# The Relationship between Methamphetamine Use and Dental Caries and Missing Teeth

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## Abstract

**Purpose:** This study examined the relationship between methamphetamine use and oral health status.

**Methods:** Using a cross-sectional design, data were collected in 1998 from 174 newly admitted prisoners in Iowa. Oral examinations identified dental caries and missing teeth, and personal interviews identified methamphetamine use and covariates. Descriptive statistics were used to summarize the data, and bivariate and multivariate linear regression analyses, including testing for interaction effects, were used to examine the effects of methamphetamine use on oral health status.

**Results:** Multivariate regression analyses for carious teeth and surfaces showed significant interaction effects: methamphetamine*race/ethnicity (carious teeth: p=0.039; surfaces: p=0.023) and methamphetamine*tooth brushing when on drugs (carious teeth: p=0.044; surfaces: p=0.035). Methamphetamine use had a significant effect on dental caries among Non-Whites and among those who brushed their teeth less than once a day when on drugs. Soda consumption (carious teeth: p=0.026; surfaces: p=0.030) and reason for last dental visit (carious teeth: p=0.025; surfaces: p=0.011) were also associated with caries. For missing teeth there was a significant methamphetamine*race/ethnicity interaction (p=0.028) among Whites who used methamphetamine compared to Whites who did not use methamphetamine. Age (p=0.0001) and reason for last dental visit (p=0.0001) were also associated with missing teeth.

**Conclusion:** The effect of methamphetamine use on missing teeth was moderated by race/ethnicity,; while its effect on dental caries was moderated by race/ethnicity and tooth brushing when on drugs.


**Keywords:** methamphetamine use, polydrug use, caries, missing teeth, oral epidemiology

This study supports the NDHRA priority area, **Health Promotion/Disease Prevention:** Investigate how environmental factors (culture, socioeconomic status-SES, education) influence oral health behaviors.

## Introduction

Both the illicit production and the use of methamphetamine, a powerful stimulant that affects the central nervous system, have a tremendous impact on people's lives and on national and state resources.[1] Between 1996 and 2012, the percentage of adults admitted to treatment facilities for methamphetamine increased from 2.6 to 8.5% for the nation and from 9.7 to 21.9% for Iowa.[2] In addition to burdening the health care system, methamphetamine production and use have negatively impacted the criminal justice system. In 2012, 50.9% of people imprisoned on drug charges in Iowa had committed a crime related to the drug methamphetamine.[3]

Methamphetamine use has been purported to cause destructive dental caries. Some authors have suggested that it may be the chemical or physical qualities of methamphetamine or its components, such as their acidity or toxicity, directly attacking tooth structure.[4,5] Other studies suggest that methamphetamine causes dry mouth which reduces protective aspects of saliva.[6-8] Others do not attribute it to methamphetamine but to users' poor oral hygiene, high consumption of refined carbohydrates and lack of routine dental care.[4,8,9] The relationship between methamphetamine use and poor oral health was first suggested for prescription use of methamphetamine and then illicit use.[10,11] The relationship with illicit use has been reported in a number of articles,[4,5,8,9,11-25] and has been investigated in research studies which measured oral health by self-report[26-29] and by clinical examinations or screenings.[7,30-33] Of the studies using clinical data, mixed results were found from bivariate analyses. Two studies concluded that methamphetamine use had a negative impact on oral health,[7,32] and 2 studies reported that there was no impact.[30,31] Multivari-

ate analysis also resulted in mixed results. Controlling for demographic variables, professional care, oral hygiene, sugar consumption and tobacco use, Cretzmeyer et al found that oral health (number of teeth present and total filled and carious surfaces) was not statistically different for methamphetamine abusers and those who abused other drugs.[31] Conversely, Shetty et al, controlling for demographic and professional care variables, found that methamphetamine abusers had more missing teeth and poorer self-reported oral health than adult NHANES III respondents; however, they did not find a difference for dental caries.[33] Based on a systematic review of methamphetamine use and health for adolescents, Marshall and Werb concluded that there is a research gap in that there is insufficient evidence of an association between methamphetamine use and dental outcomes and that future research should assess potential covariates and adjust for them using stratified or multivariate analyses.[34]

This study examined the relationship between methamphetamine use and oral health using data collected in 1998 from a population of recently admitted prisoners. This study is important because previous research has not resolved this question. Studies using clinical measures of oral health status are few in number and none of these studies adequately controlled for covariates. Additionally, the findings from these studies have been inconsistent. A better understanding of the relationship of methamphetamine use on oral health status should assist dental professions in providing treatment to methamphetamine users, especially preventive services like those provided by dental hygienists, and could have implications for policy decisions related to dental care for methamphetamine users in prisons, drug treatment centers and dental health clinics.

## Methods and Materials

This cross-sectional study was conducted within the confines of the staff dental hygienists' work day. Oral health evaluations and personal interviews were used to collect data from a sample of inmates newly admitted to the Iowa Medical Classification Center (IMCC) between June and December 1998.

All inmates entering Iowa's prison system are evaluated at the IMCC for mental and physical health conditions. Oral health evaluations are conducted on the day after admission and new inmates are examined by the staff dentist or dental hygienist. Mouth mirrors, explorers and panographic radiographs are standard equipment used at the IMCC to evaluate each tooth surface for each inmate and the oral health information is recorded on the IMCC anatomical odontogram, a chart depicting the crown and root for each of the 32 teeth possibly present in an adult mouth. Because the evaluations are conducted to determine treatment needs, adequate fillings are not differentiated from sound surfaces. When the data were collected, the dental hygienist had 16 years of clinical experience, 3 years at IMCC, 7 years at a maximum security prison and 6 years in private practice. The purpose of the study was discussed with the dental and medical directors and warden during the planning phase and a design which restricted data collection to the dental hygienist's patients was accepted. The medical director and warden approved the study protocol and consent form. The University of Iowa institutional review board (IRB) determined that, because this study was limited to analysis of de-identified data, it did not meet the regulatory definition of research involving human subjects and therefore was not subject to further IRB review.

As stated above, study participants were drawn from the inmates evaluated by the staff dental hygienist. On days when there were too many inmates for the dental hygienist to both provide an oral health evaluation and collect study data, a set format of offering study participation to every second, third or fourth inmate, depending on the number of inmates to be examined, was used. Within this time constraint, inmates were invited to be a part of the study and there were no exclusions based on gender, race, age or any other covariate. Inmates who elected to participate were read the consent form, which they signed prior to the oral health evaluation.

Photocopies of the odontograms were made and identifying information was removed. Each photocopy and corresponding questionnaire was given a unique identifier. Oral health was measured by 3 variables: total number of carious teeth, total number of carious surfaces and total number of missing teeth. For the study, incipient lesions, those not into the dentin, were excluded, which is consistent with oral health epidemiological and survey research.

Data regarding demographic, oral hygiene, professional dental care, sugar consumption and drug use were obtained from personal interviews administered by the dental hygienist after the oral evaluation. Demographic variables included sex, age, race/ethnicity, education, marital status and employment. Oral hygiene was measured by usual tooth brushing frequency, using a 6-point scale

from 3 or more times/day to less than weekly, and tooth brushing frequency when on drugs. The latter was obtained with the open-ended question "When you were using drugs, how frequently did you brush your teeth?" Of 92 subjects' responses (measured on the 6-point scale previously described), 32 stated they brushed the same as usual, 23 stated they never brushed when on drugs and were coded at the lowest frequency, 4 stated they brushed more when on drugs and were raised 1 usual frequency level, 20 stated they did not use drugs or only cigarettes and were coded at their usual frequency, and 3 subjects' answers could not be coded. For regression analysis, the 3 were included using their respective usual frequencies. Professional dental care included the number of years since the last dental visit and the reason for the last dental visit. Consumption of 8 types of sweetened beverage and food was measured with the same 6-point scale as tooth brushing. Sugar consumption was analyzed using 2 variables: soda (the frequency of soda consumption) and non-soda sugars (a summed variable of the other 7 sugar items). For multivariate analysis, both sugar variables were rendered closer to scale by converting them to the common denominator of times per week. Participants were asked if they had ever used tobacco, alcohol, marijuana, methamphetamine, other stimulants, cocaine and heroin and were given the option to name up to 2 additional drugs. Respondents were divided into users and non-users for each of the drugs for data analysis.

Data were entered in the computer by student research assistants and one of the authors. All data were verified and then analyzed using IBM SPSS Statistics 19 and SAS.

Distributions and descriptive statistics were calculated. Bivariate analysis was conducted to test for differences between users and non-users of methamphetamine. Continuous, normally-distributed variables were compared using two-sample t tests, while Mann-Whitney U Tests were used for non-normally distributed and ordinal variables. Pearson's chi-square or the Fisher's Exact Test was used for comparing categorical variables. Bivariate analysis was also conducted to examine the association of covariates with the 3 dependent variables using Spearman's Rho, Mann-Whitney U Tests and Kruskal-Wallis Tests.

Since the primary objective was to describe the effect of methamphetamine use on oral health controlling for the influence of covariates, multivariate linear regression analysis was used. Separate regression models were analyzed for each of the 3 oral health dependent variables. As none of the oral health variables was normally distributed, they were transformed for regression analysis: caries with the square root transformation and missing teeth with the natural log transformation.[35,36]

The covariates included in the regression models were demographics (sex, age, race/ethnicity and marital status), sugar consumption (soda and non-soda sugars), personal oral hygiene (tooth brushing frequency when on drugs), professional dental care (number of years since last dental visit and reason for last dental visit) and drug use (tobacco, alcohol, methamphetamine, marijuana and cocaine). Heroin use was not included due to the small number of heroin users (n=6). None of the sample used other stimulants.

In addition to fitting a main-effects-only-regression model, interaction effects involving methamphetamine and other covariates were also examined. This was done by fitting separate regression models with a single interaction effect added to the main effects model. Interaction effects with a p-value $\leq 0.10$ were considered for possible inclusion in the final model. The presence of a significant interaction effect of any of these variables with methamphetamine indicates that the effect of methamphetamine on caries or missing teeth is moderated by this variable. Among the interaction effects that were tested, there were 3 variables that met the inclusion criteria: race/ethnicity, age and frequency of tooth brushing when on drugs. Regression models were then fitted that included various combinations of these interaction variables. The extent to which each model provided the best fit was assessed by the Akaike Information Criterion.[37]

From the final model that included interaction effects, the effect of methamphetamine was then examined using the test of mean contrast to test for differences in dental caries or missing teeth between methamphetamine users and non-users at each level of the moderating variable. Since multiple tests were performed to test for the effect of methamphetamine (i.e. 2 tests by race/ethnicity), the p-values for these tests were adjusted using Bonferroni's method.[38]

## Results

There were 174 individuals in the study, with only one individual declining to participate (99.4%). The average age was 30 years (SD=8.3,

Table I: Distribution of Subjects by Covariates and by Methamphetamine Use

| Variable | Total (n=174) n (percent) | Meth User (n=95) n (percent) | Meth Non-user (n=79) n (percent) | p–value |
|---|---|---|---|---|
| Age (in years) | | | | 0.596[t] |
| 17 to 20 | 25 (14.4%) | 9 (9.5%) | 16 (20.2%) | |
| 21 to 30 | 75 (43.1%) | 43 (45.3%) | 32 (40.5%) | |
| 31 to 40 | 55 (31.6%) | 40 (42.1%) | 15 (19.0%) | |
| 41 to 55 | 19 (10.9%) | 3 (3.2%) | 16 (20.2%) | |
| Sex | | | | 0.006[P] |
| Male | 149 (85.6%) | 75 (78.9%) | 74 (93.7%) | |
| Female | 25 (14.4%) | 20 (21.1%) | 5 (6.3%) | |
| Race/Ethnicity | | | | <0.001[P] |
| White | 142 (81.6%) | 89 (93.7%) | 53 (67.1%) | |
| Non-White | 32 (18.4%) | 6 (6.3%) | 26 (32.9%) | |
| Marital status | | | | 0.060[P] |
| Never married | 88 (50.6%) | 42 (44.2%) | 46 (58.2%) | |
| Married | 39 (22.4%) | 23 (24.2%) | 16 (20.3%) | |
| Divorced/separated | 46 (26.4%) | 29 (30.5%) | 17 (21.5%) | |
| Widowed | 1 (0.6%) | 1 (1.0%) | 0 (0.0%) | |
| Education (highest grade completed) | | | | 0.244[M] |
| 5 to 11 | 70 (40.2%) | 41 (43.2%) | 29 (36.7%) | |
| 12 | 41 (23.6%) | 21 (22.1%) | 20 (25.3%) | |
| GED | 45 (25.9%) | 28 (29.5%) | 17 (21.5%) | |
| Some college | 18 (10.3%) | 5 (5.3%) | 13 (16.5%) | |
| Employment | | | | 0.355[P] |
| Full time | 136 (78.2%) | 72 (75.8%) | 64 (81.0%) | |
| Part time | 11 (6.3%) | 6 (6.3%) | 5 (6.3%) | |
| Unemployed/laid off | 21 (12.1%) | 15 (15.8%) | 6 (7.6%) | |
| On disability | 4 (2.3%) | 1 (1.0%) | 3 (3.8%) | |
| Homemaker | 2 (1.1%) | 1 (1.0%) | 1 (1.3%) | |
| Usual tooth brushing frequency | | | | 0.739[M*] |
| 3 or more per day | 23 (13.2%) | 13 (13.7%) | 10 (12.7%) | |
| 2x per day | 62 (35.6%) | 32 (33.7%) | 30 (38.0%) | |
| 1x per day | 69 (39.7%) | 43 (45.3%) | 26 (32.9%) | |
| 3 to 6x per week | 11 (6.3%) | 4 (4.2%) | 7 (8.9%) | |
| 1 to 2x per week | 5 (2.9%) | 2 (2.1%) | 3 (3.8%) | |
| <weekly | 4 (2.3%) | 1 (1.1%) | 3 (3.8%) | |
| On drugs tooth brushing frequency[#] | | | | 0.907[M*] |
| 3 or more per day | 16 (9.4%) | 8 (8.7%) | 8 (10.1%) | |
| 2x per day | 47 (27.5%) | 23 (25.0%) | 24 (30.4%) | |
| 1x per day | 63 (36.8%) | 36 (39.1%) | 27 (34.2%) | |
| 3 to 6x per week | 16 (9.4%) | 9 (9.8%) | 7 (8.9%) | |
| 1 to 2x per week | 5 (2.9%) | 2 (2.2%) | 3 (3.8%) | |
| <weekly | 24 (14.0%) | 14 (15.2%) | 10 (12.7%) | |

t=t-Test; P=Pearson Chi Square; M=Mann-Whitney U Test; M*=Mann-Whitney U Test (based on the 6 ordinal responses on frequency of use); F=Fisher's Exact Test; #User=92; ##Non-user=78; ###User=94

range 17 to 53), 85.6% were male, 81.6% were White, 50.6% had never been married, 49.5% had either graduated high school or obtained a GED, and 78.2% had been employed full-time prior to incarceration (Table I).

The main reasons for last dental visit were a toothache (55.2%), checkup (28.2%) and other dental work (15.5%). More than half (n=101, 57.9%) had not been to the dentist in the past year and the average number of years since last dental visit was 4 (SD=4.3).

Most subjects usually brushed their teeth once (39.7%) or twice a day (35.6%); however, when subjects were using drugs, 36.8% brushed once a day and only 27.5% brushed twice a day. While 2.3% of subjects usually brushed less than

Table I: Distribution of Subjects by Covariates and by Methamphetamine Use (continued)

| Variable | Total (n=174) n (percent) | Meth User (n=95) n (percent) | Meth Non-user (n=79) n (percent) | p–value |
|---|---|---|---|---|
| Years since last dental visit | | | | 0.042[M] |
| 1 | 73 (42.0%) | 47 (49.5%) | 26 (32.9%) | |
| 2 | 20 (11.5%) | 10 (10.5%) | 10 (12.7%) | |
| 3 to 4 | 22 (12.6%) | 9 (9.5%) | 13 (16.4%) | |
| 5 to 9 | 35 (20.1%) | 19 (20.0%) | 16 (20.2%) | |
| 10 to 25 | 22 (12.6%) | 9 (9.5%) | 13 (16.4%) | |
| Never been | 2 (1.1%) | 1 (1.0%) | 1 (1.3%) | |
| Reason for last dental visit | | | | 0.032[P] |
| Toothache | 96 (55.2%) | 62 (65.3%) | 34 (43.0%) | |
| Other work | 27 (15.5%) | 8 (8.4%) | 19 (24.1%) | |
| Check up | 49 (28.2%) | 24 (25.3%) | 25 (31.6%) | |
| Never been | 2 (1.1%) | 1 (1.1%) | 1 (1.3%) | |
| Number of drugs | | | | <0.001[F] |
| None | 12 (6.9%) | 0 (0.0%) | 12 (15.2%) | |
| Only one | 18 (10.3%) | 1 (1.1%) | 17 (21.5%) | |
| Multiple | 144 (82.8%) | 94 (98.9%) | 50 (63.3%) | |
| Ever used drugs | | | | |
| Tobacco | | | | <0.001[F] |
| Yes | 151 (86.8%) | 92 (96.8%) | 59 (74.7%) | |
| No | 23 (13.2%) | 3 (3.2%) | 20 (25.3%) | |
| Alcohol | | | | 0.508[P] |
| Yes | 101 (58.0%) | 53 (55.8%) | 48 (60.8%) | |
| No | 73 (42.0%) | 42 (44.2%) | 31 (39.2%) | |
| Marijuana | | | | <0.001[P] |
| Yes | 91 (52.3%) | 67 (70.5%) | 24 (30.4%) | |
| No | 83 (47.7%) | 28 (29.5%) | 55 (69.6%) | |
| Cocaine | | | | <0.001[P] |
| Yes | 41 (23.6%) | 33 (34.7%) | 8 (10.1%) | |
| No | 133 (76.4%) | 62 (65.3%) | 71 (89.9%) | |
| Heroin | | | | 0.032[F] |
| Yes | 6 (3.4%) | 6 (6.3%) | 0 (0.0%) | |
| No | 168 (96.6%) | 89 (93.7%) | 79 (100.0%) | |
| Other | | | | 0.060[P] |
| Yes | 14 (8.0%) | 11 (11.6%) | 3 (3.8%) | |
| No | 160 (92.0%) | 84 (88.4%) | 76 (96.2%) | |

t=t-Test; P=Pearson Chi Square; M=Mann-Whitney U Test; M*=Mann-Whitney U Test (based on the 6 ordinal responses on frequency of use); F=Fisher's Exact Test; #User=92; ##Non-user=78; ###User=94

weekly, 14.0% brushed less than weekly when on drugs.

Almost half or more of the subjects reported that they ingested soda (83.3%), chips and/or snack crackers (59.0%), cake and/or cookies (54.3%), or candy (47.1%) at least once a day. Soda was consumed 3 or more times a day by 64.9% of the subjects for a mean consumption of 15.9 times per week. Non-soda sugars were consumed, on average, 34.7 times per week.

While the majority of subjects (82.8%) used multiple drugs, 12 did not use any drugs and 18 used only 1 drug. Four drugs were used by more than half of the subjects: tobacco (86.8%), alcohol (58.0%), methamphetamine (54.6%) and marijuana (52.3%). Cocaine was used by 23.6% of the subjects and heroin by 3.4%. Fourteen subjects reported using other types of drugs.

Bivariate analysis determined significant associations between methamphetamine use and being White, being female, having visited the

Table I: Distribution of Subjects by Covariates and by Methamphetamine Use (continued)

| Variable | Total (n=174) n (percent) | Meth User (n=95) n (percent) | Meth Non-user (n=79) n (percent) | |
|---|---|---|---|---|
| Sugar consumption | | | | |
| Soda | | | | 0.007[M*] |
| 1 to 3x per day<br>1 to 6x per week<br><weekly | 145 (83.3%)<br>13 (7.5%)<br>16 (9.2%) | 84 (88.4%)<br>4 (4.2%)<br>7 (7.4%) | 61 (77.2%)<br>9 (11.4%)<br>9 (11.4%) | |
| Chips/crackers[##] | | | | 0.339[M*] |
| 1 to 3x per day<br>1 to 6x per week<br><weekly | 102 (59.0%)<br>34 (19.7%)<br>37 (21.4%) | 59 (62.1%)<br>18 (18.9%)<br>18 (18.9%) | 43 (55.1%)<br>16 (20.5%)<br>19 (24.4%) | |
| Cakes/cookies[###] | | | | 0.149[M*] |
| 1 to 3x per day<br>1 to 6x per week<br><weekly | 94 (54.3%)<br>29 (16.8%)<br>50 (28.9%) | 57 (60.6%)<br>16 (17.0%)<br>21 (22.3%) | 37 (46.8%)<br>13 (16.5%)<br>29 (36.7%) | |
| Candy | | | | 0.188[M*] |
| 1 to 3x per day<br>1 to 6x per week<br><weekly | 82 (47.1%)<br>41 (23.6%)<br>51 (29.3%) | 49 (51.6%)<br>23 (24.2%)<br>23 (24.2%) | 33 (41.8%)<br>18 (22.8%)<br>28 (35.4%) | |
| Kool-Aid/lemonade | | | | 0.759[M*] |
| 1 to 3x per day<br>1 to 6x per week<br><weekly | 62 (35.6%)<br>19 (10.9%)<br>93 (53.4%) | 34 (35.8%)<br>9 (9.5%)<br>52 (54.7%) | 28 (35.4%)<br>10 (12.7%)<br>41 (51.9%) | |
| Sweetened cereal[##] | | | | 0.312[M*] |
| 1 to 3x per day<br>1 to 6x per week<br><weekly | 58 (33.5%)<br>23 (13.3%)<br>92 (53.2%) | 35 (36.8%)<br>12 (12.6%)<br>48 (50.5%) | 23 (29.5%)<br>11 (14.1%)<br>44 (56.4%) | |
| Sweet rolls/cereal bars | | | | 0.391[M*] |
| 1 to 3x per day<br>1 to 6x per week<br><weekly | 55 (31.6%)<br>17 (9.8%)<br>102 (58.6%) | 32 (33.7%)<br>10 (10.5%)<br>53 (55.8%) | 23 (29.1%)<br>7 (8.9%)<br>49 (62.0%) | |
| Sweetened coffee/tea | | | | 0.099[M*] |
| 1 to 3x per day<br>1 to 6x per week<br><weekly | 45 (25.9%)<br>8 (4.6%)<br>121 (69.5%) | 28 (29.5%)<br>5 (5.3%)<br>62 (65.3%) | 17 (21.5%)<br>3 (3.8%)<br>59 (74.7%) | |

t=t-Test; P=Pearson Chi Square; M=Mann-Whitney U Test; M*=Mann-Whitney U Test (based on the 6 ordinal responses on frequency of use); F=Fisher's Exact Test; #User=92; ##Non-user=78; ###User=94

dentist in the previous year, having visited the dentist for a toothache, having consumed soda at the highest frequency, using multiple drugs, using tobacco, using marijuana, using cocaine, and using heroin (Table I).

Eighteen participants had no teeth with untreated dental caries and 32 had no missing teeth. Users had significantly higher numbers of carious teeth (p=0.020), carious surfaces (p=0.018) and missing teeth (p=0.009) than those who had never used methamphetamine (Table II).

The significant bivariate associations between each covariate and the dependent variables of carious teeth and surfaces are as follows. Dental caries were significantly greater among those using methamphetamine (carious teeth: p=0.020; surfaces: p=0.018), being White (carious teeth: p=0.016; surfaces: p=0.014), consuming soda more frequently (carious teeth: p=0.000; surfaces: p=0.002), brushing once a day or less when on drugs (carious teeth: p=0.031; surfaces: p=0.050), and visiting the dentist for a toothache or other work (carious teeth: p=0.030; surfaces: p=0.005). The number of missing teeth was significantly greater among those using methamphetamine (p=0.009), being older (p=0.000), being male (p=0.021), being married (p=0.000), not visiting the dentist in the past

Table II: Summary Statistics for Oral Health Variables and Statistical Significance by Methamphetamine Use

| Variable | Mean | SD | Median | Q1 | Q3 | p-valueM |
|---|---|---|---|---|---|---|
| Decayed teeth | | | | | | 0.02 |
| Total | 6.9 | 5.8 | 6 | 3 | 10 | |
| User | 7.8 | 6.2 | 7 | 3 | 10 | |
| Non-user | 5.8 | 5.1 | 4 | 2 | 8 | |
| Decayed surfaces | | | | | | 0.018 |
| Total | 17.5 | 17.4 | 14 | 5 | 23 | |
| User | 20.4 | 19.2 | 15 | 6 | 28 | |
| Non-user | 13.9 | 14.1 | 11 | 4 | 20 | |
| Missing teeth | | | | | | 0.009 |
| Total | 4.2 | 4.3 | 3 | 1 | 6 | |
| User | 4.7 | 3.9 | 4 | 2 | 7 | |
| Non-user | 3.7 | 4.7 | 3 | 1 | 4 | |

M=Mann-Whitney U Test; SD=Standard Deviation; Q1=25$^{th}$ Percentile; Q3=75$^{th}$ Percentile

year (p=0.004), and visiting the dentist for a toothache or other work (p=0.000).

Regression analyses to control for covariates in assessing the effect of methamphetamine use on dental caries showed a significant interaction between methamphetamine use and race/ethnicity (carious teeth: p=0.039; surfaces: p=0.023) and a significant interaction between methamphetamine use and tooth brushing frequency when on drugs (carious teeth: p=0.044; surfaces: p=0.035) (Table III). Among Non-Whites there were significantly more carious teeth and surfaces in methamphetamine users (n=6) compared to non-users (n=26) (Bonferroni adjusted p=0.014 and p=0.011, respectively). However, no significant effect of methamphetamine was seen among Whites (carious teeth Bonferroni adjusted p=0.367; carious surfaces Bonferroni adjusted p=0.287) (Table IV). Likewise, among those who brushed their teeth less than once a day when on drugs, there were significantly more carious teeth and surfaces in methamphetamine users (n=25) compared to non-users (n=20) (Bonferroni adjusted p=0.007 and p=0.003, respectively). There was no significant effect of methamphetamine on carious teeth and surfaces (Bonferroni adjusted p=0.216 and p=0.221, respectively) among those who brushed their teeth at least once a day when on drugs (Table IV). Other significant covariates for dental caries were reason for last dental visit (carious teeth: p=0.025; surfaces: p=0.011) and soda (carious teeth: p=0.026; surfaces: p=0.030). Those who visited the dentist for a toothache or other work and those who more frequently consumed soda had more carious teeth and surfaces (Table III).

For missing teeth, regression analyses to assess the effect of methamphetamine use showed a significant methamphetamine and race/ethnicity interaction (p=0.028) (Table III). This interaction indicated that the effect of methamphetamine on missing teeth differed within race/ethnicity categories, with significantly more missing teeth in Whites who used methamphetamine (n=89) than in Whites who did not (n=53) (Bonferroni adjusted p=0.038). There was no significant association between methamphetamine use on missing teeth among Non-Whites (Bonferroni adjusted p=0.431) (Table IV). Other significant covariates were age (p=0.0001) and reason for last dental visit (p=0.0001). Being older and visiting the dentist for a toothache or other work resulted in more missing teeth (Table III).

## Discussion

Previous studies reported a lower percentage of methamphetamine users who brushed their teeth at least daily when on drugs (35.3 to 41%)[30-33] than found in this study (72.8%). Only one study reported a significant bivariate relationship between methamphetamine use and tooth brushing when on drugs.[32] While this study did not find significant bivariate relationships between methamphetamine use and usual tooth brushing and methamphetamine use and tooth brushing when on drugs, it did find a significant bivariate relationship between tooth brushing when on drugs and dental caries. Additionally, multivariate analysis of this data indicated that methamphetamine use results in statistically more dental caries for those who brush less than once a day when on drugs.

Table III: Regression Coefficient Estimates and Statistical Significance of the Fitted Models with Interaction Effects for Each Oral Health Variable

| Variable | Decayed Teeth | | | Decayed Surfaces | | | Missing Teeth | | |
|---|---|---|---|---|---|---|---|---|---|
| | b | SE | p–value | b | SE | p–value | b | SE | p–value |
| Intercept | 0.698 | 0.645 | 0.281 | 0.405 | 1.096 | 0.712 | -0.237 | 0.342 | 0.489 |
| Methamphetamine use | -0.066 | 0.268 | 0.806 | -0.145 | 0.456 | 0.751 | 0.314 | 0.132 | 0.019 |
| Cocaine use | -0.038 | 0.230 | 0.869 | -0.043 | 0.392 | 0.912 | -0.060 | 0.123 | 0.625 |
| Marijuana use | 0.076 | 0.214 | 0.722 | 0.234 | 0.363 | 0.520 | 0.155 | 0.113 | 0.174 |
| Tobacco use | -0.051 | 0.288 | 0.860 | -0.362 | 0.489 | 0.461 | 0.153 | 0.153 | 0.322 |
| Alcohol use | -0.145 | 0.197 | 0.462 | -0.237 | 0.334 | 0.479 | -0.104 | 0.104 | 0.316 |
| Sex (male) | 0.427 | 0.274 | 0.122 | 0.521 | 0.466 | 0.265 | -0.083 | 0.146 | 0.571 |
| Age | 0.010 | 0.015 | 0.494 | 0.041 | 0.025 | 0.104 | 0.032 | 0.008 | <.000 |
| Race/ethnicity (Non-White) | -0.624 | 0.290 | 0.033 | -1.093 | 0.493 | 0.028 | 0.385 | 0.154 | 0.013 |
| Never married (other) | 0.074 | 0.261 | 0.777 | 0.114 | 0.444 | 0.798 | -0.052 | 0.138 | 0.707 |
| Married (other) | -0.063 | 0.265 | 0.812 | 0.033 | 0.451 | 0.941 | 0.078 | 0.141 | 0.584 |
| Last visit to dentist (>1 year) | 0.279 | 0.202 | 0.170 | 0.450 | 0.343 | 0.192 | -0.185 | 0.108 | 0.088 |
| Reason for last visit to dentist (toothache/other) | 0.499 | 0.220 | 0.025 | 0.965 | 0.374 | 0.011 | 0.500 | 0.117 | <0.000 |
| On drugs tooth brushing frequency (<1/day) | -0.200 | 0.322 | 0.536 | -0.463 | 0.548 | 0.400 | 0.160 | 0.111 | 0.151 |
| Soda | 0.030 | 0.014 | 0.026 | 0.051 | 0.023 | 0.030 | 0.008 | 0.007 | 0.254 |
| Non-soda sugars | 0.002 | 0.004 | 0.598 | 0.005 | 0.007 | 0.475 | 0.000 | 0.002 | 0.858 |
| Methamphetamine*race/ ethnicity | 1.204 | 0.579 | 0.039 | 1.645 | 0.718 | 0.023 | -0.684 | 0.308 | 0.028 |
| Methamphetamine*On drugs tooth brushing frequency | 0.856 | 0.422 | 0.044 | 2.097 | 0.985 | 0.035 | – | – | – |
| R squared | | | 19% | | | 21% | | | 41% |

SE=Standard Error

Previous methamphetamine studies did not include reason for dental visit, which this analysis found was related to both dental caries and missing teeth. In this study, subjects who saw the dentist for toothaches or other treatment had poorer oral health than those who saw the dentist for a check-up. In addition to the advanced stage of disease, the large number of missing teeth found in these prisoners may reflect the culture of dental care.[39]

In 3 previous studies, consumption of soda varied from 35.3%[30] to 94%[32] among methamphetamine users. This study found that 92.6% of methamphetamine users consumed soda. Morio et al found a significant difference in percent consuming soda between methamphetamine users and non-users, as was found in this study.[32] However, Cretzmeyer et al[31] and Brown et al[30] did not. This analysis found that the frequency of soda consumption correlated with dental caries, as did Ravenel et al,[7] but Cretzmeyer et al[31] did not. When covariates were controlled, soda consumption remained significantly related to dental caries. None of the other sugar variables studied individually or as a combined frequency correlated with methamphetamine use or with dental caries. Sugar variables, including soda consumption, were not related to missing teeth.

In addition to this study, Cretzmeyer et al were the only ones to investigate the relationship between age and oral health.[31] Although they found that methamphetamine users were significantly younger than their other-substance-abuse comparison group, logistic regression indicated that age was not related to oral health. In this study age was not related to methamphetamine use nor to dental caries; however, age was related bivariately and multivariately to missing teeth, with older inmates having more missing teeth.

Table IV: Effect of Methamphetamine on Oral Health Variables Based on Estimates from the Regression Models

| Oral Health Measures | Interaction | User | | | Non-user | | | p–valueB |
|---|---|---|---|---|---|---|---|---|
| | | n | mean | SE | n | mean | SE | |
| Decayed teeth | Methamphetamine*race/ethnicity | | | | | | | |
| | Non-Whites | 6 | 9.7 | 3.0 | 26 | 3.1 | 0.9 | 0.014 |
| | Whites | 89 | 6.8 | 1.0 | 53 | 5.2 | 1.2 | 0.367 |
| | Methamphetamine*On drugs toothbrushing frequency | | | | | | | |
| | Less than once a day | 25 | 10.1 | 2.1 | 20 | 3.7 | 1.2 | 0.007 |
| | Once a day or more | 70 | 6.6 | 1.4 | 59 | 4.4 | 0.9 | 0.216 |
| Decayed surfaces | Methamphetamine*race/ethnicity | | | | | | | |
| | Non-Whites | 6 | 26.8 | 8.4 | 26 | 8.0 | 2.3 | 0.011 |
| | Whites | 89 | 18.7 | 2.8 | 53 | 13.9 | 2.9 | 0.287 |
| | Methamphetamine*On drugs toothbrushing frequency | | | | | | | |
| | Less than once a day | 25 | 28.2 | 5.9 | 20 | 9.4 | 2.9 | 0.003 |
| | Once a day or more | 70 | 18.0 | 3.8 | 59 | 12.0 | 2.4 | 0.221 |
| Missing teeth | Methamphetamine*race/ethnicity | | | | | | | |
| | Non-Whites | 6 | 2.1 | 0.8 | 26 | 3.5 | 0.7 | 0.431 |
| | Whites | 89 | 3.2 | 0.5 | 53 | 2.1 | 0.4 | 0.038 |

B=Bonferroni Adjusted Method
Means and Standard Errors (SE) Computed by Back Transformation

Although methamphetamine users commonly use other illicit drugs,[40] previous researchers[7,30-33] did not investigate them. In this study, while use of tobacco, marijuana, cocaine and heroin were significantly correlated with methamphetamine use, none of these drugs correlated with dental caries and missing teeth. Additionally, multivariate analyses controlled for these 4 drugs and none was found to be related to the oral health variables. However, polydrug use was high and this sample of 174 subjects was not adequate to consider all the interaction effects of the drugs with methamphetamine.

The findings that methamphetamine's effects on dental caries are moderated by tooth brushing when on drugs, and that the reason for dental visit influences both caries and missing teeth, suggest intervention points. One intervention would focus on preventive behaviors. For persons with few dental caries, secondary preventive measures would comprise appropriate traditional home care and routine dental visits. However, many of the prisoners in this study are at the tertiary level and may require prescription strength fluoride toothpaste, frequent professional cleanings and elimination of soda. Since methamphetamine use may alter saliva so that it is more acidic and has less buffering capacity, saliva testing and appropriate neutralizing and re-mineralizing agents should be considered.[7] Drugs used to treat drug abuse should not have high sugar content.

Researchers have found that habituated oral health behaviors can withstand changes in a person's social environment, and this underscores the importance of primary prevention.[41] Had the methamphetamine users in this study had well-established oral care habits they would have maintained their usual higher tooth brushing frequency and regular dental visits when on drugs. This would have reduced the number and size of carious lesions for the prisoners who used methamphetamine. Given what is known about developing dental health habits, primary prevention should start at birth.[42-45]

Changing adults' health behavior is not easy, nor is altering dental procedures in institutions. Research on dental hygienists' role in providing

preventive services to drug users has not been reported. However, given administrative support for establishing policies and funding, these interventions are within the scope of dental hygiene practice and thus could be provided cost-effectively by dental hygienists. It is likely that dental hygienists, especially those employed in rehabilitation or correctional facilities, could advocate for restrictions on access to sodas and other sugar intake similar to those for diabetic prisoners, for shorter intervals for prophylaxes and closer supervision of personal oral hygiene.

Another intervention to consider would be dental screenings for high school seniors, especially in states where methamphetamine use is prevalent. In the newly admitted prisoners in this study, by age 18, 63% of this high risk group had tried methamphetamine. Thus, such a dental screening program may not only lead to early detection of dental caries and the prevention of destructive caries but may also lead to early identification of drug use.

While these interventions are primarily directed at dental caries, they also would address missing teeth. Osborn found that approximately 86% of prisoners ages 25 to 40 needed teeth extracted due to dental caries; for those younger than 25 and those older than 40, 65% needed extraction.[46]

A limitation of this study which may have influenced the results was that the number of missing teeth attributed to dental disease may have been over-estimated because the reason for teeth being absent was not ascertained. In addition to dental disease, teeth could have been missing due to trauma and orthodontic care. Salive suggested that the higher mean number of missing teeth in the prisoners he studied, as compared to a national sample, may have been due to trauma.[47]

Additionally, there were 3 variables which were not captured completely: the upper limit of soda consumption, the lower limit of tooth brushing when on drugs and a complete history of dental caries (because filled teeth were not charted as part of the oral examination at the IMCC). However, it is unlikely that these limitations on completeness altered the findings of this study.

Since the data were collected 16 years ago, this raises the question: Are the data still pertinent today? The authors believe they are for a number of reasons. Methamphetamine use still creates a meaningful and growing burden on health care facilities and penal institutions in Iowa.[2,3] Methamphetamine used in 2014 in Iowa is purer than that which was used in 1998.[3] Whether more pure methamphetamine would result in higher levels of decay is unknown. If it did, methamphetamine users would be further differentiated from non-users. The research methodology used in this study is consistent with current approaches and the Substance Abuse and Mental Health Services Administration's measurement of methamphetamine use.[40] The dental evaluations are conducted in the same manner at the IMCC, and dental caries and missing teeth are still common measures of oral health status. Dental caries preventive and treatment procedures have changed little since 1998.

The prison population was selected because the authors expected that prisoners would have more oral disease and more use of illicit drugs than the general population. Additionally, this population was accessible and was not expected to be affected by socially-correct answers. Conducting the study within the confines of this particular penal institution restricted data collection to inmates evaluated by the staff dental hygienist and precluded using more than one examiner as well as conducting intra-examiner reliability tests.

The setting did allow for non-threatening, confidential and routine implementation of the personal interviews. The structure of the interview and sequencing of items were done to be consistent, clear, and easy to answer, to enhance recall and unbiased responses, and to give equal attention to all drugs. While self-reported information is often considered suspect, it is the most common methodology to obtain personal information and it is the most practical in terms of privacy and expense. Donovan concluded that self-reported drug use can be accurate if the foregoing techniques of interview design and implementation are utilized.[48]

Future studies are needed to elucidate the role of methamphetamine use on oral health status. Large sample sizes are needed to study main effects regarding use of other drugs and to test the interaction effect regarding race/ethnicity found in this study among the small number (n=6) of Non-White users. Additional research using users and nonusers could test the validity of anecdotal information regarding the unique location and appearance of methamphetamine-associated caries. In addition to comparing users and nonusers, quantity and frequency of methamphetamine use and oral health should also be investigated. Another area of research would be to develop and test the effectiveness of interventions regarding oral hygiene, professional care, and soda consumption for methamphetamine users.

## Conclusion

The effect of methamphetamine use on missing teeth was moderated by race/ethnicity; whereas the effect of methamphetamine use on dental caries was moderated by race/ethnicity and tooth brushing when on drugs. Methamphetamine use together with poor oral hygiene resulted in significantly more dental caries. As is evident from this study the relationship between methamphetamine use and oral health is complex. The findings from this study suggest that it may be possible to mitigate oral health problems associated with methamphetamine use through preventive oral hygiene programs. The avenues for further research stated above would add to the limited body of work on the relationship of methamphetamine use and oral health and would elucidate the role dental hygienists could play in reducing dental disease in methamphetamine users.

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## Acknowledgments

The authors wish to thank: R.D. Axelson, PhD, Associate Professor, Department of Sociology, Director, Center for Social Research, North Dakota State University; K. Kelly, PhD, Associate Research Scientist, Department of Occupational and Environmental Health, College of Public Health, the University of Iowa; J. Yang, PhD. Associate Professor, Department of Pediatrics, College of Medicine, The Ohio State University; and secretarial and research assistant support from the Department of Community and Behavioral Health.

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