (20 to 29, 30 to 39, 40 to 49 years).
Model 3 additionally adjusted for marital status (married, not married), education (less than high school, high school, above high school), poverty status (poor, low income, middle income, high income), and health insurance (insured, not insured).
Model 4 additionally adjusted for health status (excellent, very good, good, fair/poor), alcohol use (heavy, moderate, none), smoking status (current, former, never), moderate exercise (yes, no), body mass index (normal/underweight, overweight, obese).

Dental hygienists routinely provide topical fluoride treatments (which do not cause fluorosis) to their patients. It is a time in which they are often queried about the safety and efficacy of fluoride. The questions provides an opportunity for dental hygienist to discuss the benefits of fluoride, the distinction between topical and systemic fluoride, and they may use the results of this study to indicate continued support of the safety of fluoride, in therapeutic levels, in terms of its effect on bone mineral density.

Conclusion

Dental hygienists, in presenting oral hygiene instruction, provide patients with anticipatory guidance information to help avoid dental fluorosis in the permanent dentition of their children, particularly the maxillary anterior teeth. Hard tissue formation occurs between ages 3 months to 7 years for the maxillary anterior teeth. Dental hygienists continue to remind adults to secure toothpaste tubes from very young children, and to prevent child access to prescribed fluoride tablets or gels. Dental hygienists inform patients with children that the American Academy of Pediatric Dentists recommends a smear of fluoridated toothpaste for children under age 2 years, and the American Dental Association recommends seeking dentist/physican advice for the use of fluoridated toothpaste for children under age 2 years. When queried about the safety of fluoride and bones, dental hygienists may report that this study of adults ages 20 to 49 did not show an association of fluorosis and low BMD.

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