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Oral health among New Mexican decedents aged 35-44 using NMDID postmortem CT scans

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ABSTRACT
Using postmortem CT scans from the New Mexico Decedent Image Database, we investigated dental health among recently (2010-2017) deceased New Mexicans who experienced premature deaths while not under the care of a health professional. In this study, we predicted that race/ethnicity, substance use, and rural living are associated with poor dental health. The sample (n = 305; nfemale = 130) consists of similar representation of race/ethnicity (European American, Hispanic, and Native American) with decedents 35-44 years old at time of death. Approximately 50% of deaths were substance use related. Data included the total number of missing teeth, restorations, abscesses, and decayed teeth. Two indices of oral health were calculated for each decedent and used in linear regressions with sociodemographic variables such as sex, race/ethnicity, socioeconomic status, residential location, drinking status, tobacco use, and death involving substance use. Both indices show that being Native American ($p < 0.001$) or European American ($p < 0.01$) were significantly associated with having worse oral health. These same factors relate to health disparities in general and indicate long standing issues with health equity in New Mexico.

Introduction
Oral health is an important component in analyses of health disparities. Unfortunately, there is a cultural decoupling of oral health from overall systemic health, which is especially evident in the discrepancy between the number of individuals of the US population with medical insurance (90.3%; Cohen et al., 2021), and those who also have dental coverage (50.2% of that 90.3%; Blackwell et al., 2019). Therefore, since more than half of the US population is without dental insurance, their oral health needs are likely not being met. Oral diseases are considered one of the most pressing public health concerns (Peres et al., 2019; Edelstein, 2006; Gaskin et al., 2021; Stephens et al., 2018; Koppelman & Singer-Cohen, 2017; Reda et al., 2018; Fischer et al., 2017; Lenaker, 2017). Health disparities are systemic differences in one or more aspects of health across social, economic, demographic, or geographic groups. The differences in the quality of healthcare received can exacerbate the divide between groups (Starfield, 2011; Starfield et al., 2012; WHO, 2008). Oral health is "[m]ultifaceted and includes the ability to speak, smile, taste, touch, chew, swallow, and convey a range of emotions through facial expressions with confidence and without pain, discomfort, and disease of the craniofacial complex" (Hescot, 2017: 2). Health-enhancing and health-damaging conditions affect oral health. In fact, the risk factors that cause a decline in overall health and oral health are the same, such as a diabetes diagnosis (Ahmad & Haque, 2021) or cardiovascular disease and respiratory disease (Kotronia et al., 2021).

Sex, race/ethnicity, and geographic location are important predictors of oral disease (Lipsky et al., 2021; Atchison & Gift, 1997; Ogunbodede et al., 2015). The increased caries rates in females have been attributed to hormonal fluctuations and social roles within the family (Ferraro and Vieira, 2010).

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Studies have also identified poorer oral health outcomes in racially and ethnically minoritized groups (Brockie et al., 2013; Gaskin et al., 2021; Schwartz et al., 2018). Rural populations experience higher rates of caries, limited dental care access, higher rates of poverty, lower rates of insurance, and are more likely to become edentulous (Skillman et al., 2010; Vargas et al., 2002).

Oral health disparities are not equally distributed across populations. The current study examines a small piece of the broader oral health disparity puzzle: oral disease relating to the dentition that can be observed through postmortem computed tomography (PMCT) scans. We investigated the sociodemographic predictors of oral disease in the forms of caries burden (severe decay; due to ≥1/2 of tooth crown missing), tooth loss, infection (abscess presence), and restorations in a sample of New Mexicans who died prematurely outside of the care of a healthcare professional.

Measures of Oral Health

We measure oral health by examining rates of tooth decay, abscesses, tooth loss, and caries restorations. Poor oral health maintenance, such as not routinely brushing teeth or not regularly receiving dental exams, can lead to a proliferation and accumulation of bacteria in the mouth. These bacteria live in a biofilm called plaque, and can erode enamel and lead to tooth decay, eventually resulting in caries or periodontal disease (Attin & Hornecker, 2005). Diet, oral pH, biology, environment, and behavior are all factors in caries formation. Everyone experiences plaque formation, but caries development varies by individual (Selwitz et al., 2007). Differences in pH, biofilm, and ingested carbohydrates determine the acidity and alkalinity levels in the mouth, and when acid generation outnumbers alkali generation, caries result (Burne & Marquis, 2000). Abscesses form when anaerobic bacteria accumulate around a tooth, eventually penetrating the hard and soft tissues of the mouth, resulting in an infection in the root canal. Abscesses can also start from inflammation and infection within the tooth and move down the root canal. Abscesses can cause severe infections and life-threatening complications, becoming detrimental to not only oral health, but overall physical health (Siqueira & Rôças, 2013). Another common indicator of poor oral health is missing teeth, which can result from congenital defects, poor hygiene, oral disease, and trauma (Terheyden & Wüsthoff, 2015). Altogether, missing teeth, abscesses, and severely decayed teeth can be treated by several procedures. Restorations are placed to increase functionality and aesthetics by reinforcing the surface of the tooth (Ababneh et al., 2011). Prior research that investigated how well metal artifacts (i.e. fillings and implants) and pathologies like tooth loss, carious lesions, and periodontal disease can be detected from CT scans show that radiography can be an important tool in oral health assessments (Sakuma et al., 2012; Minnema et al., 2019; Bulbul et al., 2017).

Oral Health in New Mexico

Previous research indicates there are increased risks for negative oral health outcomes among people who are low-income, uninsured, of racial/ethnic minority, immigrants, and/or live rurally (Northridge et al., 2020). New Mexico, with its high poverty rate (16.8%) and diverse population (10.6% Native American, 49.3% Hispanic; US Census, 2021), has many characteristics that suggest its population would have poor oral health. For reference, Native Americans make up 2% of the United States population with numbers at 5.2 million (US Department of Health and Human Services, n.d.). As of 2020, approximately 15% of New Mexicans do not have medical insurance, compared to the 13% uninsured nationwide. Further, 47% of New Mexicans do not have dental insurance (New Mexico Behavioral Risk Factor Surveillance System, 2020). In 2004, 66% of adult New Mexicans had seen a dentist and/or had their teeth cleaned during the previous year, compared to the national average of 69% (Chattopadhyay, 2008).

New Mexico is a sparsely populated state, with 42% of people living in dental health professional shortage areas, where the dentist to population ratio is <1:5,000 (Pew Charitable Trusts, 2017). Of the state's 33 counties, only seven are *not* considered dentist shortage areas. However, six of these counties have portions that are in shortage areas, meaning only one county in the state has appropriate access to dental care, given the size of its population (Rural Health Information, 2022). Further, New Mexico is one of the few US states without a dentistry school (although there is a dental hygiene program; Formicola et al., 2008). It is important to study oral health outcomes specifically at state and regional levels to understand the variability present across the US population.

In this study, we investigate the relationship between oral health (measured by missing teeth, abscesses, restorations, and decayed teeth) and social determinants of health in New Mexicans who had premature deaths outside of the care of a healthcare professional. There are limited methods of studying oral health, so in this study we use these four metrics combined into two separate indices. We used PMCT scans to examine a sample of New Mexican decedents aged 35-44 years. The overarching questions for this study are: 1) Is the presence of oral disease (measured by caries burden, tooth loss, and infection) associated with oral health disparities among our sample of New Mexican decedents aged 35-44 years and 2) what are the social predictors of oral disease in this New Mexican forensic sample.

We predicted that higher rates of poor oral health indicators would be present among individuals with: 1) lower SES; 2) Hispanic and Native American race/ethnicity; 3) the use of alcohol, tobacco, and illicit substances; 4) rural residence. These predictions were informed by Eke et al. (2015), Dye et al. (2015), and Gaskin et al. (2021), who showed that Hispanic individuals were at a higher risk of having poor oral health compared to European American individuals. Other research indicates that Native Americans and Alaskan Natives have more untreated dental caries than all other racial or ethnic groups in the United States (Phipps & Rick 2016). Those with lower SES, whether defined by income or educational attainment, have been shown to have poorer oral health outcomes than those with a higher SES (Gaskin et al., 2021; Bersell, 2017; Eke et al., 2015). Skillman et al. (2010) showed that rural populations have less access to dentists and higher rates of poverty. Additionally, tobacco and high alcohol consumption both correlate with reduced oral health outcomes (Donaldson & Goodchild, 2006; Chaffee et al., 2021; Sachdev & Garg, 2018; D'Amore et al., 2011).

Materials and methods

This study used a sample derived from the New Mexico Decedent Image Database (NMDID; Edgar et al., 2020). NMDID includes PMCT scans for >15,000 decedents who died between 2010-2017 while not under the care of a physician. These scans were taken at the Office of the Medical Investigator (OMI) in Albuquerque, New Mexico as a standard part of medicolegal investigations. NMDID also includes data from as many as 69 variables associated with demography, life, and death. These data, including SES and other demographic data, were collected through death investigations and phone interviews with next of kin (Daneshvari Berry et al., 2021). NMDID includes 11% of the total New Mexican population who died between those years (Daneshvari Berry et al., 2021) drawn from across the state. These individuals provide a forensic sample from New Mexico but may not be representative of the of the general New Mexican population.

We drew a sample of PMCT scans of 305 decedents from NMDID. As age correlates with the number of missing teeth due to natural senescence (Dye et al., 2015), we selected individuals who died between the ages of 35-44 to capture the effects of oral health disparities prior to age-related changes (Peter Loomis, DDS, pers. comm.). Additional inclusion criteria were natural cause of death (e.g., cardiovascular disease, irregular heartbeat, substance intoxication, ethanolism), non-traumatic homicide, or non-traumatic suicide. Causes of death included are hypertension, liver failure, suicide, exposure, gastrointestinal hemorrhage, epilepsy, drowning, blood clot, diabetes, cardiac arrythmia, asphyxia, carbon monoxide poisoning, asthma, cancer, and aneurysm. Individuals were excluded who had trauma-related deaths (gunshots, car accidents, head/neck injuries, and burns) that could result in inconclusive dentition scores. We prioritized including individuals who had information available on SES and substance use. We also prioritized sampling for equal representation of sex and race/ethnicity among European Americans, Hispanics, and Native Americans from all areas of the state (using partial zip codes provided to ensure representation). Because the database lists "Hispanic" as either a race or ethnicity, decedents were categorized as Hispanic in our study if either their ethnicity or race was Hispanic.

Data Collection

HC recorded all oral health data from PMCT scans. All CT slices and 3D reconstructions were examined using Amira™, a software used for data visualization, processing, and analysis. We used a threshold of 250 Hounsfield units to segment soft tissue from bone to visualize dentition, maxillae, and mandibles. CT slices were examined using slice thickness of 1 mm with 0.5 mm overlap and a soft tissue reconstruction algorithm. First, 3D reconstructions were evaluated for an initial inventory of the dentition and to score abscesses (Figure 1). Individual slices were then used to finalize the inventory and abscess scores and to record which teeth had restorations, if any, where restorations of metal or composite fillings appear noticeably brighter than the surrounding enamel and bone (Figure 2). Values for each of the four oral health indicators for each decedent were recorded in a custom LibreOffice (LibreOffice 7.0, 2020) database.

NMDID provides the categories for most health and lifestyle variables (Edgar et al., 2020). However, we had to establish our own categories for rural/urban living, tobacco use, and substance use. Rural residence was determined based on the county of death for each decedent, following the US census. The US census defines rural as counties with >50% of the population living in rural areas and counties with <50% of the population living in rural areas as urban. Tobacco use was divided into "former", "light", and "heavy" user categories. Although NMDID provides data on substance use history, it is not available for all individuals, likely due to the limited number of next of kin interviews during the creation of the database. We defined substance use based on manner of death where "Substance Death" was scored as "Yes" if the decedent's death was attributed to substance intoxication (drug, poison, alcohol, etc.), ethanolism (chronic, alcoholism, alcoholic liver), ethanol (alcohol) intoxication, or narcotic abuse.

Analytical methods

Many prior studies have assessed oral health using the decayed, missing, and filled teeth (DMFT) index, which is an amalgamation of these indicators calculated into one metric (Moradi et al., 2019; Peres et al., 2010; Vano et al., 2014; Zeng et al., 2020). This is a common method used to calculate overall dental health, focusing on tooth loss specifically caused by caries (Gorji et al., 2021). Unfortunately, PMCT image quality is not sufficient to detect all variables traditionally used in the DMFT, such as small filled or un-filled caries, and we have no record of the reason for missing teeth (as opposed to studies using the DMFT index having a record of

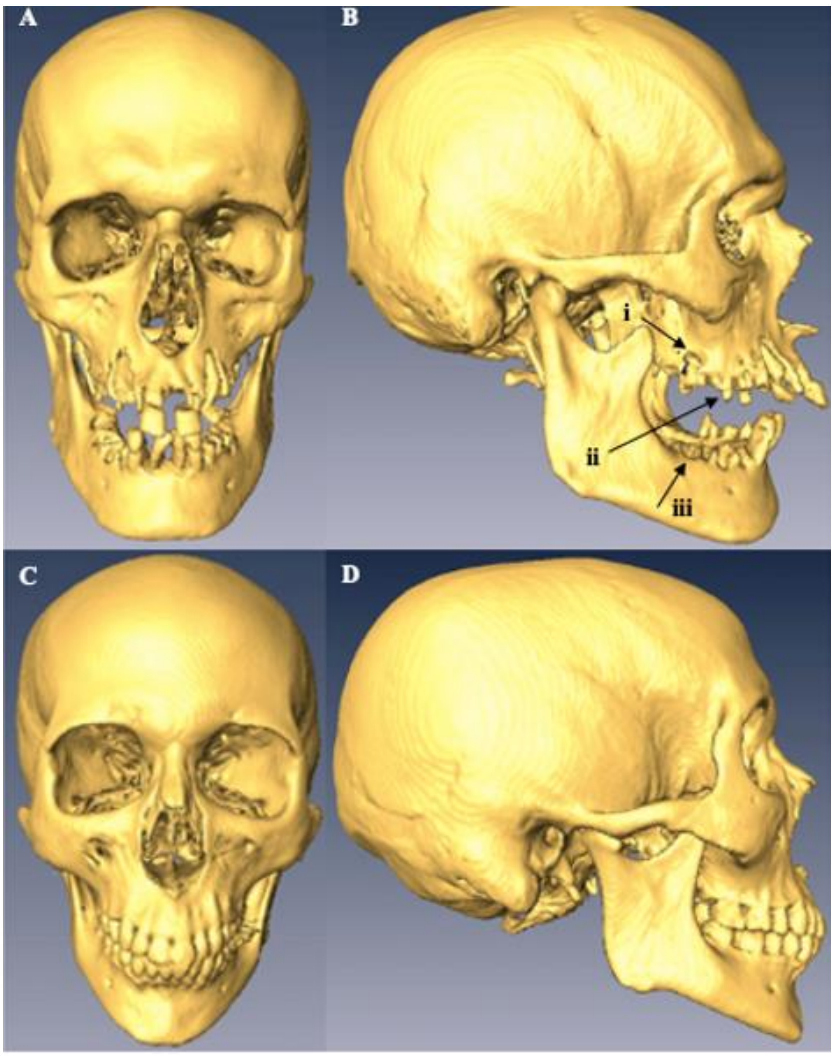

Figure 1. Example 3D reconstructions from two separate individuals. (A) Anterior view: abscesses, decayed, missing teeth (B) Right lateral view: abscesses (i), decayed (ii), missing teeth (iii) (C and D) Anterior and right lateral views: teeth intact.

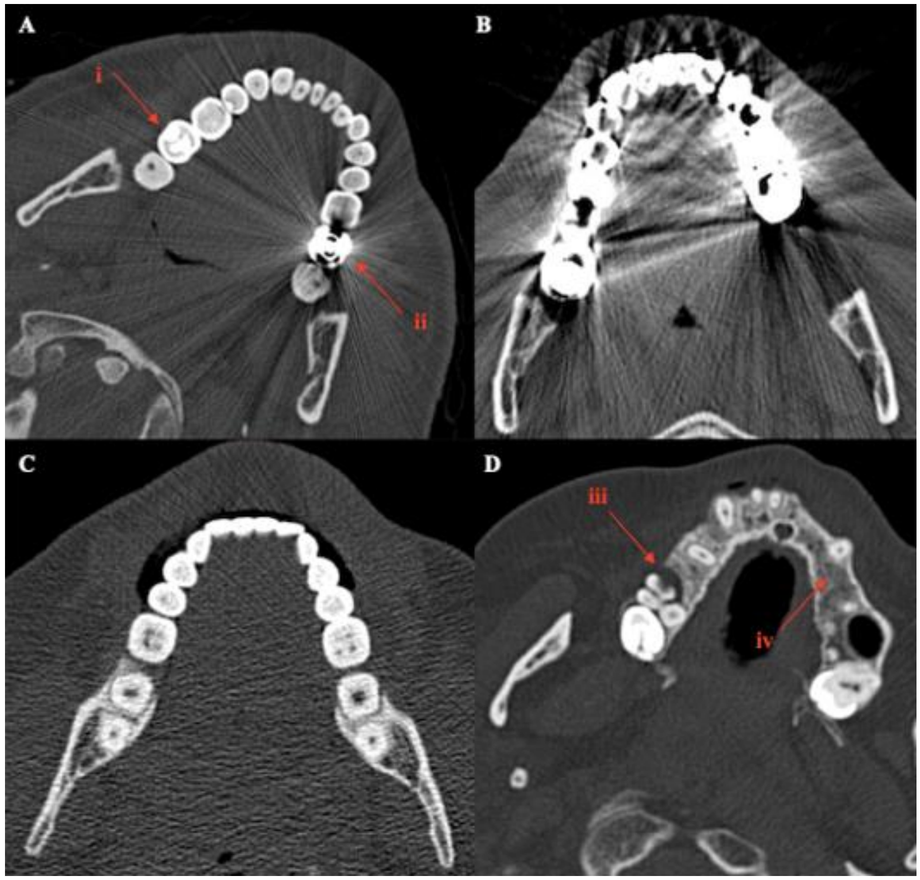

Figure 2. Example CT slices from the same individuals as in Figure 1 displaying mandible views (A-C) and a maxilla (D) from PMCT scans. (A) Composite (i) and metal filling (ii), (B) Multiple restorations, (C) No dental work, (D) Abscess (iii) and missing teeth (iv).

teeth lost due to known caries). Therefore, the current research draws on a modified version of the DMFT index. We created two indices: Index A, being the sum of the number of missing teeth, restorations, abscesses, and decayed teeth (to reliably score caries) for each individual and Index B is the same as Index A but omits the number of restorations. For example, an individual with antemortem tooth loss of their mandibular first molars, with restorations observable on 10 teeth, and another tooth with an abscess, would have an Index A score of 13. We created Index B to reflect non-restorative or absence of dental care, which may be a better metric of oral health driven by the socio-demographic factors in New Mexico. All variables were weighted equally when indices were counted. During data collection, each tooth was scored as either present without condition, missing, restored, abscessed, or decayed. Twelve instances existed in which a tooth was abscessed and had a restoration. These were specially coded to reflect this outcome. Teeth with these codes were left out of analyses. Additionally, ten instances were encountered in which a tooth was severely decayed and had an abscess. In these situations, the tooth was scored as abscessed. In this way, every individual was originally recorded as having only 32 scores. However, because third molars (M3) are often prophylactically removed, they were excluded from analyses, resulting in a maximum of 28 scores included in each index. Missing premolars (but not decayed, restored, or abscessed, therefore these ones could still count towards the index score) were also excluded from index calculations as they can be congenitally absent or removed for orthodontic purposes (Little et al., 1981).

We used linear regressions to test if SES, sex, race/ethnicity, residential location, tobacco use, and substance death are predictors of our DMFT indices. An alpha (α) of 0.05 was used for the regression. All analyses were done in RStudio (R Studio Team, 2020).

Results

Out of 305 decedents, 274 were missing teeth, 54 had abscesses, 240 had restorations, and 57 had decayed teeth. Despite efforts to balance the demographics in the sample, we included *n* = 175 males (57% of the sample), n = 110 Hispanic individuals, n = 74 Native American individuals, and *n* = 121 European Americans. Additionally, almost everyone had used tobacco at some point during their lives, 137 decedents had a "high" drinking status, 143 died of substance use, and there were 224 decedents who lived rurally. The mean DMFT Index A value was 7.23 and ranged between 0-27. The mean Index B value was 2.83 and ranged between 0-25. All descriptive statistics are included in Table 1.

Table 2 displays the results from the linear regression for Index A and Index B. Multicollinearity between the predictor variables was calculated (Variance Inflation Factor [VIF]; Tsagris & Pandis, 2021) and ranged between 1.1-1.6, indicating multicollinearity is not a concern in the models. Rural vs urban living was not found to be significant in any models.

Linear regression results for Index A showed that race/ethnicity is independently associated with the DMFT index, when also controlling for sex, SES, residential location, tobacco use, alcohol use, and substance use. Specifically, Native Americans (relative to Hispanics; $p < 0.001$) and European Americans (relative to Hispanics; $p < 0.001$) were significantly associated with higher indices (Index A) of oral health. Neither sex, residential location, nor use of tobacco, alcohol, or substances were significantly associated with the oral health Index A.

Linear regression results for Index B, which omits restorations from its calculation, showed that race/ethnicity is independently associated with the DMFT index, when also controlling for sex, SES, residential living, tobacco use, alcohol use, and substance use. Specifically, Native Americans (relative to Hispanics; $p < 0.01$) and European Americans (relative to Hispanics; $p < 0.01$) were both significantly associated with higher indices (Index B) of oral health. Neither sex, residential location, nor SES, nor use of tobacco, alcohol, or substances were significantly associated with the oral health Index B.

Discussion

We examined the relationship between sociodemographic predictors and measures of oral health in recently deceased New Mexicans aged 35-44 years. Our results indicate that the significant predictor of differences in oral health in this sample is race/ethnicity.

Race/Ethnicity

Native Americans are associated with higher indices, and therefore poorer oral health, compared to Hispanics. In this study, we did not investigate specific causes of poor oral health outcomes for Native Americans, but this could relate to the remote locations of many tribal reservations, with little to no access to dental health care. Previous work (Hinnant et al., 2019; Walters et al., 2011; Brockie et al., 2013) has shown that Native Americans have some of the poorest health conditions in the United States. On average, they have a reduced life expectancy of five years when compared to European Americans (Jones, 2006; Sequist et al., 2011; Howard et al., 1999; Howard et al., 2000). This leads to the question: what factors contribute to Native American vulnerability to oral health and disease ailments?

Nationwide, Native Americans and Alaska Natives have the highest rates of tooth decay, especially in children ages two to four (Nash & Nagel, 2005). Factors contributing to this disparity are physical locations of many tribal nations resulting in Indian Health Services' (IHS) struggle to attract practicing dentists (Nash & Nagel, 2005). According to a Pew Charitable Trusts (2015) review, 43% of Native Americans aged 35-44 had untreated tooth decay and periodontal disease in 2011. Additionally, Pine Ridge Reservation in South Dakota (one of the largest reservations in the country) reported that 97% residents had untreated tooth decay and 68% had gum disease. Lastly, 83% of Native Americans and Alaska Natives aged 40-64 years have lost at least one permanent tooth while this occurs in only 66% of the rest of the U.S. population (Phipps & Ricks, 2016).

There are many factors behind health inequity in Native Americans, such as differences in culture (more specifically, differences in the way health is treated and perceived), historical trauma, beliefs, and behaviors (Hinnant et al., 2019; Safran et al., 2009). On average, Native Americans living on reservations are poor and isolated from the nearest population centers (Marley, 2018; Leung & Takeuchi, 2011). Another hurdle for Native Americans receiving proper healthcare is inadequate funding to IHS. Due to this disparity, IHS does not offer the extent and level of services as other healthcare systems. IHS serves 2.56 million of the 5.2 million Native Americans and Alaska Natives (IHS, 2019; Sequist et al., 2011). Of note for the current study, only one dental IHS clinic exists on the entire Navajo Reservation, and it is located in the state of Arizona. A second dental clinic is in Albu-

Table 1. Descriptive statistics showing n, mean, and standard deviation for each predictor and outcome variable.

(Possible N)	Variable	*n*	Missing Teeth			Abscesses			Restorations			Decayed Teeth			DMFT Index A		DMFT Index B	
			n	mean	SD	*n*	mean	SD	*n*	mean	SD	*n*	mean	SD	mean	SD	mean	SD
Sex (305)	Female	130	124	6.15	6.79	23	0.36	1.00	109	4.83	4.37	25	0.85	2.70	8.25	4.95	3.42	4.05
	Male	175	150	4.51	5.91	31	0.37	1.18	131	4.15	3.86	32	0.49	2.06	6.53	4.30	2.38	3.40
Race/Ethnicity (305)	Hispanic	110	89	3.94	5.44	11	0.23	0.85	83	3.48	3.25	10	0.22	0.88	5.23	3.49	1.75	2.54
	Native American	74	72	4.36	3.02	21	0.42	0.79	62	4.99	4.55	22	1.12	3.30	8.38	5.31	3.39	3.95
	European American	121	113	6.88	8.03	22	0.45	1.42	95	4.98	4.36	25	0.74	2.54	8.44	4.56	3.46	4.24
SES (303)	Lower class	82	70	5.85	7.10	17	0.39	1.21	63	4.02	3.69	16	0.76	2.20	7.45	4.34	3.43	3.77
	Lower middle class	35	29	6.03	8.99	4	0.31	1.08	28	5.26	4.60	4	0.83	3.92	8.20	5.23	2.94	5.02
	Middle class	168	156	4.54	5.09	30	0.36	1.05	134	4.36	3.96	31	0.55	2.09	6.80	4.51	2.44	3.35
	Upper middle class	8	7	7.88	8.54	1	0.62	1.77	5	2.00	2.00	3	0.38	0.52	5.50	4.31	3.50	4.96
	Upper class	10	10	6.70	5.85	1	0.10	0.32	9	8.20	6.37	2	0.80	1.93	11.8	5.65	3.36	2.99
Residential Location (301)	Rural	224	199	5.25	6.34	41	0.43	1.25	170	4.23	4.00	44	0.73	2.64	7.22	4.65	2.99	3.98
	Urban	77	72	5.19	6.50	11	0.17	0.44	66	4.88	4.30	12	0.40	1.28	7.23	4.69	2.35	2.91
Tobacco Use (235)	Former	32	25	3.25	4.21	7	0.44	0.98	23	4.59	4.63	4	0.34	1.12	6.47	4.63	1.88	2.88
	Light	106	93	4.72	5.80	19	0.31	0.87	86	4.05	3.63	25	0.99	3.46	7.24	4.96	3.15	4.40
	Heavy	97	92	6.73	7.55	15	0.44	1.51	76	4.52	4.17	17	0.52	1.82	7.67	4.50	3.16	3.59
Drinking Status (257)	High risk	137	122	4.71	5.89	24	0.36	0.99	113	4.53	3.90	30	0.80	2.86	7.32	4.79	2.80	3.94
	Low risk	94	81	6.16	7.61	18	0.46	1.47	70	3.90	3.83	16	0.40	1.28	6.95	4.24	3.04	3.54
	Never drank	13	13	8.46	9.54	2	0.54	1.33	9	3.77	4.49	2	1.00	3.32	8.31	5.63	4.54	5.11
	Previous high risk	13	13	5.62	4.46	2	0.15	0.38	11	5.08	5.42	4	1.08	2.50	8.46	4.79	3.38	3.91
Substance Death (297)	Yes	143	130	4.80	5.92	26	0.31	0.97	118	4.69	4.16	18	0.36	1.44	7.09	4.41	2.41	3.06
	No	154	136	5.36	6.47	27	0.40	1.19	118	4.30	4.04	36	0.88	2.95	7.40	4.91	3.10	4.18

*Table 2. Linear regression results with coefficients, standard error, and p-values for Index A and Index B. Bolded values indicate **p < 0.05**.*

Regression Results	Index A		Index B	
	coef. (SE)	*p*	coef. (SE)	*p*
Sex				
Female	-	-	-	-
Male	-0.66 (0.68)	0.33	-0.47 (0.59)	0.43
Race/Ethnicity				
Hispanic	-	-	-	-
Native American	3.63 (0.89)	**<0.001**	2.25 (0.77)	**<0.01**
European American	3.39 (0.78)	**<0.001**	1.82 (0.68)	**<0.01**
SES				
Lower class	0.55 (0.81)	0.5	0.61 (0.71)	0.39
Lower middle class	1.67 (0.93)	0.14	0.56 (0.81)	0.49
Middle class	-	-	-	-
Upper middle class	-0.89 (2.34)	0.7	0.82 (1.57)	0.6
Upper class	3.45 (1.79)	0.06	0.16 (1.22)	0.9
Residential Location				
Rural	-	-	-	-
Urban	-1.25 (2.75)	0.65	0.49 (2.40)	0.84
Tobacco Use				
Former tobacco user	-0.85 (0.1)	0.39	-0.33 (0.87)	0.13
Light tobacco user	-	-	-	-
Heavy tobacco user	0.24 (0.75)	0.75	-0.18 (0.65)	0.79
Drinking Status				
Never drank drinking status	-	-	-	-
Low risk drinking status	-0.77 (1.37)	0.58	-1.29 (1.2)	0.28
Previous high risk drinking status	0.89 (1.94)	0.65	-1.62 (1.7)	0.34
High risk drinking status	-0.03 (1.35)	0.98	-1.14 (1.18)	0.34
Substance Death				
Death by no substance use	-	-	-	-
Death by substance use	0.4 (0.67)	0.55	-0.53 (0.59)	0.37
Model *p-value*	**<0.001**		**<0.05**	
Adj. R^2	0.11		0.04	

querque, New Mexico, which is hours by car from the Navajo Reservation and from many Pueblos as well (IHS, 2022). Our findings on increased oral health disparities among Native Americans in New Mexico could influence support for more funding to IHS dental clinics on reservations (Marley, 2018; Niederdeppe et al., 2013; Sequist et al., 2011).

Previous studies have shown that inequity in access to dental healthcare is mostly seen in non-Hispanic Blacks and Mexican Americans (Gaskin et al., 2021; Shelley et al., 2011; Sharif & Edelstein, 2016). In the current study, European American decedents had worse mean oral health indices (for Index A and Index B) than Hispanic decedents. According to Gaskin et al. (2021), identifying as Hispanic was protective against having missing teeth relative to being non-Hispanic European American (2021). This finding is consistent with another study that found no statistically significant result between missing teeth in European American and Hispanic individuals (Huang & Park 2015). Our results support these findings. On the other hand, several studies have suggested Hispanics were more likely than non-Hispanic European Americans to experience poorer dental health (Fisher-Owens et al., 2013; Eke et al., 2015; Huang & Park, 2016).

Potential explanations for conflicting results may include differences in sample compositions and specific data collection methods. For example, Huang and Park's (2016) sample included individuals older than 65 who completed self-reported surveys about their oral health. Our sample was aged 35-44 at time of death and individuals were not surveyed, rather their dentition was examined more systematically. Huang and Park conducted a tooth count but did not go further in assessing dentition. Because our sample sizes within each race/ethnicity are comparable, the differences in our results could be caused by methodological differences. Additionally, identification of race and ethnicity varies regionally across the US and has varied throughout time (Bradby, 2003), and in New Mexico (Healy et al., 2018). Due to the colonial and immigration history of New Mexico, individuals who identify as Hispanic are found throughout the entire state, with very diverse genetic, cultural, and socioeconomic backgrounds (Healy et al., 2018; Hunley et al., 2017, 2021). Therefore, variations in genetic makeup, residential variation, personal identity, and cultural behavior could be the reasons for differences in Hispanic samples from New Mexico and other areas.

We did not compare European American oral health indices to Native American oral health indices. However, according to the descriptive statistics (Table 1), it is worth discussing that European Americans have similar oral health profiles as Native Americans for each of the variables in the DMFT indices. European Americans in this sample have, on average, more missing teeth than Native Americans, but Native Americans have slightly more decayed teeth. They have similar amounts of restorations and abscesses. Our specific sample might explain some of this outcome, in that a population with 50% of substance-related deaths, ethnicity may not be a key predictor in these oral health outcomes. D'Amore et al. (2011) found that in a sample of "White, Black, Hispanic, and Other" substance users, race/ethnicity was not significantly associated with their self-rated oral health status. According to their results, age and current type of substance being used was significant. Many other studies on oral health disparities in the US found that Non-Hispanic White individuals had better oral health than all other groups included their samples (Shelley et al., 2011; Han, 2019; Huang & Park, 2015; Fisher-Owens et al., 2013; Flores & Lin, 2013). As mentioned, the New Mexican identity of "Hispanic" includes a diverse and broad subpopulation within the state (Healy et al., 2018; Hunley et al., 2017, 2021), complicating the interpretation of oral health. On the same note, those identified as "European American" may be less socially/economically diverse in their backgrounds, so some aspects of marginalization in this group are more prominent and consequently lead to a higher oral health index.

Note that residential location is not significant in this model, but the Index A beta coefficient (-1.25) is negative for Urban. This suggests that when compared to those who lived in rural counties, urban dwellers have better oral health indices, likely due to access to dentists (since urban living has almost no effect in Index B). It would be interesting to investigate the extent to which rural vs. urban living drives poor oral health specifically among Native Americans.

Sex

According to both Index A and B means (Table 1), we found that the females in our sample have a higher oral health index than males, although sex was not a significant predictor in the regressions (Table 2). Previous research found that females had better dental health outcomes than males, possibly due to women being more concerned about dental health (Bencosme, 2018; Buunk-Werkhoven, 2015, Eke et al., 2015; Gaskin et al., 2021). Males are generally less concerned with their oral health, demonstrated by fewer preventative dentistry visits (Thompson et al., 2016; Lipsky et al., 2021) and show a less positive attitude than women when it comes to going to the dentist (Furuta et al., 2011).

Ferraro and Vieira (2010) found that women were at greater risk of developing dental caries (92.66% likely in women and 90.57% likely in men). Other factors contributing to sex differences in dental health outcomes are genetic predisposition and hormones. Pregnancy and the associated physiological changes, such as peaking estrogen levels, can exacerbate dental health risks due to an increased blood flow to the gums, which can result in pregnancy gingivitis, tooth erosion, dental caries, and more (Bencosme, 2018; Michalowicz et al., 2013). Our interpretation of the results may be informed by this because females in our sample have more missing teeth as well as more restorations. More restorations could support the conclusion that females may be more concerned about dental health and would therefore see the dentist more often than males to get treatment (Bencosme, 2018; Lipsky et al., 2021). There were no differences between females and males in the presence of decayed teeth or abscesses. This could be because females had dental work done before it resulted in decayed teeth or abscesses, which would again support our finding that restorations are of higher prevalence in females than males. Women are more likely to go to the dentist early enough to get restorations before caries result in severe decay or abscesses (Lipsky et al., 2021).

Differences in male and female behavior, such as males using tobacco products more than females do (Abuse, 2020) or that males brush and floss less than females (Lee et al., 2012) is another reason for poorer oral health. Males are more often diagnosed with cardiovascular disease than females (Lipsky et al., 2021) and the medication (beta-blockers, diuretics, and calcium channel blockers) they take for the disease can have negative implications for oral health. Additionally, men experience higher rates of periodontal disease, oral cancers, and dental trauma (Lipsky et al., 2021), none of which were examined in the current study.

Death Associated with Substance Use

Substance use was not a significant predictor of either oral health index (Table 2). It may not be a differentiating factor in oral health outcomes in individuals who experience social and economic marginalization, as was likely prevalent in the current sample. "Substance use" or "death by substance use" in this sample did not control for any specific substances that may have an outsized effect on poor oral health compared to other kinds of substances. For example, the substances used by the decedents in this sample include cocaine, opioids, inhalants, stimulants, cannabinoids, and sedative hypnotics/depressants. Sample size precluded consideration of oral health and specific substance use.

The adjusted R2 value of Index A is 0.11 and Index B is 0.04, indicating that only 11% and 4% of the variability in the oral health indices are explained by the sociodemographic variables in our study. Although these values are small, we acknowledge that the interplay between health and lived experiences is multifaceted. There could be many variables contributing to the variation of this sample, including some that are unknown or included in these analyses. Nevertheless, our results indicate that race/ethnicity can explain part of the story behind oral health variation in this specific New Mexican sample of ~50% decedent deaths being attributed to substance use.

Limitations and Future Directions

Intra-observer error was not accounted for during data collection. Scoring for composite fillings was difficult at times due to the inability to recognize them from axial slices. This was not a problem for amalgam (metal) fillings, which were easy to score on the CT scans (Figure 2, panel B). Additionally, the composition of this sample includes its own biases. This sample is a mortality sample, which could represent a more accurate cross-sectional sample of the New Mexican population. However, the manner or cause of death of these decedents could have been a result of social risks or hazards they experienced while living, which could be reason for both poor dental health outcomes and premature deaths (decedents died aged 35-44). Therefore, the sample could be biased in the way that these decedents might have faced unfavorable living and social conditions, causing them to die prematurely. Therefore, our results cannot be directly applied to the general New Mexican population. The methods used in this paper precluded an accurate representation of caries throughout life. Since restorations are a sign of dental care and decay represents the opposite, we cannot say anything concrete about caries. While we cannot directly address total caries frequency across the lifespan, the comparison of results seen in Index A and B show that there needed to be a separation of indices, one with and one without the inclusion of restorations.

The ways in which decedents in this sample died must also be considered a limitation in this study. Substance abuse contributed to nearly 50% of deaths in the sample. Substance abuse has been shown to affect oral health negatively (Baghaie et al., 2017). Even though substance use death was not a significant predictor of oral health in the linear regression, our study did not account for behavioral substance use unrelated to cause of death. A validation study could be helpful for future research that examines the effect of various behavioral substance uses on oral health.

One variable that was not examined in this study that could provide further insight into dental health in New Mexicans is education level. Tanner and colleagues (2015) mentioned in their study that high education level protected against declination of dental health more than other variables examined. Similarly, Gaskin et al. (2021) found that less educated and low-income US residents were less likely to have visited a dentist in the last five years. This paper also contributes to the idea of dental therapists in states like New Mexico, who would serve to increase awareness of the importance of dental health and how it influences overall physical health by providing basic dental care (Bersell, 2017). As dental therapists may be more likely to reach underserved communities, future research might investigate the potential effects of dental therapist licensing in the state.

Conclusion

The goals of this study were to explore the associations between oral health and sociodemographic factors such as sex, SES, race/ethnicity, substance use, and urban or rural living. Oral health indicators were calculated into one index by the sum of missing teeth, restorations, abscesses, and severely decayed teeth per decedent. Our results indicate that the most significant predictor of poor oral health is race/ethnicity. Native American and European American decedents were significant sociodemographic variables in our analysis.

Inaccessible dentistry and social determinants of health can exacerbate oral disease. Narrowing down the causes and implications of New Mexican inequity on oral health outcomes offers new insights on overall healthcare quality and access in the state, even in this subsample of New Mexicans who died while not under care of a healthcare professional. Uncovering and describing oral health disparities is the first step in furthering oral health research in New Mexico and implementing possible interventions.

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IN MEMORIAM:
BRIAN E. HEMPHILL (1959-2023)

Brian was born in Boise, Idaho on September 29, 1959 to Barbara G. and James D. Hemphill; he passed away on December 24, 2023 in Fairbanks, Alaska (at age 64 yrs., 2 mos., 25 days: Fig. 1).

Figure 1. Brian E. Hemphill (1959-2023)

The main focus here is Brian's graduate academic record while at the University of Oregon (UO) and our collaboration in research and publication. Brian entered the graduate program at the UO in fall 1982, with Prof. John Lukacs as his advisor. Some of his diverse and significant contributions to the field of dental anthropology will be known to readers of this journal. His early research focused on prehistoric native American skeletal remains of Oregon and the Great Basin. Brian's career was dedicated to the fields of dental anthropology and bioarchaeology.

After earning two BS degrees (1982) in Anthropology and History (with honors) from Portland State University, Brian entered the graduate program in biological Anthropology at the University of Oregon as my advisee in Fall term 1982. The UO graduate program in Anthropology at the time was a four-field approach with requirements in research methods and skills (statistics or languages). Brian's success in the four core-courses was outstanding, earning high scores in Socio-Cultural Guidance; Anthropol. Linguistics; Anthropol. Archaeology; and Basic Graduate Physical Anthropol. His Master of Science (1984), was based in part on a thesis entitled "*Dental Pathology at Sarai Khola*". Brian's paleodemographic analysis focused on a data I collected in 1982 in collaboration with Michael Schultz (Univ. of Göttingen). The Sarai Khola specimens were on loan to the University of Mainz from the Department of Archaeology, Govt of Pakistan. In Spring 1989, with all program requirements completed and his dissertation prospectus approved Brain was advanced to candidacy for the PhD. Consistent with his academic aspirations, Brian's doctoral committee included an archaeologist (Don E. Dumond), a biological anthropologist (Paul E. Simonds), and me as committee chair. Paul Vos (statistician, Mathematics Department) served as an "outside member", representing the UO Graduate School for key aspects of dissertation research, including presentation and defense. His doctoral research addressed tooth size apportionment among contemporary South Asians, based on odontometric data collected from dental impressions of living castes and tribes of north, central and south India. The collection of plaster dental casts on which his research was based were collected by me in collaboration with three investigators (V. Rami Reddy, Sri Venketeswara University, Tirupati; P.K. Basu, R. Ahmed Dental College and Hospital, Calcutta; and staff of Deccan College, Pune University), and was funded by fellowships and grants to me from the American Institute of Indian Studies (1974-75, 1981-82), and the Smithsonian Institution (Foreign Currency Program, 1982-1984). Brian's doctoral research creatively analyzed odontometric data to assess population affinities using a method pioneered by Ed Harris known as 'tooth size apportionment'. While Harris focused on Solomon Islanders, Oceanic populations, and global samples, Brian addressed inter-group bio-distance among two south Indian Hindu caste groups (Madiga and Reddy), a non-Hindu tribal group (Chenchu) and two Indo-European speaking multi-caste samples from Calcutta, West Bengal and Pune, Maharashtra.

During his time as a graduate student in biological anthropology, Brian served as my lab and field assistant in Pakistan and India in the winters of 1987 and 1988. First, at the French Archaeological Mission to Pakistan lab in Karachi, Pakistan, in 1987 (director Jean-Francois Jarrige, Musée Guimet, Paris) he assisted in the preparation and inventory of skeletal and dental remains recovered from Neolithic and Chalcolithic periods at Mehrgarh (Baluchistan Province, Pakistan). Later that season, in collaboration with Nancy Lovell, Kenneth Kennedy and me, Brian was involved in the excavation, lifting and analysis of Bronze Age skeletal remains from the Indus Civilization site at Harappa (Punjab Province, Pakistan; Fig. 2). The Harappa Archaeological Research Project was conceived and initially implemented by George F. Dales (Univ. of California, Berkeley) and subsequently administered by J. Mark Kenoyer (Univ. of Wisconsin, Madison) and Richard H. Meadow (Peabody Museum, Harvard Univ.). In 1988, following a second season at Harappa, Brian accompanied me to Allahabad (Uttar Pradesh, India) to prepare, inventory, and analyze skeletal and dental remains of aceramic hunter-foragers of north India in collaboration with J. N. Pal (Dept of Ancient History, Culture and Archaeology, University of Allahabad). A timely summary of bioarcheological results from 1987 and 1988 Harappa cemetery excavations were published by Hemphill and colleagues (1991). Brian's assistance in research at Harappa and in Karachi, and Allahabad was funded by Smithsonian grants to the Harappa Archaeological Research Project, and to me by the National Geographic Society, Committee for Research and Exploration.

Figure 2. Bio-anthropology members Harappa Archaeological Research Project (1987). From left to right, Kenneth Kennedy, John Lukacs, Nancy Lovell, and Brian Hemphill.

Our collaborative research endeavors resulted in a series of publications on the dental pathology, tooth crown morphology and odontometrics of prehistoric samples from India and Pakistan. His analysis of dental attributes of living South Asians were based on dental plaster casts I collected with Smithsonian support in 1982-84. These included statistical analyses of odontometric and morphologic variability among Hindu castes and tribal groups in northwest, central, and southeast India. Brian and I co-authored 14 publications on dental variation between 1989 and 2000; authorship was equally shared - five with Brian as first author, six with me as initial author and three papers with other colleagues as first author (KAR Kennedy -2; M. Schultz - 1).

After leaving Oregon, Brian held academic positions, at Moorhead State University (1992-1993), Vanderbilt University (1993-1999), California State University, Bakersfield (1999-2013), and University of Alaska, Fairbanks (2013-2023). Cal State Bakersfield does not have a graduate program in Anthropology; hence his teaching was focused on undergraduates, some of whom he included as co-authors in research and conference presentations on dental anthropology. Later, his research expanded to include prehistoric central Asian samples and dental casting programs among northwest Pakistani groups. The prime goal focused on understanding population affinities and patterns of genetic affiliation. Brian's career emphasized teaching, research and publication and is distinguished by high productivity and diversity of coverage. For example, while at Cal State Bakersfield, he taught undergraduate introductory courses in biological and cultural anthropology, evolution and creationism, the prehistory and ethnography of native North Americans, the archaeology of death, and bioarchaeology, as well as primate behavior and primate evolution. His courses exhibited a broad range of subjects and show breadth of familiarity with the main subdisciplines in the field. While at the University of Alaska, Fairbanks Brian chaired two master's student's committees and department chair Robin Shoaps says that Brian "… was a rigorous, trusted and supportive Chair to the students who had the fortune to work with him. They describe him as "old school" in the best way." Brian's two PhD students in biological anthropology had not been advanced to candidacy at the time of his passing.

Following our early research collaboration, Brian included intensive research dental anthropology of prehistoric skeletal series from the Iranian Plateau, Central Asia and the Hindu Kush borderlands. Brian's CV (see Supplementary File) includes numerous publications on these regions and on dental casts of living groups, often with local research collaborators as co-authors and appearing in local or regional journals such as *Pakistan Herit-*

age, Ancient Pakistan, Pakistan J of Zool, and Conservation Biol of Pakistan. Though not required, investigators engaged in research abroad have a duty to publish results in countries where their work was conducted. This practice has definite advantages and shortcoming. Disseminating research results among colleagues involved in the study or granting access to study collections is ethical, responsible and facilitates local scholars' access to research results. Alternatively, research published abroad may not be as widely disseminated, as rigorously peer-reviewed, or as extensively indexed as international journals. My own publications with Indian colleagues have appeared in the *Bull Deccan College Res Inst, Pakistan Archaeol, J of the Indian Anthropol Society, and Man and Environ*). Brian and I shared a commitment to working closely with Indian and Pakistani researchers and to co-authoring results published in both local and international journals.

Brian actively disseminated his research results, prior to publication, at Annual Meetings of the American Association of Physical Anthropologists. Each year his podium and poster presentations often involved undergraduate anthropology majors as presenters. A few of the more memorable conferences that we attended together include: the European Association of Archaeologists in Western Europe (1997; Rome, Italy), the Associación Mexicana de Antropología Biológica (2005; Campeche, Mexico, Fig. 3), the American Anthropological Association (2008; San Francisco, CA), and the American Association of Physical Anthropologists (2012; Portland, OR). These meeting included either special events, awards and honors ceremonies, or non-conference excursions that made them special.

Of the 12 doctoral committees I chaired at the University of Oregon between 1989 - 2009, I would rank Brian Hemphill in the top 3. He was an exemplary graduate student and enthusiastic collabora-

Fig 3. Delegates to the Mexican Association of Biological Anthropology (2005, Campeche, Mexico). Left to right: Brian Hemphill, Elizabeth Newell, Greg Nelson, Jaymie Brauer, and John Lukacs.

tor in research and publication. Students will remember his dedication and devotion to teaching, including courses in archaeology, cultural anthropology and biological anthropology. Professional colleagues in all aspects of dental anthropology - odontometry, morphology and pathology - will miss his analytical and insightful conference presentations and journal publications. May he rest in peace.

JOHN R. LUKACS
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