Oral Health Epidemiology and Policy in Disadvantaged Populations

by

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Abstract

This dissertation seeks to study important questions regarding oral health epidemiology and policy affecting oral health care access and outcomes in disadvantaged populations.

Chapter one introduces the research problems.

Chapter two evaluates the relationship between oral health measures and systemic disease. Little is known about the role periodontal disease plays in the development of cardiovascular complications in type 1 diabetes. Using data from a longitudinal cohort of patients with type 1 diabetes, we evaluate the association between periodontal disease and cardiovascular complications and mortality. We find that periodontal disease increases the risk of cardiovascular complications, but not mortality, among type 1 diabetes patients who smoke.

Chapter two examines the association between dental policies for adults in Medicaid and children's receipt of preventive dental services. Although prior research has found "spillover effect" between adults Medicaid coverage and children's use of preventive medical visits, this relationship has not been studied in dentistry. We use 14 years of nationally representative survey data to link parents and their children and run two quasi-experimental analyses. We evaluate the effect of changes in dental benefits for adults in Medicaid and the effect of Medicaid expansions for adults under the Affordable Care Act on children's use of preventive dental services. We find no evidence of a "spillover" effect between adult dental policies and children's receipt of preventive dental services.

Chapter three evaluates the problem of excess opioid prescribing for dental procedures. We evaluate the risk of an initial opioid fill and subsequent opioid fills based on the likelihood of pain associated with the dental procedure among opioid naïve PA Medicaid beneficiaries. Using Medicaid claims data from 2012-2017, we find that patients who filled an opioid for procedures with low likelihood of pain were more likely to use opioids in the short term compared to those who did not fill an opioid for the same procedures and compared to patients with an initial opioid for procedures with moderate and high likelihood of pain.

This dissertation has important implications for public health. Our findings provide evidence for health system interventions to: 1) improve the integration of oral health with systemic health for patients with type 1 diabetes. 2) The need for policy interventions that have a more direct impact on improving low-income children's use of preventive dental services. 3) Emphasizing NSAID as a first line of therapy for management of dental pain and re-evaluating the current guidelines for opioid prescribing in the dental practice.

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To my amazing children, Omar, Zaina and Adam

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1.0 Chapter One: Introduction

Oral Health is important for overall health and wellbeing(Health & Services, 2000). The oral health systemic health connection is an area of research that is gaining more attention. Oral disease such as periodontal disease has been linked to cardiovascular disease, diabetes, progressive kidney disease and Alzheimer's disease (Leira et al., 2017; Ricardo et al., 2015; Sanz et al., 2017; Yu, Chasman, Buring, Rose, & Ridker, 2015). Although the causal pathway has not been established yet, the association is strong. Therefore, preventing oral disease could potentially be a cost-effective measure to prevent more disastrous outcomes. Many studies have evaluated the connection between PD and cardiovascular complications in type 2 diabetes, but little is known in Type 1 Diabetes (T1D).

Minorities and low-income children and adults suffer disproportionately from oral health problems. Low-income and minority children have higher rates of dental caries and levels of untreated tooth decay (Eleanor Fleming & Joseph Afful, 2018), which has negative effects on speaking, eating, sleeping and learning (Jackson, Vann Jr, Kotch, Pahel, & Lee, 2011; Seirawan, Faust, & Mulligan, 2012). Oral health disparities persist into adulthood, minorities and low-income adults have higher rates of dental caries, periodontal disease (PD) and tooth loss (K. Y. Li, C. E. Okunseri, C. McGrath, & M. C. Wong, 2018). In addition, disadvantaged populations have problems accessing adequate oral healthcare. Medicaid expansions for low-income children has vastly improved access to dental services, however these children still face barriers to adequate access to dental care (Vujicic & Nasseh, 2014). Factors such as limited number of dental providers who accept Medicaid patients and inadequate referral systems between physicians and dentists place an extra burden on children and their caregivers to access care (Harnagea et al., 2017; Kranz,

Rozier, et al., 2015). On the other hand, as dental benefits are optional in Medicaid, low-income adults have no guaranteed source of dental insurance. Previous research has found 'spillover' effects between providing adult Medicaid coverage and children's use of well child visits. However, this relationship has not been evaluated in dentistry.

Pain is a common symptom of dental disease and a consequence of some forms of dental treatment, which can be managed effectively by medications such as Non-Steroidal Anti-Inflammatory Drugs (NSAID) (P. A. Moore et al., 2018). Due to difficulties accessing dental care, many low-income adults use the costly ED for non-traumatic dental conditions, where they get prescribed pain medication, usually an opioid, and/or antibiotics with no definitive treatment (Okunseri, Dionne, Gordon, Okunseri, & Szabo, 2015; Pajewski & Okunseri, 2014). The US remains an outlier where opioid prescribing for dental pain management is a common practice, especially for youth following wisdom tooth extraction (Denisco et al., 2011; Suda et al., 2019). Prescribing opioids for acute pain management can lead to long term use of opioids. The risk of continuous use of opioids following an initial prescription by a dentist has not been evaluated following all possible dental procedures based on the pain associated with the procedure in the Medicaid population. With the ongoing opioid crisis, dentists can play a crucial role in preventing unnecessary and excess opioid prescribing.

This dissertation is composed of three manuscripts that uses three different data sets to answer different epidemiological and policy questions relevant to oral health in disadvantaged populations. A broad overview of the three chapters is provided in the following paragraphs.

Chapter two (manuscript one), seeks to provide evidence on the oral health systemic health connection through examining the role of PD in the development of cardiovascular complications and mortality in a cohort of patients with type 1 diabetes (T1D). In this study we use longitudinal

prospective data from the Pittsburgh Epidemiology of Diabetes Complications study of T1D (EDC), who received an oral health exam between 1992-1994 and were followed up for 19 years to ascertain complications. We find that PD is a predictor for cardiovascular complications but not for mortality. We further stratify the analysis by smoking status as smoking was found to be an effect modifier. PD remains a predictor for cardiovascular complications among T1D patients who smoke only. We conclude that PD can be used as an early predictor for cardiovascular complications in T1D patients who smoke.

Chapter three (manuscript two), uses 14 years of nationally representative data from the Medical Expenditure Panel Survey to evaluate the relationship between providing adult dental benefits in Medicaid and low-income children's receipt of preventive dental services. We conducted two quasi-experimental analyses using linked parent-child dyads in low-income families. First, we examined the relationship between state Medicaid programs' coverage of adult dental services with children's probability of receiving preventive dental care. Second, we assessed whether state Medicaid expansions for nonelderly adults after 2014 were associated with increases in children's receipt of preventive dental services, comparing states that did vs. did not cover these services for adults. We find no significant association between these adult policies and children's receipt of preventive dental services. We conclude that policies other than adult dental coverage in Medicaid might be more salient determinants of preventive dental care use among low-income children.

Chapter four (manuscript three), evaluates the risk of opioid prescribing and subsequent short- and long-term use of opioids associated with a dental procedure. We use PA Medicaid claims data from 2012-2017 to identify a cohort of opioid naïve beneficiaries who received an index dental procedure. To categorize pain, we extend an existing classification scheme of select

dental procedures to include all dental procedures. We used logit models with random intercept to evaluate the risk of an initial opioid prescription associated with the procedure based on the likelihood of pain associated with the procedure and the risk of short-term (4-90 days) and long-term (91-365 days) use of opioids following a dental procedure. We find that patients who received an initial opioid prescription for procedures with low likelihood of pain had not only the highest relative risk compared to those not receiving opioids initially but also compared to their counterparts filling opioid prescriptions after moderate and high risk of pain procedures. We conclude that more attention should be paid to reducing opioid prescribing for common dental procedures with low pain risk.

2.0 Chapter Two: Periodontal Disease, Smoking, Cardiovascular Complications and Mortality in Type 1 Diabetes

Abstract

Aim: To assess the role of periodontal disease (PD) as a predictor of coronary artery disease (CAD) and mortality in a prospective type 1 diabetes (T1D) cohort and to evaluate the role of smoking in this relationship.

Methods: Data were based on 320 participants of the Pittsburgh Epidemiology of Diabetes Complications study of T1D who, during 1992-94, received a partial mouth periodontal exam, and who were followed for up to 19 years to ascertain complication incidence. PD was defined as clinical attachment loss of ≥4 mm for at least 10% of the examined sites. Predictors of all-cause mortality; Hard CAD (CAD death, myocardial infarction or revascularization), and Total CAD (Hard CAD, angina, ischemic ECG) were assessed using Cox models.

Results: During 19 years of follow-up, 33.7% (97/288) developed CAD, 27.3% (83/304) developed Hard CAD, and 16.9% (54/320) died. Among current smokers, 46.4% (26/56) developed CAD, 42.7% (24/56) developed Hard CAD and 29.5% (18/61) died. PD was not associated with all-cause mortality, although it was a significant predictor of both CAD (HR=1.12, CI=1.01-1.23) and Hard CAD (HR=1.30, CI=1.11-1.51). As smoking modified the PD-CAD and PD-Hard CAD associations, analyses were stratified by smoking status. PD was associated with an increased risk of CAD (HR=1.25, CI= 1.03-1.50) and Hard CAD (HR=1.85, CI=1.17-2.93) only among smokers.

Conclusion: PD was a significant predictor of CAD and Hard CAD among current smokers with T1D.

Key words: type 1 diabetes; periodontal disease; coronary artery disease; smoking; diabetes complications

2.1 Introduction

Type 1 diabetes (T1D) is one of the most common chronic diseases of childhood. Recent data from the U.S. suggest that the incidence of T1D among youth has increased by 1.8% annually from 2001 to 2012.(Mayer-Davis et al., 2017) T1D is associated with increased morbidity and mortality with an associated cost of $14.4 billion per year in direct medical expenses and indirect costs.(Tao, Pietropaolo, Atkinson, Schatz, & Taylor, 2010) Periodontal disease (PD) is one of the main oral manifestations of T1D .(Mauri-Obradors, Estrugo-Devesa, Jane-Salas, Vinas, & Lopez-Lopez, 2017)

PD is a chronic inflammatory disease of the surrounding tooth structure caused by pathogens, leading to tissue destruction and tooth loss. It is estimated that 47.2% of US adults have some form of PD, based on data from NHANES 2009-2012.(Eke et al., 2015) Smoking and hyperglycemia are two modifying risk factors for PD.(Jepsen et al., 2018) Smoking leads to a strong inflammatory reaction that has detrimental effects on the periodontium and can increase the risk of periodontitis 2-5 times.(Jepsen et al., 2018; Johannsen, Susin, & Gustafsson, 2014) Hyperglycemia in patients with diabetes leads to oxidative stress and the formation of advanced glycation end products (AGE) that activate various proinflammatory mediator cascades leading to periodontal tissue damage.(Chapple et al., 2018; Lappin et al., 2015)

PD has been linked to systemic diseases such as cardiovascular disease (CVD), diabetes and chronic kidney disease.(Chang et al., 2017; Ricardo et al., 2015; Sanz et al., 2018) Although studies have found a strong association between PD and CVD, a large NHANES study suggested that smoking plays a significant role in the PD-CVD relationship as an effect modifier(Hyman, Winn, & Reid, 2002), while others have found the relationship to be independent of smoking.(Andriankaja et al., 2007) Both diabetes and PD have been individually identified as risk

factors for CVD. The combined effect of PD and diabetes on the development of CVD has been studied widely in type 2 diabetes.(Graziani, Gennai, Solini, & Petrini, 2018) Thus, individuals with type 2 diabetes and PD were shown to have a higher incidence of coronary artery disease (Southerland et al., 2012), carotid atherosclerosis (Zeng et al., 2016) and myocardial infarction.(S. Xu et al., 2017) Findings from the Study of Health in Pomerania further suggested that although measures of PD were independently associated with all cause and CVD mortality, there was no evidence of interaction between diabetes and periodontitis.(Kebede et al., 2017) A single study in individuals with T1D suggested that PD was significantly associated with coronary artery calcium progression, a marker of subclinical atherosclerosis.(Groves et al., 2015) The aim of this study was therefore to assess the role of PD as a predictor of documented cardiovascular complications and mortality in a cohort of individuals with childhood-onset T1D and to evaluate the effect of smoking on this relationship.

2.2 Methods

2.2.1 Study population

The Pittsburgh Epidemiology of Diabetes Complications (EDC) study is a prospective cohort study of childhood-onset (<17 years) T1D. All participants of the EDC study were diagnosed, or seen within 1 year of diagnosis, at Children's Hospital of Pittsburgh between 1950 and 1980. The cohort has been described in detail elsewhere.(Pambianco et al., 2006; Wagener, Sacks, LaPorte, & MaCgregor, 1982) In brief, participants (n=658) have been followed with biennial surveys since study initiation (1986-1988). Clinical examinations occurred biennially for

the first 10 years and thereafter at 18- and 25-years post baseline. Between March 1992 and August 1994, of 412 participants scheduled for an EDC clinic visit, 406 enrolled in a dental study. Of these, 16 were missing all their teeth, two had scheduling conflicts that prevented complete oral health assessments, and 68 were excluded for possible risk of bacteremia, leaving 320 eligible to receive a comprehensive oral health assessment, including a periodontal examination. The methodology of the oral health assessment is described in detail elsewhere.(Paul A Moore et al., 1999) Briefly, a periodontal examination was conducted following the National Institute of Dental Research (NIDR) adult survey methodology.(Miller, Brunelle, Carlos, Brown, & Löe, 1987) Three facial sites (mesial, mid-cervical and distal) of the right maxillary/left mandibular or left maxillary/right mandibular quadrants were probed, excluding third molars. Clinical attachment loss and pocket depths were measured using a standard WHO Community Periodontal Index of Treatment Needs (CPITN) pressure-controlled probe by one of two calibrated dentist examiners. Bleeding on probing and visual assessment of supragingival calculus was assessed as present or absent on each tooth examined. In addition, all missing teeth excluding the third molar were recorded using modified criteria from the NIDR adult survey to determine the cause of extraction (disease or orthodontic treatment).

2.2.2 Assessment of PD

Participants who had clinical attachment loss of ≥ 4 mm in more than 10% of periodontal sites examined were defined as having PD. This definition reflects the Healthy People 2000 and 2010 definition of PD(Gift, Drury, Nowjack-Raymer, & Selwitz, 1996; US Department of Health and Human Services, 2000). This parameter was selected to describe a clinically significant

amount of disease, include an ample sample size for analysis and minimize misclassification of cases due to measurement error.(Paul A Moore et al., 1999)

2.2.3 Assessment of covariates

Covariates of interest were selected for analysis from the time of the oral health exam. The number of missing teeth was assessed clinically during the oral health exam. Demographic data, including age, sex, educational status (used as an indicator of socioeconomic status), and alcohol consumption were assessed via survey. Smoking status was assessed by self-report to the question "Have you smoked at least 100 cigarettes in your lifetime?" Participants who responded in the affirmative were asked if they currently smoke in a follow-up question. Those who responded positively were classified as current smokers, while all others, including former smokers, were considered non-smokers.

Fasting blood samples were taken to measure HbA1, lipids, lipoproteins, serum creatinine and serum albumin. HbA1 values were converted to DCCT (Diabetes Control and Complications Trial)-aligned values HbA1c using a regression equation derived from duplicate assays [DCCT HbA1c = 0.14 + 0.83 (EDC HbA1)].(Prince, Becker, Costacou, Miller, & Orchard, 2007) Total cholesterol and triglycerides were determined enzymatically.(Allain, Poon, Chan, Richmond, & Fu, 1974; Bucolo & David, 1973) High density lipoprotein (HDL) cholesterol was determined using a modified precipitation technique.(Warnick & Albers, 1978) Non-HDL cholesterol (non-HDLc) was calculated by subtracting HDL from total cholesterol. Blood pressure was measured according to the Hypertension Detection and Follow-Up protocol with a random-zero sphygmomanometer.(Hypertension detection and follow- up program, 1976) Hypertension was defined as blood pressure >140/90 mm/Hg or use of blood pressure-lowering medications.

Serum and urinary albumin were measured by immunonephelometry (D Ellis & Buffone, 1977; Demetrius Ellis et al., 1989) and creatinine was assayed by an Ectachem 400 Analyzer (Eastman Kodak Co., Rochester, NY). Albumin excretion rate (AER) was calculated for each of three timed urine samples (24-hr, overnight and 4-hr collections obtained over a 2-week period); the median of the three AERs was used in analyses and was natural logarithm transformed due to its skewed distribution. White blood cell (WBC) count and hemoglobin were measured using a Coulter Counter S-Plus IV. Height and weight were measured using standard methods to calculate body mass index (BMI).

2.2.4 Assessment of outcomes

Participants were followed until October 31, 2014 to ascertain complication status (median follow-up time, 19 years). Three main outcomes were assessed for this analysis. All-cause mortality; Hard Coronary Artery Disease (Hard CAD; CAD death, myocardial infarction confirmed by Q-waves on electrocardiogram (Minnesota codes 1.1 or 1.2) or hospital records, or revascularization); and total Coronary Artery Disease (CAD; Hard CAD but also including angina, determined by the EDC study physician, and ischemic electrocardiogram changes (Minnesota codes 1.3, 4.1-4.3, 5.1-5.3, 7.1)). In the EDC study, mortality was ascertained using medical records, death certificates, autopsy reports, and/or interview with next of kin.

2.2.5 Statistical analysis

Differences in baseline characteristics were evaluated between PD cases and non-PD cases using the Student's t-test for normally distributed continuous variables, the Wilcoxon rank sum

(Mann-Whitney U) test for non-normally distributed continuous variables and the chi-square or Fischer's exact test for categorical variables. The Cochran–Armitage test for trend was used for ordinal variables.

Kaplan Meier curves were used to assess survival probabilities between PD cases and non-PD cases for each of the outcomes. Predictors of CAD, Hard CAD and all-cause mortality were assessed using Cox models, excluding prevalent cases of CAD or Hard CAD, as appropriate, at the time of the oral health exam. Survival time was defined as the time in years from the oral health exam to the date of the first event for each outcome studied or censorship. The proportional hazards assumption was assessed visually and confirmed by testing time-dependent PD interaction variables. PD violated the proportional hazard assumption for both CAD and Hard CAD and was therefore added to models relating to these two outcomes as a time-varying covariate.

We assessed the role of current smoking as an effect modifier by including an interaction term between PD and current smoking in the models along with the lower order terms. Stratified analyses by current smoking status were conducted when effect modification was observed. Cox proportional hazards models stratifying by current smoking status were first constructed assessing the association between each potential risk factor and the outcome of interest, allowing only for diabetes duration. Variables that were significantly associated with the outcome were subsequently included in separate multivariable Cox models for current smokers and non-smokers. Backward elimination with a significance level of 0.05 was used to retain significant covariates in the models. All analyses were repeated replacing the dichotomous covariate for hypertension status with a continuous variable for systolic blood pressure. All statistical analyses were conducted using SAS® 9.4 software (SAS Institute Inc., Cary, NC, USA.)

2.3 Results

Participants with prevalent CAD at the time of the oral health exam (n=32) were excluded from analyses. The prevalence of PD in this cohort was 10.6%. Table 2.1 describes the baseline characteristics of the study population based on PD status. PD cases were significantly older, with a later age at the onset of T1D, more likely to have less than a high school education as well as more likely to have more missing teeth compared with non-PD cases. The prevalence of current smoking was significantly higher among PD cases compared with non-PD cases (current smoker 61.8% vs 14.0%). WBC count was also significantly higher among cases, although there were no differences in other biological markers by PD status. PD cases had a higher incidence of CAD, Hard CAD and all-cause mortality.

During 19 years of follow-up, 33.7% (97/288) developed CAD, 27.3% (83/304) developed Hard CAD, and 16.9% (54/320) died. Among current smokers, 46.4% (26/56) developed CAD, 42.7% (24/56) developed Hard CAD and 29.5% (18/61) died. Table 2.2 shows the characteristics of the study population at the time of the oral health exam by the follow-up status of each of the three outcomes of interest. Regardless of outcome studied, participants who experienced an event were older, with a longer duration of diabetes, more likely to be hypertensive, with higher levels of HbA1c, white blood cell count, non-HDL cholesterol and albumin excretion rate. Incident cases were also more likely to be missing a larger number of teeth and a greater proportion of incident cases had PD. Figure 2.1 shows a clear separation of the Kaplan Meier survival curves according to PD status for all outcomes studied: CAD (Figure 2.1a), hard CAD (Figure 2.1b) and Mortality (Figure 2.1c).

Results from Cox proportional hazard models for the risk of CAD and Hard CAD are displayed in Tables 2.3 and 2.4, respectively. In unadjusted Cox models, PD was significantly

associated with a greater risk of CAD (HR=1.11, CI=1.01-1.23), Hard CAD (HR=1.24, CI=1.08-1.43) and all-cause mortality (HR=2.41, CI=1.24-4.7). However, after allowing for covariates, PD was no longer a significant predictor of all-cause mortality (HR=0.87, CI=0.41-1.83), although it remained significantly associated with both CAD (HR=1.12, CI=1.01-1.23) and Hard CAD (HR=1.30, CI=1.11-1.51) (not shown).

Significant effect modification by current smoking status was observed for both CAD (p-interaction <0.01) and Hard CAD (p-interaction <0.001) but not for mortality (p-interaction = 0.65). Indeed, in unadjusted analyses stratifying by current smoking status, PD significantly predicted the development of CAD and Hard CAD among current smokers (HR_{CAD}=1.29, CI= 1.07-1.56 and $HR_{\text{Hard CAD}}$ =1.93, CI=1.23-3.05) but not among those not currently smoking (HR_{CAD} = 1.10, CI=0.85-1.42 and $HR_{\text{Hard CAD}}$ = 1.19, CI=0.84-1.68). Adjusting for covariates did not alter these findings (Tables 3 and 4). When analyses were repeated replacing the categorical covariate for hypertension with a continuous variable for systolic blood pressure, similar results were obtained.

2.4 Discussion

In this prospective cohort study of individuals with childhood-onset T1D, we observed that PD significantly increased the risk of both CAD and Hard CAD among current smokers only. This is similar to the finding from the Coronary Artery Calcification in Type 1 Diabetes study, where self-reported PD was significantly associated with CAC progression at 6 years follow-up.(Groves et al., 2015) Our study presents stronger evidence of this association as we have verified measure of periodontal disease, a longer follow up time and verified clinical outcomes. A recent meta-

analysis also showed that PD was associated with cardiovascular mortality and coronary heart disease among patients with type 2 diabetes, however there was not enough evidence for this association in T1D.(Graziani et al., 2018) Studies in the general population found that PD was associated with all-cause mortality and was an independent risk factor for CVD, after adjusting for traditional risk factors including smoking and diabetes.(Hansen, Egeberg, Holmstrup, & Hansen, 2016) (F. Xu & Lu, 2011) We observed a significant association between PD and all-cause mortality in the unadjusted models, although this association was no longer significant after adjusting for confounders. This different finding could be due to a smaller sample size and our study focusing on T1D patients only.

Because smoking is a major risk factor for PD and CVD(Johannsen et al., 2014) and based on findings from previous studies(Hyman et al., 2002), we tested for effect modification by current smoking status. We found current smoking to be an effect modifier as the PD – CAD / Hard CAD association was restricted to current smokers only. Both smoking and diabetes are known risk factors for periodontal disease.(Genco, 1996) Although it is known that compared to controls, T1D patients have elevated periodontal pro-inflammatory factors, different periodontal pathogen composition(Polak & Shapira, 2018) and lower salivary flow rates(Coelho et al., 2018; P. A. Moore, Guggenheimer, Etzel, Weyant, & Orchard, 2001; Saes Busato, Antoni, Calcagnotto, Ignacio, & Azevedo-Alanis, 2016), further research is required to investigate how these factors, in addition to genetics, differ in T1D by smoking status. Among the type 2 diabetes population, a study found that two inhibitors of the osteoblastogenesis pathway, Sclerostin and Dickkopf, were upregulated in patients with chronic periodontitis and type 2 diabetes and/or smoking.(Miranda et al., 2018) Joaquim et al(Joaquim et al., 2017), found no difference in key periodontal pathogens between smoking and non-smoking patients with type 2 diabetes compared to smoking and non-

smoking non-diabetic patients who had generalized chronic periodontitis. In addition, there is no direct mechanism for how periodontitis affects diabetic complications; suggested pathways include oxidative stress, dyslipidemia, endothelial dysfunction and elevated CRP.(Sanz et al., 2017) There is evidence that periodontal treatment improves short-term glycemic control and circulating levels of markers of inflammation in type 2 diabetes.(Graziani et al., 2018) However, there is insufficient evidence on the effect of PD therapy on HBA1c levels in T1D.(Graziani et al., 2018)

As the risk of CVD associated with PD among patients with diabetes is significant, screening for PD may provide a cost-effective modality for identifying patients at high CVD risk. A recent systematic review showed that most patients with diabetes were unaware of the PD-diabetes connection; they were not aware of their risk of PD and did not receive information about their oral health risk or advice about oral healthcare from their diabetes care provider.(Poudel et al., 2018) This issue has been addressed in the recent guidelines developed by the International Diabetes Federation and the European Federation of Periodontology to integrate the health care, including oral health care, of patients with diabetes between physicians and dentists.(Sanz et al., 2018) The guidelines state that children and adolescents with type 1 diabetes should be placed on annual oral screenings as soon as possible.(Sanz et al., 2018) It is important to note that although smoking is a significant risk factor for periodontal disease, bleeding on probing, which is one of the classical signs of active periodontal disease, is usually masked in smokers due to the vasoconstrictive effect of nicotine on blood vessels.(Calsina, Ramon, & Echeverria, 2002; Tarnowski, Duda-Sobczak, Lipski, Zozulinska-Ziolkiewicz, & Wyganowska-Swiatkowska, 2018) Consequently, patients can be unaware of periodontal problems until the disease progresses to an advanced stage, which could increase their risk of CAD. Therefore, patients with T1D should be

advised by their healthcare providers that PD, in addition to smoking, places them at increased risk of CVD complications beyond the traditional risk factors. These patients should be referred to a periodontist and placed on a periodontal treatment regimen.

2.4.1 Strengths and Limitations

Our study has some limitations. The use of partial mouth measure with three facial sites only could have underestimated the prevalence of PD.(Eke, Thornton-Evans, Wei, Borgnakke, & Dye, 2010) Partial mouth measures have been shown to bias epidemiological measures of association between PD and smoking, alcohol, obesity and diabetes.(Akinkugbe, Saraiya, Preisser, Offenbacher, & Beck, 2015) However, when the EDC oral health exam took place in 1992-94, this partial mouth exam was commonly used as an acceptable measure of the prevalence of periodontal disease. In addition, we used a definition of periodontal disease (>=4mm of attachment loss in >=10% of examined sites). Research shows that the association of PD with systemic diseases differs according to the classification or definition of PD used.(Beck, Moss, Morelli, & Offenbacher, 2018) Data for this cohort were collected to reflect the Healthy People 2000 and 2010 definition of PD(Gift et al., 1996; US Department of Health and Human Services, 2000) and do not allow the application of different definitions of PD. However, our main conclusion is that patients with T1D who have clinically verified PD and who currently smoke might be at increased risk of developing CVD complications. Moreover, oral health measures were assessed at one point and we cannot account for changes in PD over time. Smoking status was based on self-report and could be subject to reporting bias. Inflammation is suspected to play a role in the restriction of PD-CAD/HCAD association to smokers. However, we were unable to adjust for markers of inflammation beyond WBC count, as they were not collected for this sample. Adding markers of

inflammation such as IL-8, TNF and CRP would help further understand the relationship between PD and smoking in the development of CVD complications of T1D. Despite these limitations, this study is unique in that it uses longitudinal data from a prospective study with 19 years of follow up with verified CVD events. This enables us to establish a strong association with the exposure (PD) proceeding the outcome (CVD complications) in T1D, a topic that is understudied.

2.4.2 Conclusion

PD could be used as an early clinical predictor of CAD complications in TID patients who smoke. In addition, T1D patients who smoke should receive coordinated care from both a periodontist and their usual healthcare provider to ensure optimal treatment of both their periodontal disease and CAD risk. Studies that investigate complications of diabetes should examine PD to further aid our understanding of the PD-diabetes complications association. Clinical trials to evaluate the effect of periodontal treatment on outcomes in patients with T1D are warranted.

2.5 Tables/Figures

Table 2-1 Baseline characteristics of EDC participants who received an oral health exam (1992-1994) by periodontal disease (PD)

	Non-PD cases (n=286)	PD cases (n=34)	p-value
Age (years)	31.47 (7.67)	37.61 (6.06)	<0.0001
Age at onset (years)	8.09 (4.08)	10.71 (3.75)	0.0004
Duration of diabetes (years)	23.38 (7.34)	26.90 (7.47)	0.009
Female sex	130 (45.45)	12 (35.29)	0.26
More than high school education	208 (72.73)	18 (52.94)	0.02
≥7 ounces alcohol/wk (n=282,33)	199 (70.57)	20 (60.61)	0.24
Current smoker	40 (13.99)	21 (61.76)	<0.0001
Number of missing teeth			
None	161 (56.29)	6 (17.65)	
1-4	97 (33.92)	10 (29.41)	<0.0001
≥5	28 (9.79)	18 (52.94)	
White blood cell count ($x10^3/\mu L$, n=283,34)	7.11 (1.97)	8.80 (2.92)	<0.0001
BMI (kg/m^2 n=284,33)	24.66 (3.35)	23.90 (3.26)	0.22
Hypertension	50 (17.48)	10 (29.41)	0.09
HDL cholesterol (mg/dL, n=285,34)	52.07 (12.40)	53.01 (14.03)	0.68
Non-HDL cholesterol (mg/dL, n=285,34)	134.2 (37.07)	145.3 (39.19)	0.10
Albumin excretion rate (μg/min)	14.74 (5.18-69.07)	23.82 (6.27-143.33)	0.44
HbA1c (%, n= 284,34)	9.25 (1.41)	9.40 (1.36)	0.53
CAD incidence (n=259,29)	79 (30.50)	18 (62.07)	0.0006
Hard CAD incidence (n=273,31)	68 (24.91)	15 (48.39)	0.005
All-cause mortality	43 (15.03)	11 (32.35)	0.01

Data are means (SD), medians (interquartile range) or n (%)

Table 2-2 Baseline characteristics for all EDC participants who received an oral health exam by incident outcome of interest

Participant characteristics	CAD (N=288)			Hard CAD (N=304)			All- Cause Mortality (N=320)		
	No (n=191)	Yes (n=97)	p-value	No (n=221)	Yes (n=83)	p-value	No (n=266)	Yes (n=54)	p-value
Age (years)	29.73 (7.44)	35.33 (6.38)	<0.0001	30.38 (7.54)	35.78 (6.40)	<0.0001	31.19 (7.51)	36.67 (7.26)	<0.0001
Age at onset (years)	8.38 (4.18)	8.21 (4.01)	0.67	8.46 (4.05)	8.34 (4.31)	0.83	8.41 (4.09)	8.15 (4.29)	0.67
Duration of diabetes (years)	21.35 (6.65)	27.11 (7.20)	<0.0001	21.93 (6.86)	27.43 (7.03)	<0.0001	22.79(6.98)	28.53 (7.74)	<0.0001
Female sex	87 (45.55)	44 (45.36)	0.23	99 (44.80)	38 (45.78)	0.88	122 (45.86)	20 (37.04)	0.23
More than high school education	139 (72.77)	65 (67.01)	0.78	157 (71.04)	57 (68.67)	0.69	187 (70.30)	39 (72.22)	0.78
Alcohol consumption	N=187	N=96		N=217	N=82		N=261	N=54	
>=7ounces/week	130 (69.52)	67 (69.79)	0.96	149 (68.66)	60 (73.17)	0.45	186 (71.26)	33 (61.11)	0.14
Current smoker	30 (15.71)	26 (26.80)	0.02	32 (14.48)	24 (28.92)	0.01	43 (16.17)	18 (33.33)	0.017
Periodontal disease	11 (5.76)	18 (18.56)	0.01	16 (7.24)	15 (18.07)	0.005	23 (8.64)	11 (20.37)	0.011
Number of missing teeth									
None	114 (59.69)	40 (41.24)	<0.0001	129 (58.37)	31 (37.35)	0.0004	154 (57.89)	13 (24.07)	<0.0001
1-4	55 (28.80)	40 (41.24)		68 (30.77)	33 (39.76)		82 (30.83)	25 (46.30)	
≥5	22 (11.52)	17 (17.53)		24 (10.86)	19 (22.89)		30 (11.28)	16 (29.63)	

Table 2.2 Continued

Participant characteristics	CAD (N=288)			Hard CAD (N=304)			All- Cause Mortality (N=320)		
	No (n=191)	Yes (n=97)	p-value	No (n=221)	Yes (n=83)	p-value	No (n=266)	Yes (n=54)	p-value
HbA1c (%)	N=190	N=96		N=220	N=82		N=266	N=52	
	9.11	9.58	0.0065	9.12	9.63	0.0031	9.14	9.90	0.0003
	(1.42)	(1.27)		(1.35)	(1.35)		(1.33)	(1.60)	
White blood cell count	N=190	N=95		N=220	N=81		N=264	N=53	
($x10^3/\mu L$)	7.021	7.78	<0.0001	6.98	7.74	0.004	7.06	8.42	<0.0001
	(1.98)	(2.39)		(1.98)	(2.10)		(2.03)	(2.40)	
BMI (kg/m^2)	N=189	N=96		N=219	N=82		N=263	N=54	
	24.14	25.20	0.94	24.42	24.96	0.21	24.58	24.61	0.94
	(3.02)	(3.70)		(3.19)	(3.69)		(3.35)	(3.30)	
Hypertension	18 (9.42)	27 (27.84)	<0.0001	25 (11.31)	27 (32.53)	<0.0001	35 (13.16)	25 (46.30)	<0.0001
	N=196	N=96		N=221	N=82		N=266	N=53	
HDL cholesterol (mg/dL)	52.49	52.05	0.79	52.31	52.36	0.98	52.26 (12.46)	51.74 (13.17)	
	(12.49)	(12.73)		(12.50)	(12.81)				0.79
Non-HDL cholesterol	N=191	N=96		N=221	N=82		N=266	N=53	
(mg/dL)	126.7	150.6 (38.56)	<0.0001	128.6	151.2	<0.0001	130.9 (33.50)	158.1 (46.91)	<0.0001
	(34.02)			(33.74)	(41.13)				
Albumin excretion rate	N=190	N=97		N=220	N=83		N=265	N=54	
(μg/min)	11.04	21.30	<0.0001	11.04	39.54	<0.0001	11.50	107.03	<0.0001
	(4.36-	(6.79-		(4.36-	(9.33-		(4.42-44.27)	(21.15-	
	37.33)	146.54)		42.30)	366.43)			1209.51)	

Data are means (SD), medians (interquartile range) or n (%).

Table 2-3 Cox proportional hazard models for the prediction of CAD

	Crude model (n=283, 95 events)	Model with interaction term for PD*smoking	Crude model for smokers (n=55, 25 events)	Crude model for non-smokers (n=228, 70 events)	Adjusted model for smokers (n=55, 25 events)	Adjusted model for non-smokers (n=228, 70 events) [a]
PD (time-dependent)	1.10 (1.002-1.21) [b]	1.15 (1.04-1.28) [c]	1.29 (1.07-1.56)[c]	1.10 (0.85-1.42)	1.25 (1.03-1.50) [b]	1.09 (0.84-1.40)
PD*smoking		9.45 (1.80-49.74)[c]				
Diabetes duration					1.08 (1.01-1.54) [b]	1.09 (1.05-1.12)[d]
HbA1c					Not allowed	1.20 (1.01-1.42) [b]
Non-HDL cholesterol					Not allowed	1.02 (1.01-1.02) [d]
WBC					Not allowed	1.16 (1.01-1.33) [b]

Data are HR (95%CI)

Multivariable models allowed for univariate predictors of CAD.

[a] The model also allowed for log Albumin Excretion Rate and hypertension.

[b] p-value <0.05 [c] p-value <0.01 [d] p-value <0.001

Table 2-4 Cox proportional hazard models for the prediction of Hard CAD

	Crude model (n=299, 81 events)	Model with interaction term for PD*smoking	Crude model for smokers (n=55, 23 events)	Crude model for non-smokers (n=244, 58 events)	Adjusted model for smokers (n=55, 23 events)	Adjusted model for non-smokers (n=244, 58 events) [a]
PD (time-dependent)	1.26 (1.09-1.46)[c]	1.35 (1.15-1.58) [d]	1.93 (1.23-3.05) [c]	1.19 (0.84-1.68)	1.85 (1.17-2.93) [c]	1.18 (0.83-1.70)
PD*smoking		7.02 (1.31-37.59) [b]				
Diabetes duration					1.13 (1.05-1.21) [d]	1.09 (1.05-1.13) [d]
HbA1c					Not allowed	1.32 (1.10-1.60) [c]
Non-HDL cholesterol					Not allowed	1.01 (1.002-1.02) [c]
Log Albumin excretion rate					Not allowed	1.20 (1.05-1.38) [c]
WBC					Not allowed	1.17 (1.01-1.35) [b]

Data are HR (95%CI)

Multivariable models allowed for univariate predictors of CAD.

[a] The model also allowed for hypertension.

[b] p-value <0.05 [c] p-value <0.01 [d] p-value <0.001

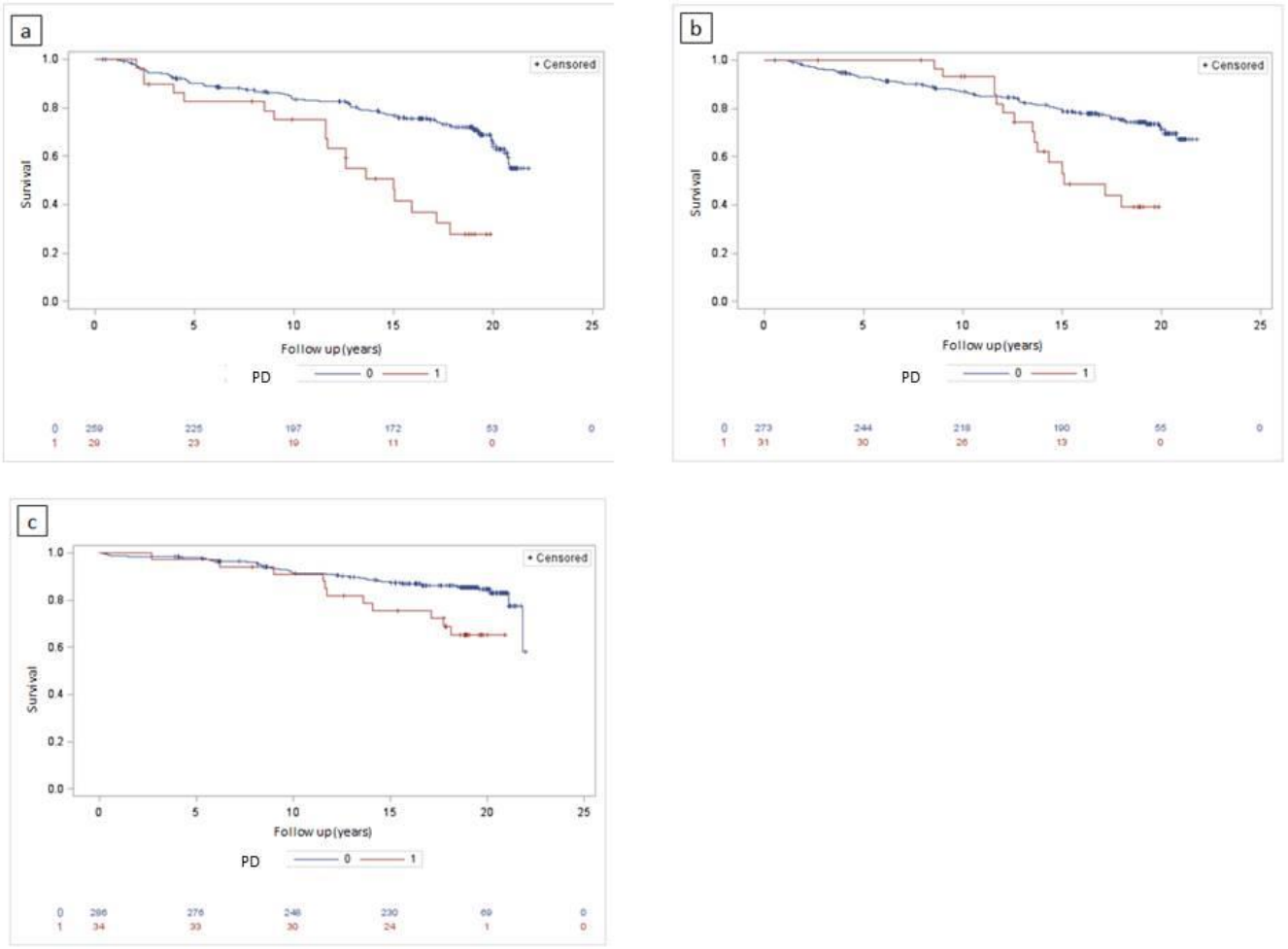


Figure 2-1 Kaplan Meier Survival Curves Stratified by Periodontal Disease (PD)

a.CAD, b.Hard CAD, c. All-cause mortality (0=non-PD cases, 1=PD cases)

3.0 Chapter Three: Association Between Medicaid Expansion, Dental Coverage Policies for Adults and Children's Receipt of Preventive Dental Services

Abstract

Objective: To examine whether low-income children's use of preventive dental services is linked to variation in state Medicaid policies that affect parents' access to dental care in Medicaid.

Data sources: Medical Expenditure Panel Survey (2011-2016), Area Health Resources File, and Medicaid adult dental coverage policies.

Study design: We conducted a quasi-experimental analysis using linked parent-child dyads in low-income families (≤125% of the Federal Poverty Level). We assessed whether expansions of Medicaid to low-income adults under the Affordable Care Act were associated with increases in the use of preventive dental services among low-income children when state Medicaid programs did vs. did not cover these services for adults.

Principal findings: Over the study period, 37.8% of low-income children received at least one annual preventive dental visit. We found no change in children's receipt of preventive dental care associated with Medicaid expansions in states that covered vs. did not cover preventive dental services for adults (differential change: -1.76 percentage points; 95% CI: -8.09, 4.56)., with wide confidential intervals that are unable to rule out sizable effects in either direction.

Conclusion: We did not find an association between Medicaid expansions with concurrent coverage of preventive dental services for adults and children's use of these services. Factors other than parental access to dental benefits through Medicaid may be more salient determinants of preventive dental care use among low-income children.

Keywords: Medicaid, Dentistry, State Health Policies

3.1 Introduction

Medicaid expansions for children and the introduction of the Children's Health Insurance Program (CHIP) in the 1990s have reduced disparities in dental care use by race and income.(Kamyar Nasseh & Vujicic, 2016; Vujicic & Nasseh, 2014) Despite improvements in oral health over the last two decades, dental caries remain the most common chronic disease of childhood, affecting an estimated 46% of US children ages 2-19, with disproportionate prevalence in low-income families and among racial and ethnic minorities.(E. Fleming & J. Afful, 2018) Poor oral health can lead to problems eating, speaking, and learning(Jackson et al., 2011; Seirawan et al., 2012) whose ramifications can persist into adulthood(Kar Yan Li et al., 2018), affecting long-term health(Health & Services, 2000; Otomo-Corgel, Pucher, Rethman, & Reynolds, 2012) and economic outcomes.(Glied & Neidell, 2010)

Preventive dental care has been shown to reduce the incidence of dental caries and associated health care costs,(Lee, Monahan, Serban, Griffin, & Tomar, 2018; Sen et al., 2013) but the use of preventive dental services among children varies widely. Children who are black, Hispanic or in low-income families are 40-50% less likely to receive preventive dental care than children who are white or of higher socioeconomic status.(Burton L Edelstein & Chinn, 2009) Although preventive dental services are covered for all children in Medicaid and CHIP, research has found substantial variation across states in the level of access to dental services, due in part to state-level differences in Medicaid payment rates to providers and geographic variation in the supply of dentists.(Fisher-Owens et al., 2016)

In addition to these factors, one study identified a parent's receipt of dental care as a salient determinant of their child's dental care use.(Isong et al., 2010) Although this study's observational design limited the extent to which its authors could control for other determinants of parents' and children's dental care use, its findings are consistent with a larger literature that finds "spillover" effects of parental access to care on their children's receipt of care. For example, Medicaid expansions for low-income parents have been shown to increase the likelihood that their children received an annual well-child visit.(DeVoe et al., 2015; Dubay & Kenney, 2003; Hudson & Moriya, 2017; Venkataramani, Pollack, & Roberts, 2017) However, no research has examined the relationship between policies that affect parental access to dental services in Medicaid and children's likelihood of receiving preventive dental care.

Two sources of state policy variation can affect low-income parents' access to preventive dental care in Medicaid. First, state Medicaid programs vary considerably in the level of dental benefits provided to adults, with some covering preventive dental care and others covering emergency services only.(Medicaid.Gov) This stands in contrast to children, for whom states have consistently provided preventive dental services in Medicaid and CHIP under the Early Periodic Screening Diagnosis and Treatment benefit (made mandatory in 2009).(B. L. Edelstein, 2018) Second, states differ in their implementation of the Affordable Care Act's (ACA) Medicaid expansion, which increased Medicaid eligibility for non-disabled and non-pregnant adults. Although the ACA did not explicitly change dental coverage policy for adults in Medicaid (it remains an optional benefit), many low-income adults gained dental coverage in states that expanded Medicaid and covered preventive dental services for adults through their Medicaid programs.(Center for Health Care Stratigies January 2018) Recent research has linked Medicaid expansions with concurrent dental coverage to increases in oral health care use and to reductions

in dental-related emergency department visits among adults.(Elani, Kawachi, & Sommers, 2020; Singhal, Damiano, & Sabik, 2017; Wehby, Lyu, & Shane, 2019)

In this study, we analyzed linked parent-child dyads from nationally representative survey data to investigate whether state policies that affect adults' access to dental care in Medicaid have spillover effects on low-income children's receipt of preventive dental care. We employed a quasi-experimental design that compared changes in children's receipt of three preventive dental services (cleanings, fluoride treatment, and sealant applications) associated with Medicaid expansions in states where Medicaid did versus did not cover preventive dental services for adults.

3.2 Methods

3.2.1 Data

We analyzed data from the Medical Expenditure Panel Survey-Household Component (MEPS) for the years 2011-2016. The MEPS includes detailed information about individuals' health care use (including visits to a dentist), health insurance status, socioeconomic status, and family characteristics. When weighted, the MEPS is representative of the noninstitutionalized US population.(Agency for Healthcare Research and Quality, 2009, August 21; Cohen, 1997)

We linked the MEPS to annual state-level data on the status of Medicaid expansions(Kaiser Family Foundation) and to state Medicaid programs' coverage of dental benefits for adults for the period 2011-2016. We constructed this dental coverage dataset by consolidating policy information from the Medicaid and CHIP Payment and Advisory Commission((MACPAC). June 2015), the Center for Health Care Strategies(Center for Health Care Stratigies Inc., February

2015), the Kaiser Family Foundation(Kaiser Family Foundation), Medicaid state plan amendments filed with CMS(Centers for Medicare & Medicaid Services), and the peer-reviewed literature(S. L. Decker & Lipton, 2015) (Appendix).

We incorporated information from two other data sources. First, we used the Area Health Resources File (AHRF) to obtain annual county-level measures of dental provider supply, poverty, and urbanicity. Second, we obtained annual state-level data on fee-for-service Medicaid reimbursement rates for child dental prophylaxis (Dental Procedures and Nomenclature [CDT] code 1120) from the American Academy of Pediatrics' Medicaid reimbursement reports.(American Academy of Pediatrics) One of the authors (TK) checked and supplemented this payment data via personal communication with the American Dental Association's Health Policy Institute.

3.2.2 Study population

Our study sample consisted of dyads of children and parents in families with incomes ≤125% of the FPL (≤$32,750 in income for a family of four in 2020).(U.S.Department of Health & Human Services) We limited our sample to children ages 6 to18 years old living with a non-elderly, non-disabled adult (parent or guardian) age 21–64. (For brevity, we refer to the adults in these dyads as parents.) We selected children age 6 and older because these children have either begun to, or have developed, permanent teeth. Consistent with prior research examining within-family spillover effects of Medicaid policy,(Venkataramani et al., 2017) we selected the mother or female guardian for the parent-child dyad in two-parent families, such that each child appeared in our study sample once and was linked to the characteristics of one parent. Children of women who were pregnant at any point during the calendar year and who did not have a father in the

household were excluded because pregnant women gain dental coverage through Medicaid in many states during pregnancy.(Children's Dental Health Project, September 2018; Kloetzel, Huebner, & Milgrom, 2011) Additional details of our inclusion criteria are reported in the Appendix. (Appendix Figure 1).

3.2.3 Dependent variables

In our main analysis, we examined whether a child received any preventive dental service in the calendar year using the MEPS dental visit files. Preventive dental services were defined as dental prophylaxis (cleaning), fluoride treatment(Marinho, Worthington, Walsh, & Clarkson, 2013), or sealant application(Wright et al., 2016) by a dental professional (Appendix). Healthy People 2020 identifies the use of these preventive dental services as important for improving children's oral health.(Health & Services, 2011) In sub-analyses, we separately assessed children's receipt of a dental prophylaxis only versus fluoride treatment or sealants combined. We combined fluoride treatment and sealants as these methods have strong supporting evidence in preventing dental caries.(Azarpazhooh & Main, 2009; Wei, Griffin, & Robison, 2018)

3.2.4 Independent variables

We analyzed two independent variables. First, we assessed whether states had implemented the ACA's Medicaid expansion by each year of our study period (through 2016). We considered a state to have expanded Medicaid by a given year if its expansion was effective on or before September 1st of that year. Second, we assessed states' coverage of dental benefits for adults in each study year. We considered states to have provided adult dental benefits if their Medicaid

programs covered more than emergency services for adult Medicaid recipients.(S. L. Decker & Lipton, 2015; Singhal et al., 2017)

3.2.5 Covariates

We included the following covariates in our analyses. First, we controlled for the following parental characteristics: age, sex, race/ethnicity, language, education, employment, and smoking status. Second, we adjusted for family income as a categorical variable (relative to the Federal Poverty Level), family size, and parental structure (a two-parent household vs. a single-parent household). Third, we controlled for child age and sex. Fourth, at the county level, we controlled for the number of dentists per 1000 residents, the poverty rate, and an indicator for whether the family lived in an urban area (defined as a Metropolitan Statistical Area). Finally, given the well-documented relationship between Medicaid payment rates to providers and provider participation in Medicaid,(Buchmueller, Orzol, & Shore-Sheppard, 2015; Sandra L Decker, 2009; S. L. Decker & Lipton, 2015) we adjusted for Medicaid reimbursement rates to dentists for a common preventive dental procedure (child prophylaxis, CDT code 1120), which we assessed at the state-year level.

3.2.6 Statistical analyses

We assessed whether states' implementation of the ACA's Medicaid expansion was associated with increases in the probability that low-income children received preventive dental care in states whose Medicaid programs did vs. did not cover dental services for adults. Using the

parent-child dyad (indexed by *i*) as the unit of analysis, we estimated linear probability models of the form:

$$y_{ist} = \alpha + \eta DentalPolicy_{st} + \psi ACAExpand_{st} + \theta ACAExpand_{st} \times DentalPolicy_{st} + \beta X_{it} + \lambda Payment_{st} + \mu_s + \mu_t + \varepsilon_{ist}$$

In this model, y_{ist} is a binary indicator that a child received at least one preventive dental service in year *t*, $DentalPolicy_{st}$is a binary variable equal to one if a state Medicaid program covered dental services for adults in year *t*, and $ACAExpand_{st}$ indicates whether state *s* had implemented the ACA's Medicaid expansion by year *t*. We adjusted for child, parent, and county-level characteristics (X_{it}), Medicaid fee-for-service payment rates for dental prophylaxis ($Payment_{st}$), state fixed effects (μ_s) to control for time-invariant state characteristics, and year fixed effects (μ_t) to control for time trends common to all states. We adjusted for family survey weights in the MEPS and clustered standard errors at the state level for inference.

We report three estimates from this model:

1) $\hat{\eta}$, which represents the change in children's preventive dental care use associated with state Medicaid programs' coverage of preventive dental services for adults. Because our model includes state fixed effects, $\hat{\eta}$ is estimated from within-state changes in adult dental coverage policies.
2) $\hat{\psi}$, which is the change in children's preventive dental care use associated with Medicaid expansions in states that did not concurrently cover preventive dental services for adults.
3) $\hat{\theta}$, the differential change in children's preventive dental care use associated with Medicaid expansions in states that did vs. did not concurrently cover preventive dental services for adults. This is our primary estimate of interest.

3.2.7 Supplementary analyses

We conducted four supplementary analyses. First, we examined whether Medicaid expansions were associated with increases over time in children's receipt of preventive dental services when states consistently covered these services for adults. To do so, we estimated event-study models to assess time-varying treatment effects of Medicaid expansions, separately in 24 states that covered dental services for adults in each year of our study period and in 19 states that did not cover these services in any study year (Table 3-2). We plotted unadjusted estimates from these event-study models and report corresponding estimates of adjusted time-varying effects in the Appendix.

Second, to check whether we could isolate changes associated with Medicaid expansions from secular state trends, we used these event-study models to examine whether pre-expansion trends in children's preventive dental service use differed between expansion and non-expansion states categorized according to their adult dental coverage policies.

Third, we examined whether Medicaid expansions with vs. without concurrent adult dental coverage were associated with differential changes in the likelihood that low-income children were enrolled in Medicaid or CHIP. We performed this analysis to examine whether Medicaid policy changes for adults might affect children's use of preventive dental care via take-up of Medicaid or CHIP.

Fourth, we re-estimated our main empirical model using logistic regression to test whether our estimates were sensitive to functional form.

3.3 Results

Our analytic sample consisted of 7,798 annual parent-child dyads with incomes ≤125% FPL, representing 39,028,587 weighted pairs in our 6-year study period (Table 3-1). The majority (79.4%) of children in these dyads were enrolled in CHIP or Medicaid and 66.4% were racial or ethnic minorities. The preponderance of parents in the dyads (89.3%) were female and 42.9% were enrolled in Medicaid. Across all study years, 37.8% of children received at least one annual preventive dental service, the majority of which were for dental prophylaxis (Appendix Figure 2). Over time, the proportion of low-income children who received at least one preventive dental service increased from 36.2% in 2011 to 40.1% in 2016.

States vary considerably in their dental coverage policies for adults (Table 3-2). By the conclusion of our study period in 2016, 19 of the 32 states that expanded Medicaid covered dental services for adults in each year from 2011-2016. Of the 19 states that had not expanded Medicaid by 2016, 5 consistently covered dental services for adults from 2011-2016. Only 8 states changed adult dental coverage policies during our study period. Because most of the variation in dental coverage is between (rather than within) states, we primarily focus on differences in the association of Medicaid expansions with children's dental care use between states with and without Medicaid dental coverage for adults.

Table 3-3 displays the adjusted associations between Medicaid expansions, Medicaid dental coverage for adults, and children's receipt of preventive dental care, as estimated from main empirical model (full regression estimates are shown in Appendix Table 2). In states that covered preventive dental services for adults in Medicaid, implementation of the ACA's Medicaid expansion was not associated with a change in the probability that low-income children received least one annual preventive dental service (1.26 percentage points; 95% CI: -3.74 to 6.27). (This

corresponds to $\hat{\psi} + \hat{\theta}$ from our model.) In states that did not cover preventive dental services for adults in Medicaid, expansion was not associated with a statistically significant change in the probability that low-income children received preventive dental care (3.03 percentage points; 95% CI: -2.76 to 8.81). The difference in these estimates, which corresponds to our regression estimate $\hat{\theta}$, was not statistically significant (-1.76 percentage points; 95% CI: -8.09 to 4.56) and small relative to mean preventive dental service utilization among children in our study population (approximately 36.2% percent of children in 2011 received at least one annual preventive dental service in 2011, and 40.1% did in 2016.) We did not find any statistically significant associations between these Medicaid policies for adults and specific categories of preventive service use among children (dental prophylaxis versus fluoride treatment or sealant application.)

In sensitivity analyses, we examined potential sources of bias in our study design and assessed the robustness of our estimates to the functional form of our regression models. First, we separately examined time-varying changes in children's use of preventive dental services associated with Medicaid expansions in states that continuously covered Medicaid dental benefits for adults and in states that did not cover dental benefits for adults in any year of our study period (Figure 3-1; estimates reported in Appendix Table 3). We found no evidence of gains in children's preventive dental care use in the post-expansion period or evidence of effects that began to emerge more prominently several years after expansion.

Second, we examined whether our estimates of changes in children's preventive dental service use before and after ACA's Medicaid expansion could have been biased by differential trends *preceding* this expansion (or prior to 2014 for non-expansion states). In states that continuously covered dental benefits for adults during our study period, we found a modest, but not statistically significant, increase in children's preventive dental service use prior to 2014 in

non-expansion states compared to pre-trends in expansion states. In states that did not cover dental benefits for adults in any year of our study period, we did not detect an appreciable difference in pre-trends between expansion and non-expansion states. Thus, while secular trends are unlikely to substantially affect our estimates, any bias they introduce would likely make our estimates slightly conservative given the secular increases in children's dental care use in non-expansion (rather than expansion) states that provided dental benefits for adults.

Third, we did not find that Medicaid expansions were associated with differential increases in Medicaid or CHIP take-up among low-income children in states that did vs. did not concurrently cover dental benefits for adults (Appendix Table 4).

Finally, we explored whether our estimates were sensitive to the functional form of the regression models we ran. Table 5 of the appendix display the results of logit model, for which our estimates were qualitatively similar to those of the linear model presented in our main analyses.

3.4 Discussion

In this study, we used nationally representative data from the Medical Expenditure Panel Survey to examine the use of preventive dental services among low income children and to assess whether changes in state Medicaid policies that affect low-income adults' access to dental care are linked to changes in children's use of preventive dental services. On average from 2011-2016, we found that 37.8% of low-income children received at least one annual preventive dental service—considerably lower than has been reported in higher-income populations(Berdahl, Hudson, Simpson, & McCormick, 2016)—which is consistent with prior evidence that low-income children face persistent barriers to dental care.(Dye et al., 2007; Li, Albuquerque, & Gooch, 2014) Given

evidence that parental access to care through Medicaid may have "spillover" effects on children's health care use,(DeVoe et al., 2015; Dubay & Kenney, 2003; Hudson & Moriya, 2017; Venkataramani et al., 2017) we studied whether expansions of Medicaid with concurrent dental coverage for adults were linked to increases in children's use of preventive dental care. We did not find statistically significant changes in children's use of preventive dental care associated with expansions in states that did versus did not cover preventive dental care for adults in Medicaid.

These results stand in contrast to other studies that found positive "spillover" effects of adult Medicaid coverage on low-income children's use of physical health care. (DeVoe et al., 2015; Dubay & Kenney, 2003; Hudson & Moriya, 2017; Venkataramani et al., 2017) Our findings may reflect differences in health services systems for medical and dental care or persistent barriers to dental care use among children. For example, dental care has historically operated separately from medical care and has focused on tertiary treatment rather than prevention.(Watt et al., 2019) In addition, inadequate referral systems between physicians and dentists(Harnagea et al., 2017; Kranz, Rozier, et al., 2015) and the limited availability of dentists accepting Medicaid patients (Seale & Casamassimo, 2003; Smith & Lewis, 2005) present continued barriers to dental care access among low-income children and might limit extent to which children benefit when their parents receive dental coverage through Medicaid.

A growing body of research demonstrates that implementation of the ACA's Medicaid expansion has had favorable effects on adult dental service use and oral health outcomes when states cover dental services for adults in Medicaid, although these effects may vary by population or local variation in the supply of dental providers.(Elani et al., 2020; K. Nasseh & Vujicic, 2017; Singhal et al., 2017; Wehby et al., 2019) This evidence led us to hypothesize a possible "spillover" effect of Medicaid expansions and dental coverage for adults on low-income children's use of

preventive dental care. However, we did not find evidence of such a spillover effect, suggesting that policies other than adult dental coverage through Medicaid may play a more prominent role in children's receipt of preventive dental services.

Policies that directly expand access to dental care for children may have more direct impacts on children's dental care use. For example, school-based oral sealant programs have been found to be effective in increasing sealant use and in preventing dental caries among low-income children.(S. Griffin et al., 2016; S. O. Griffin et al., 2017) In addition, all state Medicaid programs now reimburse primary care providers for fluoride varnish treatment following a 2014 U.S. Preventive Services Task Force (USPTF) recommendation.(U.S. Preventive Services Task Force, 2014) This has led to increased fluoride varnish use and improved oral health outcomes among low-income children.(Kranz et al., 2019; Kranz, Preisser, & Rozier, 2015)

Although we did not find evidence that expansions of Medicaid with dental coverage for adults affected children's use of preventive dental care, our findings should not be construed as evidence that Medicaid policies are unrelated to oral health care access or outcomes in low-income populations. First, low-income adults have substantial oral health needs(Hom et al., 2016; K. Y. Li, C. E. Okunseri, C. McGrath, & M. C. M. Wong, 2018; Moeller, Starkel, Quinonez, & Vujicic, 2017) and a large literature demonstrates that adults derive direct benefits when Medicaid facilitates greater access to preventive dental care. For example, providing comprehensive dental coverage for adults in Medicaid is associated with an increase in dental visits, preventive and restorative service use, and improved oral health outcomes.(Abdus & Decker, 2019; Choi, 2011; S. L. Decker & Lipton, 2015) Conversely, losing Medicaid dental coverage has been linked to increased ED use for non-traumatic dental conditions.(Singhal et al., 2015) Second, our findings

do not necessarily imply that policies restricting dental benefits for adults in Medicaid would not harm children's access to preventive dental services.

Limitations of our study design could have biased us away from finding a beneficial effect of increases in parental dental coverage in Medicaid on children's use of dental care. First, our estimates could have been biased by unobserved changes in the characteristics of Medicaid enrollees or factors linked to children's receipt of dental care. For example, we did not control for variation in dental provider networks established by Medicaid Managed Care Organizations (MCOs), payment rates negotiated between Medicaid MCOs and dental providers (which may differ from those in fee-for-service Medicaid), or whether states "carved-out" dental benefits from physical health benefits in Medicaid. Second, secular increases (though small) in children's use of preventive dental services in states that did *not* expand Medicaid but *did* cover preventive dental services for adults may have biased us away from finding a beneficial effect of Medicaid expansions in dental coverage states. Finally, we acknowledge that Medicaid expansions may take time to yield detectable gains in children's use of preventive dental services. However, we did not find any significant gains among children by the third year of expansion in states whose Medicaid programs consistently covered dental benefits for adults.

3.5 Conclusion

Although prior research found that expanded Medicaid coverage for parents has "spillover" effects on children's use of medical services, we did not find evidence of a similar relationship between Medicaid expansions with concurrent adult dental coverage and low-income children's use of preventive dental services. Factors other than Medicaid eligibility and dental coverage

policies for adults may be more salient determinants of preventive dental care use among low-income children.

3.6 Tables/ Figure

Table 3-1 Study Population Characteristics

Variable	Mean or proportion
Child characteristics	
Female, %	50.0
Child age in years, mean (SD)	10.1 (0.06)
Child age, % by age category	
6-9	15.4
10-14	32.5
15-18	52.1
Child race and ethnicity, % in category	
White non- Hispanic	33.7
Black non-Hispanic	19.7
Hispanic	37.7
Other	9.0
Child enrolled in Medicaid or CHIP, %	79.4
Parent characteristics	
Female, %	89.3
Parent age in years, mean (SD)	37.8 (0.12)
Parent race and ethnicity, % in category	
White non- Hispanic	37.4
Black non-Hispanic	19.5

Table 3-1 continued

Variable	Mean or proportion
Hispanic	35.7
Other	7.4
Parent enrolled in Medicaid, % †	42.9
Parent comfortable with English language, %	70.5
Parent smoker, %	25.5
Parent education, % in category	
Less than high school	30.4
Completed high school	35.6
Any college	33.2
Not specified	0.80
Unemployed, %	48.5
Family characteristics	
Family size, % in category	
2 or less	13.3
3	20.6
4	26.9
5	21.5
6	10.8
7 or more	6.8

Table 3-1 continued

Variable	Mean or proportion
Family income as a percent of the Federal Poverty Level in category, %	
Less than 100%	76.7
100% to less than 125%	23.3
Single parent family, %	49.5
Lives in urban area, %	77.0

Analysis of N= 151,889,212 weighted dyads (27,851 unweighted dyads) in families with income below 200% FPL who were surveyed in the MEPS 2003-2016. Estimates were adjusted for family survey weights.

Table 3-2 States categorized by Medicaid expansion status and dental coverage policies for adults

	Medicaid Expansion Status by 2016	
Medicaid coverage of preventive dental services for adults	**Expanded (32 states)**	**Did not Expand (19 states)**
All study years (2011-2016; 24 states)	19 states: AR,AK,CT,DC,IN,IA,KY,MA,MI,MN,NJ,NM,NY ND,OH,OR,PA,RI,VT	5 states: NE,NC,SD,WI,WY
Some study years (8 states)	5 states: CA,CO,IL,MT,WA	3 states: MO,SC,UT
No study years (19 states)	8 states: AZ,DE,HI,LA,MD,NV,NH,WV	11 states: AL,FL,GA,ID,KS,ME,MS,OK,TN,TX,VA

Based on Kaiser Family Foundation data on the status of state Medicaid expansions and Medicaid dental coverage policies reported by the Medicaid and CHIP Payment and Advisory Commission, the Center for Health Care Strategies, the Kaiser Family Foundation, Medicaid state plan amendments filed with CMS, and the peer-reviewed literature.

Table 3-3 Adjusted associations between Medicaid dental coverage for adults, Medicaid expansions, and children's receipt of preventive dental services

	Any preventive service		Dental Prophylaxis		Fluoride treatment or sealant application	
Percent of children in families ≤ 125% of FPL receiving services (probability of any annual use)	**2011** 36.2	**2016** 40.1	**2011** 35.5	**2016** 39.6	**2011** 11.8	**2016** 17.7
Changes in children's preventive dental care use associated with:						
Medicaid dental coverage for adults †	-4.17 [-8.17, 0.27]		-5.16 * [-10.27, -0.05]		1.91 [-2.55, 6.37]	
Medicaid expansions without concurrent dental coverage for adults ‡	3.03 [-2.76, 8.81]		3.69 [-1.76, 9.15]		-0.02 [-6.10, 6.07]	
Medicaid expansions in states with vs. without Medicaid concurrent dental coverage for adults §	-1.76 [-8.09, 4.56]		-1.88 [-8.20, 4.44]		-2.34 [-9.10, 4.40]	

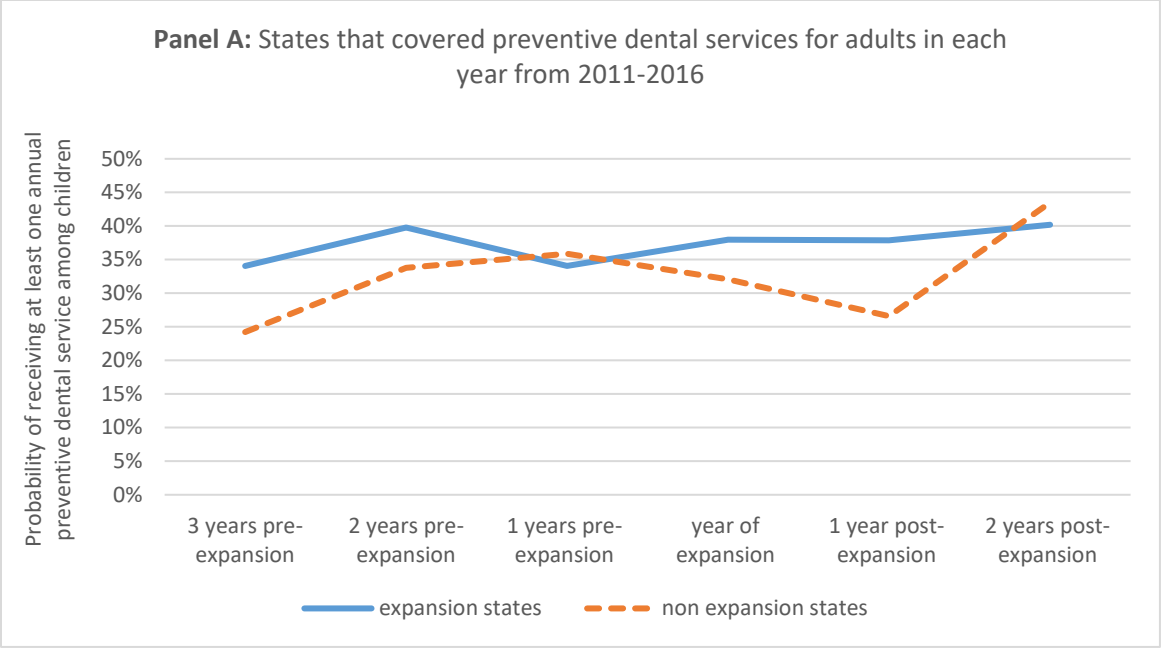
Estimates are from a multivariable linear regression model predicting child's receipt of preventive dental services as a function of Medicaid dental coverage for adults, Medicaid expansion, and an interaction between Medicaid expansion status and Medicaid dental coverage for adults, controlling for child, parent, and family-level characteristics and state and year fixed effects. Estimates were adjusted for family survey weights. 95% Confidence Intervals [in brackets] were constructed using standard errors clustered at the state level. Any preventive service was defined as any dental cleaning, fluoride treatment or sealant application visit. Analysis of N= 39,028,587 weighted dyads (7,798 unweighted dyads) in families with income at or below 125% FPL surveyed in the 2011-2016 MEPS. Estimates are reported in percentage points.

*p<0.05.

† Corresponds to $\hat{\eta}$ from the regression model.

‡ Corresponds to $\hat{\psi}$ from the regression model.

§ Corresponds to $\hat{\theta}$ coefficient from the regression model.



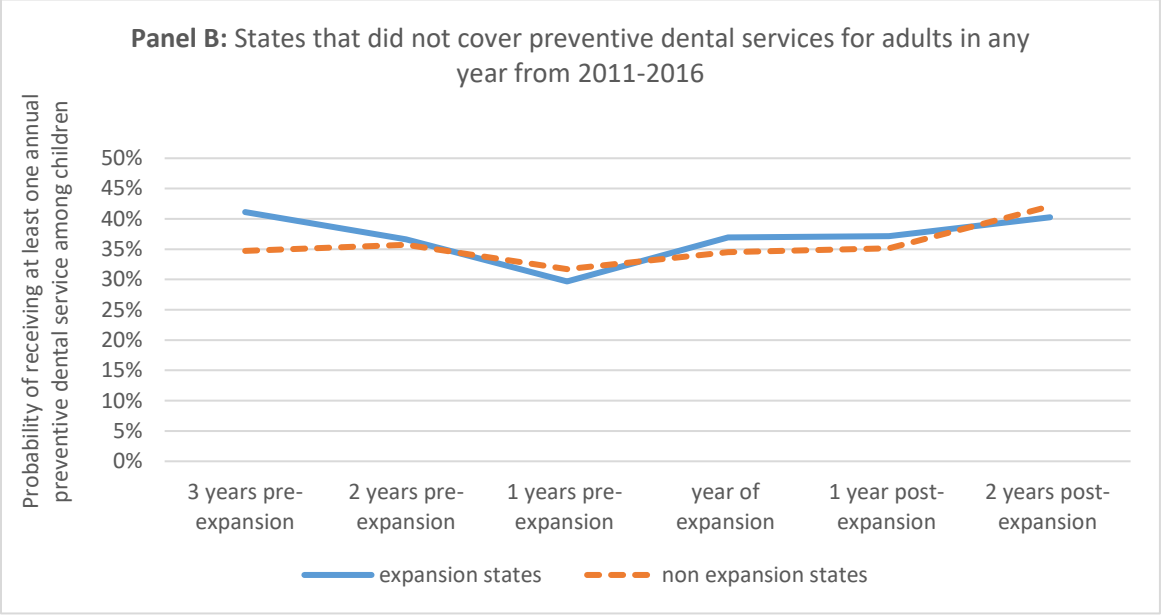


Figure 3-1 Trends in Children's use of Preventive Dental Services in states categorized by Medicaid expansion status and coverage of preventive dental services for adults in Medicaid

States were catgeorized by their Medicaid expansion status and coverage of preventive dental services for adults (see Table 2 for details). We report unadjusted probabilities of receiving at least one annual preventive dental service use among low-income children in each year relative to Medicaid expansion (in states that expanded Medicaid by 2016) or relative to 2014 (for states that had not expanded by 2016). Estimates are reported separately for 24 states whose Medicaid programs covered preventive dental services for adults in each year from 2011-2016 (Panel A) and 19 states whose Medicaid programs did not cover preventive dental services for adults in any study year (Panel B).

4.0 Chapter Four: Initial Opioid Prescribing and Subsequent Opioid Use after Dental Procedures Among Opioid Naive Patients in Pennsylvania Medicaid, 2012 to 2017

Abstract

Background Opioid prescribing by dentists has received substantial attention. Much of the evidence on opioid-related sequelae from dental opioid prescribing comes from studies of oral surgery and other procedures with high pain severity. Less is known about how frequently opioids are prescribed for procedures with low or no pain or whether that prescribing is associated with continued opioid use.

Methods We used PA Medicaid claims data from 2012-2017. We categorized dental procedures into three groups based on the likelihood of pain (low, moderate and high). Using multivariable logistic regression models with random intercept, we estimated the probability of receiving an initial opioid prescription within 7 days prior to and 3 days after a dental procedure associated with these three categories of pain and assessed subsequent short-(4-90 days) and long- term (91-365 days) opioid use, controlling for demographic, and health status characteristics.

Results We identified 1,345,360 index dental procedures (among 912,121 enrollees) of which 67% were categorized as low, 1.6% moderate, and 30.8% high-pain. The predicted probability of an initial opioid prescription was 31.8% (CI: 31.6-31.9%) for high pain, 8.3% (CI: 7.9-8.6%) for moderate pain and 2.4% (CI: 2.4-2.5%) for the low pain procedures. Predicted probabilities for short- term use for those who filled vs did not fill an opioid were :0.93 % (CI: 0.91-0.96%) vs 25.03% (CI: 24.47-25.60) for the low pain group, 1.59% (CI: 1.41-1.78%) vs 16.60% (CI: 14.85-18.36%) for the moderate pain group and 2.9% (CI: 2.84-2.975%) vs 13.51% (CI: 13.34-13.67%) for the high pain group.

Conclusions Although enrollees undergoing high-pain dental procedures were more likely to fill an initial opioid prescription than their counterparts with low to moderate pain procedures, the relative risk of sustained opioid use (4-90 days post-procedure) was actually highest in the low-pain group.

Practical Implications More attention should be paid to reducing opioid prescribing for common dental procedures with low pain risk.

Key Words: Opioid, repeat prescriptions, oral health.

4.1 Introduction

Opioid use disorders and fatalities have reached epidemic proportions in the US and have a huge economic impact.(The Council of Economic Advisers, November 2017) A major focus of health systems and policy makers has been to reduce excess opioid prescribing through numerous policy interventions such as developing prescribing guidelines,(Dowell, Haegerich, & Chou, 2016) and Prescription Drug Monitoring Programs (PDMP).

Dentists and oral surgeons are among the top opioid prescribers especially among adolescents.(Denisco et al., 2011; Volkow, McLellan, Cotto, Karithanom, & Weiss, 2011) However, evidence supports use of Non-Steroidal Anti-Inflammatory Drugs (NSAID's) to manage dental pain.(Paul A. Moore & Hersh, 2013; P. A. Moore et al., 2018) In fact, the US is an outlier in the use of opioids for dental pain management.(Suda et al., 2019) Therefore, opioid prescribing by dentists should be a focus of efforts to reduce excess opioid prescribing. Changes in guidelines for opioid prescribing has led to reductions in opioid prescribing overall,(Centers for Disease Control and Prevention, July 2017) but has increased for dental procedures in the US.(Steinmetz, Zheng, Okunseri, Szabo, & Okunseri, 2017) (Gupta, Vujicic, & Blatz, 2018b)

Opioids prescribed by dentists are immediate release opioids for acute dental pain. Opioid prescribing for short term management of acute pain following non-dental procedures has been associated with long-term use of opioids.(Alam et al., 2012; Brummett et al., 2017; Herzig, Rothberg, Cheung, Ngo, & Marcantonio, 2014; Jarlenski et al., 2017; Raebel et al., 2014; Sun, Darnall, Baker, & Mackey, 2016) Only a few studies have attempted to evaluate the risk of long-term use of opioids among opioid naïve patients following an opioid prescription for a dental procedure. Harbaugh and colleagues evaluated persistent opioid use after wisdom tooth extraction among a privately insured population from 2009-2015 and found that patients with an opioid

prescription were 2.7 times more likely to become persistent opioid users regardless of the intensity of the surgical procedure.(Harbaugh et al., 2018) Among a cohort of privately insured patients from 2010-2015, repeat dental related opioid prescription occurred 30 days post procedure and was highest among adolescents and young adults.(Gupta, Vujicic, & Blatz, 2018a) However, the risk of subsequent opioid use following an initial opioid prescription has not been evaluated for Medicaid patients following dental procedures. Opioid prescribing for dental procedures among Medicaid beneficiaries has been reported at 23% following dental procedures(Janakiram et al., 2018) and 42% following tooth extractions.(Baker, Avorn, Levin, & Bateman, 2016) The Medicaid population is at higher risk for opioid related adverse events(Control & Prevention, 2009) with a high economic burden on Medicaid because it covers 4 in 10 non-elderly adults with an opioid addiction.(Kaiser Family Foundation, 2018)

The objective of this study was to assess the risk of filling an initial opioid prescription associated with dental procedures based on the likelihood of pain associated with the procedure and to evaluate the risk of subsequent short term (4-90 days) and long term (91-365 days) opioid use among a cohort of previously opioid-naïve Medicaid beneficiaries (no opioid prescription within 180 days prior to the dental procedure) who underwent an index dental procedure. We had two hypotheses. First, patients who underwent procedures that are associated with a high likelihood of pain are more likely to fill an initial opioid prescription. Second, conditional on filling an initial opioid, the risk of short- and long-term use of opioids would be constant regardless of the likelihood of pain associated with the procedure.

4.2 Methods

4.2.1 Data sources and cohort design

In this longitudinal retrospective cohort study, we used PA Medicaid enrollment files, dental claims and pharmacy claims from January 1, 2012 through December 31, 2017, three years before and after PA expanded Medicaid in January 2015. The enrollment files were used to obtain the demographic characteristics of the study population which include age, sex, race-ethnicity, county of residence, reason for eligibility and enrollment duration. We used the dental claim files to identify beneficiaries who received dental services, the procedure date and the procedure code for which the provider billed. Procedure codes were matched to the American Dental Association Code on Dental Procedure and Nomenclature (CDT Code). Information about opioid prescribing by dentists and prescription properties such as days' supply, drug quantity dispensed, and the strength of the drug was extracted from the pharmacy claims. The National Drug Codes were used to identify opioid prescriptions that are used for pain management. The Institutional Review Board of the University of Pittsburgh designated this study as human subjects exempt.

4.2.2 Study population

Our study population includes 12-64-year-old PA Medicaid beneficiaries, who are not dual eligible for Medicare and Medicaid and are in a category of assistance with complete Medicaid benefits. For example, beneficiaries in 'select plan for women' which covers family planning services only were excluded. To be included in the sample, subjects should have received a dental procedure between the years 2012-2017, should have not filled an opioid prescription in the 180

days preceding the index dental procedure,(Harbaugh et al., 2018) and should have been continuously enrolled 180 days before and 365 days after the index procedure. Beneficiaries with a diagnosis of opioid use disorder (ICD 9/10 codes can be found in appendix Table 7) and patients with procedures that do not match with a CDT code were excluded from the sample. Cohort building flow diagram is displayed in appendix Figure 4.

In this longitudinal analysis, a subject could contribute multiple observations if s/he satisfied the inclusion criteria. The following age groups were used: 12-15, 16-21, 22-29, 30-39, 40-49, 50-59, 60-64. Those over the age of 65 were excluded because they are dual eligible for Medicare and Medicaid and we could not observe their pharmacy claims, which are covered by Medicare. We included the ages 12-21 as we were interested in opioid prescribing for adolescents and young adults. We further divided this group into 12-15 years and 16-21 years because adolescents age 16-21 are at the age of wisdom tooth extraction and are at higher risk of receiving an initial opioid prescription. In contrast, adults ages 50 and older are more likely to lose teeth due to chronic periodontal problems. In addition, there is a difference in the scope of benefits in PA Medicaid. Children under the age of 21 receive comprehensive dental benefits, whereas adults older than 21 receive limited dental benefits (description of dental benefits can be found in the appendix).

4.2.3 Identifying index dental procedures and classification of dental procedures

We created a classification hierarchy for dental procedures based on the likelihood of pain associated with the procedure. There is no standard approach in the literature to categorize dental procedures according to the likelihood of pain or pain severity. (Baker et al., 2016) (Barasch et al., 2011; McCauley, Leite, Melvin, Fillingim, & Brady, 2016; Tickle, Milsom, Crawford, &

Aggarwal, 2012; Wong et al., 2016) We modified an approach by Hersh and Colleagues that classified dental procedures based on anticipated post-procedural pain into mild pain, moderate pain and severe pain, identifying select dental procedures in each category. (Hersh et al., 2011) We extended this categorization scheme to include all dental procedures. We grouped all procedures into three categories based on the likelihood of pain associated with the procedure: Likelihood of pain low (diagnostic and preventive, restorative, prosthodontic, orthodontic and adjunctive procedures), likelihood of pain moderate (endodontics and periodontics), likelihood of pain high (oralmaxillofacial procedures and D 9110 Palliative (emergency) treatment of dental pain, D9930 Treatment of complications (post-surgical)). The CDT codes are displayed in Table 8 in the appendix. Other approaches to categorizing procedures[11] did not account for a common occurrence in our data which was for multiple procedures (e.g., diagnostic, preventive, restorative) to appear on the same claim.

We used this classification to create a hierarchy to identify index procedures so that each visit was associated with one index procedure. For example, if the procedures performed on the same dental visit were diagnostic, restorative and extraction, we assumed that the extraction procedure is the index procedure that is most likely to require pain management.

We then used the patient's unique identification number and the date of the visit of the index procedure to match it with the pharmacy claims to determine whether an opioid was prescribed within 7 days prior or 3 days after the date of the index procedure, as described by Harbaugh and colleagues (Appendix Figure 5). (Harbaugh et al., 2018) If a patient received multiple opioids within this period, we counted it as one opioid exposure. We use the same classification system to group index procedures into the three categories; likelihood of pain low, likelihood of pain moderate and likelihood of pain high. These categories were mutually exclusive;

if a patient appeared in a higher category of pain that patient was excluded from the lower pain categories.

4.2.4 Outcome

We studied three outcomes of interest. The first outcome was whether a patient filled an initial opioid prescription from a dentist within 7 days before to 3 days after an index dental procedure. The second outcome was short-term opioid use specified as at least one prescription opioid fill 4 to 90 days post-index procedure. Third, we measured long-term opioid use, specified as at least one opioid fill in the 91 to 365 days following the index procedure.(Harbaugh et al., 2018) We did not limit these short- and long-term opioid fills to prescriptions written by dentists.

Key independent variables

The main independent variable for the first analysis was the likelihood of pain associated with the dental procedure, categorized as low, moderate and high. For the second and third analyses, the main independent variable was whether the patient filled an initial opioid prescription by a dentist for the index dental procedure.

4.2.5 Covariates

Based on previous research, we included multiple patient level characteristics in our multivariable models. These included demographic factors such as sex, race/ethnicity (categorized as non-Hispanic white, non-Hispanic Black, Hispanic, Other), Medicaid category of assistance (children and families, disabled and chronically ill, and expansion) and geographic region of

residence based on the regions PA Medicaid uses to contract with Managed Care Organizations (Southeast, Southwest, Lehigh/Capitol, New East and New West).

We include indicators for diagnoses of several comorbid conditions identified in the pre-period that have been previously found to be associated with opioid use.(Cochran et al., 2017) These include preoperative history of musculoskeletal pain, mental disorders, drug or alcohol use disorders (ICD 9/10 codes can be found in appendix Table 9). Because of the contraindication of concurrent prescribing of benzodiazepines and opioids, (Dowell et al., 2016) an indicator for benzodiazepines use was added to the models. In addition, we adjust for year fixed effects to control for time trends. In alternative models, we added an indicator of whether the index dental procedure took place before or after the Commonwealth of Pennsylvania in partnership with the Pennsylvania Dental Association issued guidelines on opioid prescribing for dental procedures in June 2015. These guidelines emphasize the use of NSAID's as the first line of treatment, recommends no more than 7 days of opioid prescribing and requires dentists to register with and use the PDMP. In the alternative models we did not adjust for time trends due to collinearity.

4.2.6 Statistical analysis

We used descriptive statistics (frequencies and percentages, median and inter quantile range) to describe the characteristics of the sample with and without an initial opioid fill associated with an index procedure, stratified by the likelihood of pain associated with the procedure. We also describe the characteristics of the initial opioid prescription among patients who filled an opioid. Specifically, we report the median (inter quantile range) for the days' supply, drug quantity dispensed and Morphine Milligram Equivalent (MME) per day. The days' supply measure has been the focus of dental opioid prescribing guidelines. The CDC guidelines quantify the

prescriptions' MME per day ([drug quantity dispensed * strength of opioid* conversion factor]/days' supply). The guidelines identify prescription with 50 MME per day or higher to be associated with an increased risk of overdose.

We then conducted three analyses among opioid naïve patients using multivariable logistic regression models with random intercept and standard errors (SE) clustered at the patient level to account for patients with multiple visits that met the inclusion criteria. First, we evaluated the risk of filling an initial opioid prescription associated with an index dental procedure where the dependent variable was filling an initial opioid prescription and the main independent variable was the likelihood of pain associated with a procedure, adjusting for all covariates described above.

In our second and third analyses, we assessed the association between filling an initial opioid prescription and the outcomes of short-term (4-90 days) and long-term (91-365 days) opioid use post index dental procedure. We stratified these models based on the likelihood of pain associated with the procedure. The main comparison (independent variable) of interest was between enrollees who filled an initial opioid prescription vs. those who did not. These analyses adjusted for all covariates described above.

To control for the possibility of an opioid prescription in the 7 days prior to the procedure that could be associated with acute dental pain, such as acute pulpitis which requires root canal treatment, we ran a sensitivity analysis where we grouped the category of moderate likelihood of pain with the category of high likelihood of pain associated with the procedure.

To aid in interpretation of all models, we report marginal effects or predicted probabilities using Stata's margins command. All data management and statistical analyses were conducted using [SAS/STAT] software, Version [9.4] of the SAS System for [The University of Pittsburgh]. Copyright © [2017] SAS Institute Inc. and Stata Version16.0 (StataCorp).

4.3 Results

Over the study period there were 1,345,360 index dental procedures (by 912,121 unique enrollees) who satisfied the inclusion criteria (Appendix Figure 4). Most of the procedures (67.6%) had a low likelihood of pain, 1.59% had moderate likelihood of pain, and 30.9% had a high likelihood of pain. Table 4.1 describes the characteristics of the study cohort based on filling an initial opioid prescription and stratified by the likelihood of pain associated with the procedure. Overall, 12.6% of visits were associated with an initial opioid prescription. For the three categories of pain; 2.18% in the low group, 8.1% in the moderate group and 35.64% of the high group received an initial opioid fill. Overall and within each pain category the younger age group (12-15 years) had the lowest rates of initial opioid fill. Non-Hispanic white and blacks' patients had similar opioid filling rates and was higher than Hispanics. Initial opioid fills were higher in the Western region of PA than in other regions. Patients who received an opioid for procedures with high likelihood of pain were more likely to have a diagnosis of comorbid conditions and Benzodiazepine use.

Table 4.2 describes the characteristics of the initial opioid prescriptions for patients who received an opioid for an index dental procedure. The median days' supply was 3 days (IQR 3-5 days), the median quantity dispensed was 18 tablets (IQR 12-20 tablets) and the median MME per day was 30 (20-37.5). The majority of the prescriptions (89%) had an MME per day less than 50. Hydrocodone-Acetaminophen was the most commonly prescribed opioid overall (56%) followed by Acetaminophen-Codiene#3 (26.3%) and Oxycodone-Acetaminophen (12.9%).

The risk of receiving an initial opioid prescription was, perhaps not surprisingly, highest for procedures with a high likelihood of pain (Figure 4.1, the complete output can be found in appendix Table 10). Procedures with high likelihood of pain made up 30.9% of all index dental

procedures and 87.5% of all initial opioid fills were for procedures with a high likelihood of pain. The predicted probability of an initial opioid fill for this group was 31.76 % (95% CI: 31.63-31.90%). Procedures with moderate likelihood of pain made up 1.6% of all index procedures and represented 1% of initial opioid prescribing. The predicted probability of an initial opioid fill for the moderate likelihood group was 8.27% (95% CI: 7.90-8.64%). Procedures with low likelihood of pain made up the majority (67%) of all index procedures and 11.70% of all initial opioid fills. The predicted probability of an initial opioid fill for the low likelihood group was 2.43% (95% CI: 2.40-2.47%) after adjusting for demographic, health status, and regional differences.

Table 4.3 displays the unadjusted numbers (%) of short-term and long-term use of opioids based on initial opioid use. Overall, 46,476 (3.5%) of index dental visits were followed by a prescription opioid fill in the 4-90 days post-procedure. Of those with an initial opioid fill, 18.37% and only 1.3% of those without an initial opioid used opioids 4-90 days post procedure. In the 91-365 days post-procedure, 35,616 (2.7%) dental visits were followed by a prescription opioid fill, 9.14% of patients with an initial opioid and 1.71% of patients without an initial opioid used opioids in the 91-365 days post-procedure. Based on the categories of pain, 40.0% of those with an initial opioid fill and only 0.90% of patients without an initial opioid fill for low pain procedures used opioids in the short-term. Among patients who received an initial opioid for moderate pain procedures, 21.5% used opioids in the short term while 1.5% of those without an initial opioid were opioid users in the same time period. In the high pain category, 15.44% of patients with an initial opioid fill and 2.56% of those without an initial opioid fill, used opioids in the 4-90 days post procedure.

The predicted probabilities of subsequent short-term and long-term opioid use stratified by likelihood of pain associated with the procedure are displayed in Tables 4.4 and 4.5 respectively.

The risk of short-term opioid use was higher for patients with an initial opioid prescription compared to patients who did not receive an initial opioid in each pain category. The predicted probabilities for those with an initial opioid fill vs those without an initial opioid fill in the low likelihood of pain was 25.03% (95% CI: 24.47-25.60) vs 0.93% (95% CI: 0.91-0.96), 16.60% (95% CI: 14.85-18.36) vs 1.59% (95% CI: 1.41-1.78) for the moderate likelihood of pain and 13.51% (95% CI: 13.34-13.67) vs 2.90% (95% CI: 2.84- 2.97) for the high likelihood of pain group. Interestingly, the low likelihood of pain group had the highest absolute risk of short- term use compared to their counterparts receiving an opioid for moderate and high likelihood of pain procedures (25.03% vs 16.60% and 13.51% respectively).

The predicted probabilities for long-term use of opioids followed a similar pattern to short term use where the risk of long-term use was higher among those who received an initial opioid associated with an index dental procedure vs those who did not in all three groups of likelihood of pain; 8.77% (95% CI: 8.46-9.10) vs 1.34% (95% CI: 1.31-1.36) for the low group, 8.37% (95% CI :7.17-9.56) vs 1.88% (95% CI: 1.68-2.08) for the moderate group and 6.82% (95% CI: 6.70-6.94) vs 3.47% (95% CI:3.40--3.54) for the high likelihood of pain group. The absolute risk for long-term use was lowest for the group with high likelihood of pain

Table 4.6 displays the predicted probabilities of initial, short- and long- term use of opioids pre and post publication of the PA guidelines on the use of opioids in the dental practice. The risk of receiving an initial opioid was lower in the post guideline period (13.89, 95% CI: 13.82-13.96 vs 11.40, 95% CI: 11.33-11.48). The risk of short-term and long-term use for all three categories of likelihood of pain was also lower in the post guideline period, the biggest decrease was among the high likelihood of pain (predicted probabilities short-term; pre 8.50% 95% CI: 8.38-8.61%,

post 5.60%, 95% CI: 5.50-5.71%, long-term; pre 6.34%, 95% CI: 6.23-6.45, post 3.01% , 95% CI: 2.92-3.09).

To test for the possibility of misclassification of pain, we run a sensitivity analysis for the risk of short-term opioid use where we combined the moderate and high likelihood of pain categories into one category. The results are displayed in appendix Table 11 There were no substantial changes in the predicted probabilities and the conclusion remains unchanged.

4.4 Discussion

In this study, we used PA Medicaid claims data from 2012-2017 to evaluate the risk of filling an initial opioid prescription and the subsequent short term (4-90 days) and long term (91-365 days) opioid use following an index dental procedure among opioid naïve patients ages 12-64 years. As we hypothesized, the risk of filling an initial opioid prescription was highest among patients who had a procedure with high likelihood of pain. This is in agreement with other studies that have found that the majority of opioid prescribing by dentists was for surgical dental procedures.(Gupta et al., 2018b; Obadan-Udoh et al., 2019; Steinmetz et al., 2017)

Similar to the findings of persistent opioid use among opioid naïve patients after third molar extraction,(Harbaugh et al., 2018) we found that the risk of subsequent opioid use was higher among patients with an initial opioid prescription across all procedure types regardless of the likelihood of pain. However, contrary to our second hypothesis, we found that patients who received an initial opioid prescription for procedures with a low likelihood of pain had not only the highest relative risk compared to those not receiving opioids initially but also compared to their counterparts filling opioid prescriptions after moderate and high risk of pain procedures. There

are a number of possible explanations for this finding. First, although we adjusted for a variety of covariates that are associated with opioid use, other unmeasured confounders could explain this finding. Second, because claims data do not include diagnosis codes, we cannot verify whether the reason for the initial opioid was a patient presenting at the dental clinic with acute pain, who underwent a diagnostic procedure, was prescribed an opioid to manage pain, and was then rescheduled for definitive treatment but did not receive that treatment, and therefore remained in pain. Another explanation is that it is well known that Medicaid beneficiaries have difficulties accessing dental care.(K. Nasseh & Vujicic, 2014; Vujicic & Nasseh, 2014) Although we could not verify with our data, it is possible that these Medicaid patients have limited dental benefits and were unable to get definitive treatment because it was not covered or they were unable to find a provider who accepts their insurance.

The majority of opioid prescribing in our study (89%) was less than 50 MME per day, which is below the threshold associated with increased risk of overdose based on the CDC guidelines. There were still 11% of prescriptions that were at or above 50 MME mostly for procedures with high likelihood of pain, which would equal to 10 or more tablets of 5 mg of hydrocodone a day. The current guidelines for opioid prescribing by dentists limits opioid prescribing to a certain number of days, 7 by the ADA, but does not specify the drug quantity. Professional societies may consider providing more specific guidance to dentists and oral surgeons on the quantity not just the days' supply of opioids prescribed to reduce risk of adverse events. For example, guidelines developed by the Royal College of Dental Surgeons of Ontario specify the number of pills for each commonly prescribed opioid along with the days' supply limit. Prescribing narcotics also requires a special prescription pad, therefore the majority of prescriptions by

Canadian dentists are for the much less potent Codeine combinations and only 1% of prescriptions are Oxycodone combinations.(Falk, Friesen, Magnusson, Schroth, & Bugden, 2019)

Although much of the focus of health system interventions has been on opioid prescribing for chronic pain the risk of continued long-term use of opioids after prescribing for acute pain episodes is not trivial, especially among the youth. Findings from Monitoring the Future survey found that high school children who had no history of illicit drug use and received a legitimate opioid prescription were more likely to abuse opioids in adulthood(Miech, Johnston, O'Malley, Keyes, & Heard, 2015). Although another study among privately insured patients found an increasing trend of opioid prescribing among 11-18 year old's, (Gupta et al., 2018b) we found that the youngest age group in our Medicaid sample 12-15 had a very low risk of receiving an initial opioid prescription. However, the age group of older adolescents (16-21) had a higher risk of both initial and subsequent use of opioids, and the risk increased with age. As opioids are not optimal in managing dental pain and carry the risk of misuse, abuse or diversion, especially among adolescents, NSAID's should be used as the first line for management of dental pain as recommended by guidelines.

Initial opioid prescribing and subsequent opioid use seems to have decreased after the publication of the PA guidelines, our study design is not causal, therefore we are unable to differentiate whether this is due to the effectiveness of the guidelines specifically or the effect of the overall downward trend of opioid prescribing. Future studies should evaluate the efficacy of guidelines and other efforts to curb over-prescribing of opioids in dentistry such as the ADA policy on opioids, PDMP programs and opioid education in dental school curricula.

4.5 Limitations

Our study has several limitations. A limitation inherent in all dental claims is the lack of diagnosis codes, therefore we can only observe the procedure that was performed but we cannot ascertain why it was performed. In addition, the data do not capture cash payments for opioids. The claims report opioid fills however we cannot determine if the patient used the prescription nor can we observe opioid prescriptions written but not filled. Furthermore, our method of extending an existing classification system to incorporate all dental procedures based on the likelihood of pain associated with the procedure requires further validation of procedures under each pain category. However, we ran a sensitivity analysis reclassifying dental procedures into two pain categories (low and high) which did not alter the results. Finally, as our analysis is based on PA Medicaid claims, our results might not be generalizable to other states or other payers. However, our analysis is based on a large sample size with 6 years of longitudinal data, that spans the period before and after the publication of opioid guidelines and answers essential and timely clinical and policy relevant questions about factors associated with initial and persistent opioid use after dental procedures in the Medicaid population.

4.6 Conclusion

Filling an initial opioid prescription for a dental procedure may put patients at risk for short- and long-term opioid use especially for procedures with low likelihood of pain. Therefore, more attention should be paid to reducing opioid prescribing for common dental procedures with low pain risk. By using NSAID's as the first line of treatment for dental pain management and

educating patients about the potential harmful side effects and consequences of opioid prescribing, dentists can play an important role in the primary prevention of opioid related adverse events.

4.7 Tables/Figures

Table 4-1 Characteristics of the Study Sample

Total			Likelihood of pain associated with the procedure					
Number of index dental procedures N=1,345,360 Unique patients= 912,121			Likelihood of pain low N=908,860 (67.55%) Unique patients =544,914		Likelihood of pain moderate N=21,384 (1.59%) Unique patients =19,301		Likelihood of pain high N=415,116 (30.86%) Unique patients =347,906	
	Received an opioid 169,510 (12.6%)	Did not receive an opioid 1,175,850 (87.4%)	Received an opioid N=19,847 (2.18%)	Did not receive an opioid N=889,013 (97.82%)	Received an opioid N=1,724 (8.1%)	Did not receive an opioid N=19,660 (91.9%)	Received an opioid N=147,939 (35.64%)	Did not receive an opioid N=267,177 (64.36%)
Age Category								
12-15	8,477 (2.13)	390,315 (97.87)	449 (0.14)	319,687 (99.86)	261 (4.74)	1,935 (89.46)	7,767 (10.62)	65,385 (89.38)
16-21	37,960 (12.27)	271,437 (87.73)	2,321 (1.04)	220,518 (98.96)	1,016 (10.66)	8,513 (89.34)	34,623 (44.95)	42,406 (55.05)
22-29	39,279 (21.09)	146,927 (78.91)	5,648 (5.11)	104,800 (94.89)	228 (10.54)	1,935 (89.46)	33,403 (45.39)	40,192 (54.61)
30-39	37,343 (20.33)	146,352 (79.67)	5,935 (5.54)	101,251 (94.46)	107 (6.39)	1,568 (93.61)	31,301 (41.83)	43,533 (58.17)
40-49	22,037 (18.33)	98,181 (81.67)	3,100 (4.48)	66,130 (95.52)	57 (4.68)	1,162 (95.32)	18,880 (37.94)	30,889 (62.06)
50-59	18,585 (17.71)	86,347 (82.29)	1,907 (3.44)	53,464 (96.56)	39 (4.10)	913 (95.90)	16,639 (34.23)	31,970 (65.77)
60-64	5,829 (13.84)	36,291 (86.16)	487 (2.06)	23,163 (97.94)	16 (4.68)	326 (95.32)	5,326 (29.38)	12,802 (70.62)

Table 4-1 Continued

			Likelihood of pain low		Likelihood of pain moderate		Likelihood of pain high	
Gender								
Female	110,998 (14.05)	679,205 (85.95)	13,479 (2.6)	504,780 (97.4)	966 (8.84)	9,967 (91.16)	96,553 (36.99)	164,458 (63.01)
Male	58,512 (10.54)	496,645 (89.46)	6,368 (1.63)	384,233 (98.36)	758 (7.25)	9,693 (92.75)	51,386 (33.33)	102,719 (66.67)
Race ethnicity								
Non-Hispanic white	92,050 (13.88)	571,002 (86.12)	9,584 (2.20)	427,040 (97.80)	1,025 (10.56)	8,685 (89.44)	81,441 (37.58)	135,277 (62.42)
Non-Hispanic black	51,350 (13.36)	333,131 (86.64)	7,546 (2.91)	252,020 (97.09)	489 (7.15)	6,351 (92.85)	43,315 (36.68)	74,760 (63.32)
Hispanic	18,955 (9.04)	190,798 (90.96)					16,810 (29.78)	
Other	7,156 (8.12)	80,919 (91.88)	1,991 (1.33)	147,971 (98.67)	154 (4.61)	3,187 (95.39)	6,373 (26.7)	39,640 (70.22)
			726 (1.16)	61,982 (98.84)	56 (3.75)	1,437 (96.25)		17,500 (73.3)
Region								
Southeast	58,248 (11.06)	468,388 (88.94)	8,432 (2.37)	346,788 (97.63)	472 (4.91)	9,135 (95.09)	49,344 (30.5)	112,465 (69.5)
	39,378 (16.65)	197,156 (83.35)						46,835 (57.45)
Southwest	30,767 (11.03)	248,077 (88.97)	4,049 (2.67)	147,415 (97.33)	635 (17.93)	2,906 (82.07)	34,694(42.55)	48,480 (64.34)
Lehigh/capitol	18,372 (11.28)		3,648 (1.83)	195,563 (98.17)	251 (5.86)	4,034 (94.14)	26,868 (35.66)	31,288 (65.68)
	22,745 (16.19)	144,499 (88.72)						
		117,734 (83.81)					16,348 (34.32)	28,109 (57.61)
New East			1,924 (1.69)	111,593 (98.31)	100 (5.83)	1,614 (94.17)	20,685 (42.39)	
New West			1,794 (2.01)	87,654 (97.99)	266 (11.89)	1,971 (88.11)		

Table 4-1 Continued

			Likelihood of pain low		Likelihood of pain moderate		Likelihood of pain high	
Category of assistance								
Children and families	92,603 (11.07)	744,110 (88.93)	10,972 (1.84)	584,887 (98.16)	1,316 (9.26)	12,895 (90.74)	80,315 (35.44)	146,318 (64.56)
Disabled chronically	50,929 (13.73)	320,002 (86.27)	5,765 (2.45)	229,669 (97.55)	392 (6.03)	6,112 (93.97)	44,772 (34.71)	84,221 (65.29)
Expansion	49,438 (17.61)	231,371 (82.39)	6,063 (3.61)	161,785 (96.39)	194 (6.94)	2,601 (93.06)	43,181 (39.2)	66,985 (60.8)
Benzodiazepine use	15,965 (18.94)	68,325 (81.06)	2,235 (4.64)	45,901 (95.36)	81 (5.39)	1,423 (94.61)	13,649 (39.39)	21,001 (60.61)
Benzodiazepine use, no Comorbidities	153,545 (12.18)	1,107,525 (87.82)	17,612 (2.05)	843,112 (97.95)	1,643 (8.26)	18,237 (91.74)	134,290 (35.30)	246,176 (64.7)
Pain conditions, yes	58,877 (15.24)	327,360 (84.76)	6,991(2.88)	235,821 (97.12)	517 (9.17)	5,118 (90.83)	51,369 (37.28)	86,421 (62.72)
Pain conditions, no	110,633 (11.53)	848,490 (88.47)	12,856 (1.93)	653,192 (98.07)	1,207 (7.66)	14,542 (92.34)	96,570 (34.82)	180,756 (65.18)
Mental health conditions	26,596 (15.21)	148,271 (84.79)	3,217 (2.89)	107,964 (97.11)	211 (9.11)	2,105 (90.89)	23,168 (37.75)	38,202 (62.25)
Mental conditions, no	142,914 (12.21)	1,027,579 (87.79)	16,630 (2.08)	781,049 (97.92)	1,513 (7.93)	17,555 (92.07)	124,771 (35.27)	228,975 (64.73)
Alcohol use disorder (AUD)	3,230 (20.25)	12,724 (79.75)	475 (5.46)	8,224 (94.54)	14(9.21)	138 (90.79)	2,741 (38.59)	4,362 (61.41)
AUD, No	166,280 (12.51)	1,163,126 (87.49)	19,372 (2.15)	880,789 (97.85)	1,710 (8.05)	19,522 (91.95)	145,198 (35.59)	262,815 (64.41)

Table 4-1 Continued

			Likelihood of pain low		Likelihood of pain moderate		Likelihood of pain high	Likelihood of pain low
Substance use disorder (SUD)	4,905(18.62)	21,960 (81.74)	753 (4.89)	14,646 (95.11)	44 (10.14)	390 (89.86)	4,108 (37.24)	6,924 (62.76)
SUD, No	164,605 (12.48)	1,153,890 (87.52)	19,094 (2.14)	874,367 (97.86)	1,680 (8.02)	19,270 (91.98)	143,831 (35.59)	260,253 (64.41)
Any history of AUD/SUD	18,054 (22.00)	63,996 (78.00)	2,543 (5.74)	41,792 (94.26)	121 (12.55)	843 (87.45)	15,390 (41.88)	21,361 (58.12)
Any history of AUD/SUD, No	151, 456 (11.99)	1,111,854 (88.01)	17,304 (2.00)	847,221 (98.00)	1,603 (7.85)	18,817 (92.15)	132,549 (35.03)	245,816 (64.97)

SUD does not include opioid use disorders (OUD).

Table 4-2 Characteristics of the Initial Opioid Prescription for Patients who Received an Opioid Associated with an Index Dental Procedure

	Total N=169,510	Likelihood of pain low N=19,847	Likelihood of pain moderate N=1,724	Likelihood of pain high N=147,939
Days' Supply	3 (3-5)	3 (2-5)	3 (2-4)	4 (3-5)
Drug quantity dispensed	18 (12-20)	15 (12-20)	12 (10-16)	20 (12-20)
MME* per day	30 (20-37.5)	25 (18-30)	22.5 (18-30)	30 (20-37.5)
MME per day category				
More than 0 to less than 50	150,905 (89.02)	18,852 (94.99)	1,661 (96.35)	130,392 (88.14)
50 to less than 90	17,620 (10.39)	924 (4.66)	57 (3.31)	16,639 (11.25)
90 and more	985 (0.58)	71 (0.36)	6 (0.35)	908 (0.61)
Most commonly prescribed opioid	Hydrocodone-Acetaminophen (55.94)	Acetaminophen-Codeine#3 (48.09)	Acetaminophen-Codeine#3 (46.11)	Hydrocodone-Acetaminophen (58.7)
	Acetaminophen-Codeine#3 (26.31)	Hydrocodone-Acetaminophen (36.48)	Hydrocodone-Acetaminophen (42.92)	Acetaminophen-Codeine#3 (23.16)
	Oxycodone-Acetaminophen (12.93)	Oxycodone-Acetaminophen (9.15)	Oxycodone-Acetaminophen (5.97)	Oxycodone-Acetaminophen (13.52)

Data are presented as median (inter quantile range) or number (percent). *MME per day= Morphine Milligram Equivalent per day= (drug quantity dispensed * final strength per unit * conversion factor)/days' supply.

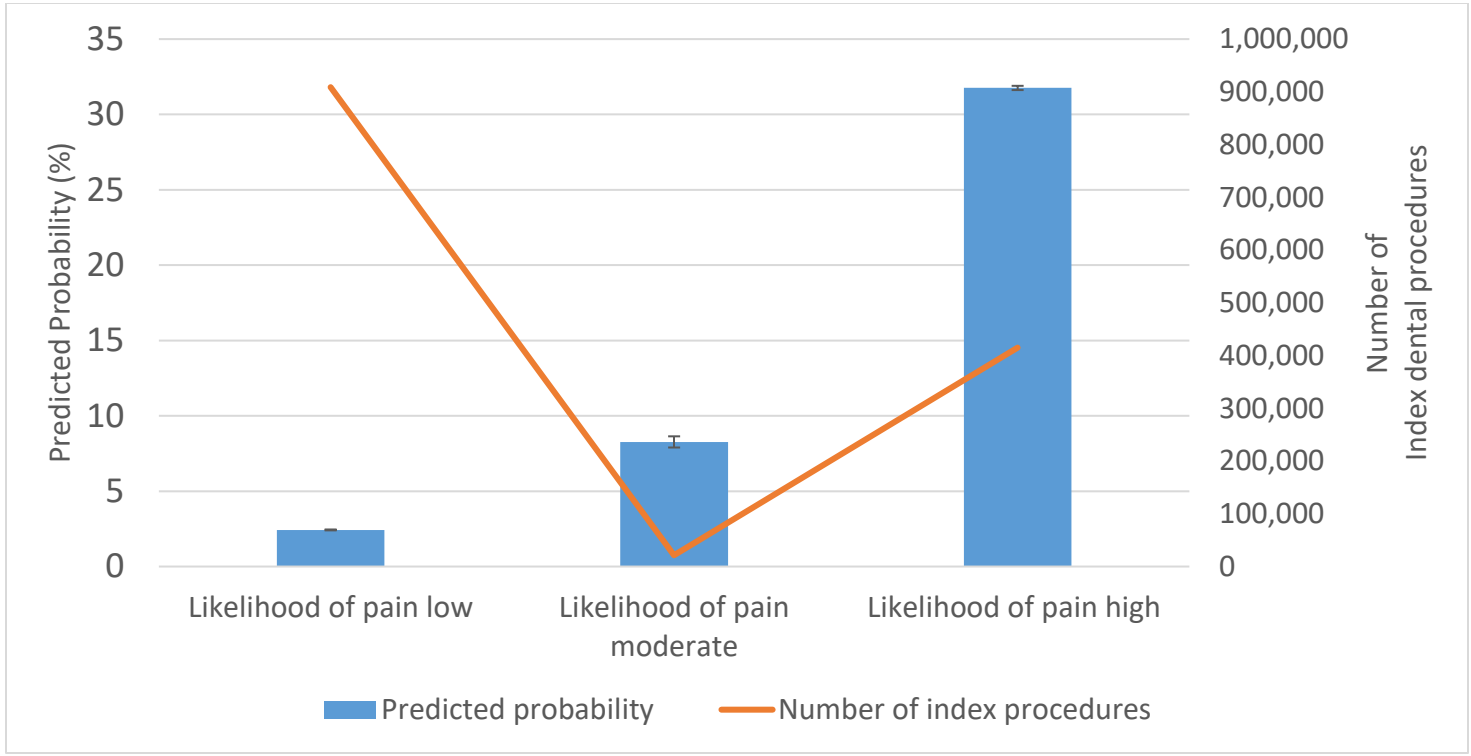


Figure 4-1 Predicted Probabilities of Initial Opiod Fill among PA Medicaid Beneficiaries 2010-2017Based on Likelihood of Pain Associated with the Procedure

Predicted probabilities were obtained from a multivariable logistic regression model with random intercept, SE were clustered at the patient level. The model adjusted for patient's characteristics including age category, gender, race/ethnicity, category of assistance, region, pain, mental conditions, alcohol and substance use disorders, benzodiazepine use and an indicator for post PA guidelines (complete output can be found in Table 10 in the appendix).

Table 4-3 Unadjusted Number (proportion) of Short-term (4-90 days) and Long-term (91-365 days) Opioid Fills in the Post Period Based on Initial Opioid Fill and Likelihood of Pain

Likelihood of pain			Short-term use n (%)		Long-term use n (%)		
			No	Yes	No	Yes	Total
Total	Initial opioid fill n (%)	No	1,160,521 (98.70)	15,329 (1.30)	1,155,722 (98.29)	20,128 (1.71)	1,175,850 (87.40)
		Yes	138,363 (81.63)	31,147 (18.37)	154,022 (90.86)	15,488 (9.14)	169,510 (12.60)
		Total	1,298,884 (96.55)	46,476 (3.45)	1,309,744 (97.35)	35,616 (2.65)	1,345,360 (100)
Low	Initial opioid fill n (%)	No	881,051 (99.10)	7,962 (0.90)	877,631 (98.15)	165,65 (1.85)	889,013 (97.82)
		Yes	11,908 (60.00)	7,939 (40.00)	11,382 (77.62)	3,282 (22.38)	19,847 (2.18)
		Total	892,959 (87.4)	15,901 (12.6)	889,013 (97.82)	19,847 (2.18)	908,860 (100)
Moderate	Initial opioid fill n (%)	No	19,373 (98.54)	287 (1.50)	19,309 (98.21)	351 (1.79)	19,660 (91.94)
		Yes	1,353 (78.50)	371 (21.52)	1,517 (88.00)	207 (12.00)	1,724 (8.06)
		Total	20,726 (96.92)	658 (3.08)	20,826 (97.39)	558 (2.61)	21,384 (100)
			No	Yes	No	Yes	Total
High	Initial opioid fill	No	260,097 (97.35)	7080 (2.65)	258,782 (96.86)	8395 (3.14)	267,177 (64.36)

Table 4-3 Continued

Likelihood of pain		Short-term use n (%)		Long-term use n (%)		
n (%)						
	Yes	125,102 (84.56)	22,837 (15.44)	135,940 (91.89)	11,999 (8.11)	147,939 (35.64)
	Total	385,199 (92.79)	29,917 (7.07)	394,722 (95.09)	20,394 (4.91)	415,116 (100)

Table 4-4 Predicted Probabilities for Subsequent Short-term Opiod Use (4-90 days Post Index Procedure) Stratified by Likelihood of Pain Associaed with the Procedure

Variable	Likelihood of pain low Predicted probability [95% CI]	Likelihood of pain moderate Predicted probability [95% CI]	Likelihood of pain high Predicted probability [95% CI]
Initial opioid fill, No	0.93 [0.91-0.96]	1.59 [1.41-1.78]	2.90 [2.84- 2.97]
Initial opioid fill, Yes	25.03 [24.47-25.60]	16.60 [14.85-18.36]	13.51 [13.34-13.67]
Male	1.76 [1.72-1.81]	2.85 [2.53-3.18]	7.24 [7.10-7.38]
Female	1.76 [1.73-1.79]	3.34 [3.03-3.66]	7.17 [7.08-7.27]
Age in years, categories			
12-15	0.30 [0.28-0.33]	1.6 [1.26-1.97]	1.94 [1.81-2.08]
16-21	1.49 [1.43-1.54]	3.08 [2.78-3.40]	4.68 [4.54-4.82]
22-29	2.54 [2.46-2.63]	4.01[3.22-4.80]	8.18 [7.99-8.36]
30-39	2.67 [2.58-2.76]	4.95 [3.84-6.05]	9.35 [9.15-9.55]
40-49	2.44 [2.33-2.55]	4.02 [2.80-5.24]	9.20 [8.95-9.44]
50-59	2.38 [2.26-2.50]	5.05 [3.42-6.69]	8.90 [8.63-9.17]
60-64	2.05 [1.87-2.22]	4.84 [2.30-7.37]	7.76 [7.35-8.18]

Table 4-4 Continued

Variable	Likelihood of pain low Predicted probability [95% CI]	Likelihood of pain moderate Predicted probability [95% CI]	Likelihood of pain high Predicted probability [95% CI]
Race and ethnicity			
White non- Hispanic	1.93 [1.90-1.97]	3.48 [3.13-3.82]	7.54 [7.43-7.65]
Black non-Hispanic	1.74 [1.69-1.78]	2.86 [2.45-3.28]	7.29 [7.15-7.44]
Hispanic	1.33 [1.27-1.40]	2.59 [1.98-3.20]	5.93 [5.71-6.15]
Other	1.31 [1.22-1.41]	2.18 [1.38-2.99]	5.51 [5.19-5.83]
Category of assistance			
Children and families no	1.76 [1.71-1.82]	3.20 [2.50-3.90]	7.12 [6.97-7.27]
Children and families yes	1.76 [1.72-1.81]	3.09 [2.74-3.43]	7.27 [7.12-7.42]
Disabled/ Chronically ill no	1.81 [1.77-1.84]	3.44 [3.04-3.84]	7.25 [7.13-7.38]
Disabled/ Chronically ill yes	1.67 [1.61-1.74]	2.47 [1.92-3.03]	7.09 [6.89-7.28]
Expansion no	1.72 [1.67-1.74]	3.12 [2.87-3.38]	7.08 [6.97-7.18]
Expansion yes	1.93 [1.86-2.00]	3.10 [2.30-3.89]	7.50 [7.29-7.71]

Table 4-4 Continued

Variable	Likelihood of pain low Predicted probability [95% CI]	Likelihood of pain moderate Predicted probability [95% CI]	Likelihood of pain high Predicted probability [95% CI]
Region			
South east	1.50 [1.46-1.54]	2.55 [2.21-2.90]	7.05 [6.92-7.19]
South west	2.30 [2.23-2.37]	3.88 [3.32-4.44]	8.98 [8.80-9.16]
Lehigh/ Capitol	1.72 [1.66-1.77]	2.70 [2.18-3.21]	5.73 [5.56-5.90]
New east	1.65 [1.58-1.72]	3.28 [2.44-4.12]	6.00 [5.78-6.21]
New west	2.01 [1.92-2.09]	4.00 [3.24-4.75]	7.43 [7.21-7.65]
Musculoskeletal pain conditions no	1.71 [1.68-1.74]	3.01 [2.75-3.28]	7.11[7.01-7.20]
Musculoskeletal pain conditions yes	1.87 [1.83-1.92]	3.37 [2.94-3.80]	7.35 [7.22-7.48]
Mental conditions no	1.76 [1.73-1.79]	3.01 [2.75-3.28]	7.13 [7.05-7.22]
Mental conditions yes	1.79 [1.72-1.85]	3.326 [2.61-3.91]	7.50 [7.30-7.69]
Alcohol use disorder (AUD) no	1.76 [1.74-1.79]	3.11 [2.88-3.33]	7.18 [7.01-7.25]
Alcohol use disorder (AUD) yes	1.72 [1.54-1.90]	4.39 [1.73-7.04]	8.01 [7.45-8.57]
Substance use disorder (SUD) no	1.76 [1.74-1.79]	3.09 [2.87-3.32]	7.18 [7.10-7.26]
Substance use disorder (SUD) yes	1.75 [1.59-1.90]	4.11 [2.21-6.01]	7.64 [7.16-8.11]
Any history of AUD/SUD no	1.72 [1.70-1.75]	3.08 [2.84-3.32]	7.10 [7.02-7.18]
Any history of AUD/SUD yes	2.17 [2.06-2.28]	3.66 [2.48-4.83]	7.93 [7.66-8.21]
Benzodiazepine use no	1.76 [1.73-1.79]	3.09 [2.86-3.32]	7.09 [7.01-7.17]
Benzodiazepine use yes	1.80 [1.72-1.88]	3.50 [2.56-4.45]	8.06 [7.80-8.32]

Predicted probabilities were derived from multivariable logistic regression models with random intercept, and SE clustered at the patient level. All models controlled for year fixed effects. Comorbidities (pain, mental conditions, AUD, SUD, any AUD/SUD) and Benzodiazepine use were assessed in the pre-period.

Table 4-5 Predicted Probabilities for Subsequent Long-term Use of Opioids (91-365 days Post Index Procedure) Stratified by Likelihood of Pain Associated with the Procedure

Variable	Likelihood of pain low Predicted probability [95% CI]	Likelihood of pain moderate Predicted probability [95% CI]	Likelihood of pain high Predicted probability [95% CI]
Initial opioid fill, No	1.34 [1.31-1.36]	1.88 [1.68-2.08]	3.47 [3.40-3.54]
Initial opioid fill, Yes	8.77 [8.46-9.10]	8.37 [7.17-9.56]	6.82 [6.70-6.94]
Gender			
Male	1.48 [1.44-1.53]	2.35 [0.21-2.66]	4.40 [4.29-4.51]
Female	1.69 [1.66-1.72]	2.81 [2.51-3.11]	5.07 [5.00-5.16]
Age in years, categories			
12-15	0.27 [0.25-0.30]	1.33 [1.00-3.03]	1.62 [1.51-1.72]
16-21	1.58 [1.53-1.64]	2.73 [2.42-3.03]	3.40 [3.27-3.52]
22-29	2.71 [2.61-2.81]	3.23 [2.50-3.95]	6.32 [6.14-6.49]
30-39	2.60 [2.50-2.69]	3.25 [2.34-4.16]	6.25 [6.08-6.42]
40-49	2.34 [2.22-2.45]	3.23 [2.11-4.34]	5.78 [5.58-5.99]
50-59	2.31 [2.17-2.44]	3.76 [2.30-5.23]	5.81 [5.59-5.99]
60-64	2.01 [1.83-2.20]	5.21 [2.50-7.92]	4.89 [4.56-5.22]

Table 4-5 continued

Variable	Likelihood of pain low Predicted probability [95% CI]	Likelihood of pain moderate Predicted probability [95% CI]	Likelihood of pain high Predicted probability [95% CI]
Race and ethnicity			
White non- Hispanic	1.73 [1.69-1.77]	2.93 [2.60-3.28]	4.94 [4.84-5.03]
Black non-Hispanic	1.72 [1.67-1.78]	2.39 [2.01-2.77]	5.23 [5.10-5.37]
Hispanic	1.19 [1.13-1.25]	2.28 [1.72-2.84]	3.95 [3.77-4.13]
Other	1.18 [1.10-1.29]	1.68 [1.00-2.39]	3.57 [3.31-3.83]
Category of assistance			
Children and families, no	1.55 [1.50-1.61]	2.04 [1.53-2.54]	4.85 [4.72-5.00]
Children and families, yes	1.67 [1.62-1.71]	2.90 [2.51-3.28]	4.84 [4.71-4.97]
Disabled/ Chronically ill, no	1.66 [1.61- 1.70]	2.62 [2.31-2.93]	4.86 [4.76-4.98]
Disabled/ Chronically ill, yes	1.53 [1.47-1.60]	2.57 [2.92-3.21]	4.81 [4.65-4.98]
Expansion, no	1.56 [1.53-1.59]	2.48 [2.27-2.70]	4.90 [4.81-5.00]
Expansion, Yes	1.83 [1.74-1.91]	3.99 [2.86-5.12]	4.67 [4.49-4.845
Region			
South east	1.35 [1.31-1.39]	2.53 [2.18-2.88]	4.68 [4.57-4.79]
South west	1.97 [1.90-2.04]	2.98 [2.47-3.49]	5.90 [5.74-6.06]
Lehigh/ Capitol	1.63 [1.57-1.69]	2.49 [1.98-2.99]	3.93 [3.78-4.08]
New east	1.70 [1.63 -1.78]	2.54 [1.79-3.28]	4.50 [4.30-4.68]
New west	1.88 [1.79- 1.98]	2.40 [1.81-2.99]	5.10 [4.90-5.29]

Table 4-5 continued

Variable	Likelihood of pain low Predicted probability [95% CI]	Likelihood of pain moderate Predicted probability [95% CI]	Likelihood of pain high Predicted probability [95% CI]
Comorbidities			
Musculoskeletal pain conditions, no	1.50 [1.47-1.53]	2.44 [2.20-2.68]	4.70 [4.62-4.78]
Musculoskeletal pain conditions, yes	1.86 [1.81-1.90]	2.98 [2.57-3.40]	5.10 [4.99-5.21]
Mental conditions, no	1.61 [1.58-1.64]	2.57 [2.34 -2.79]	4.82 [4.75-4.89]
Mental conditions, yes	1.65 [15.81-1.72]	2.86 [2.22-3.51]	4.97 [4.80-5.14]
Alcohol use disorder (AUD), no	16.12 [1.59- 1.64]	2.60 [2.39-2.81]	4.86 [4.79-4.93]
Alcohol use disorder (AUD), yes	16.46 [1.45-1.85]	3.06 [0.98-5.14]	4.34 [3.92-4.77]
Substance use disorder (SUD), no	1.62 [1.59-1.64]	2.62 [2.40-2.83]	4.83 [4.77-4.90]
Substance use disorder (SUD), yes	1.65 [1.48-1.82]	2.28 [1.03-3.52]	5.33 [4.92-5.75]
Any history of AUD/SUD, no	1.58 [1.55-1.61]	2.51 [2.30-2.73]	4.79 [4.72-4.86]
Any history of AUD/SUD, yes	2.065 [1.94-2.19]	4.05 [2.70- 5.40]	5.31 [5.07-5.56]
Benzodiazepine use, No	1.60 [1.56-1.62]	2.622 [2.40-2.84]	4.75 [4.68-4.82]
Benzodiazepine use, Yes	1.87 [1.77-1.96]	2.38 [1.59-3.17]	5.67 [5.44-5.89]

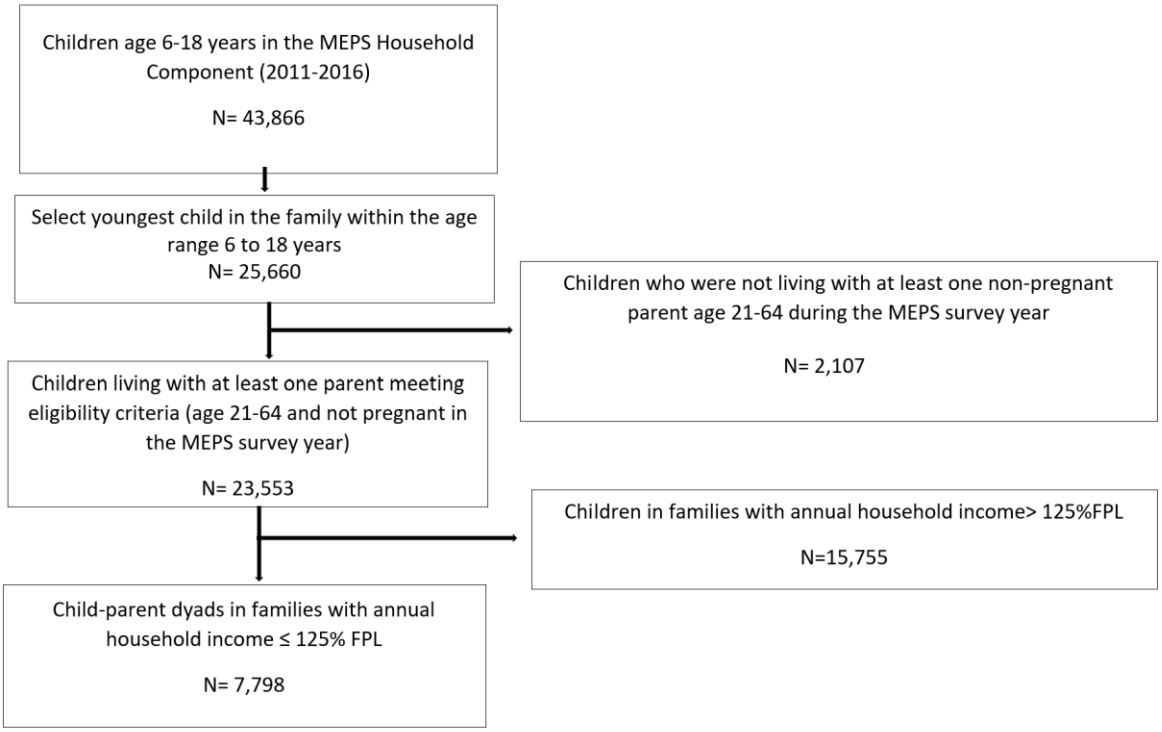
Predicted probabilities were derived from multivariable logistic regression models with random intercept, and SE clustered at the patient level. All models controlled for year fixed effects. Comorbidities (pain, mental conditions, AUD, SUD, any AUD/SUD) and Benzodiazepine use were assessed in the pre-period.

Table 4-6 Predicted Probabilities of Initial, Short-term and Long-term Use of Opioids Pre and Post PA Guidelines on the Use of Opioids in the Dental Practice (published June 2015)

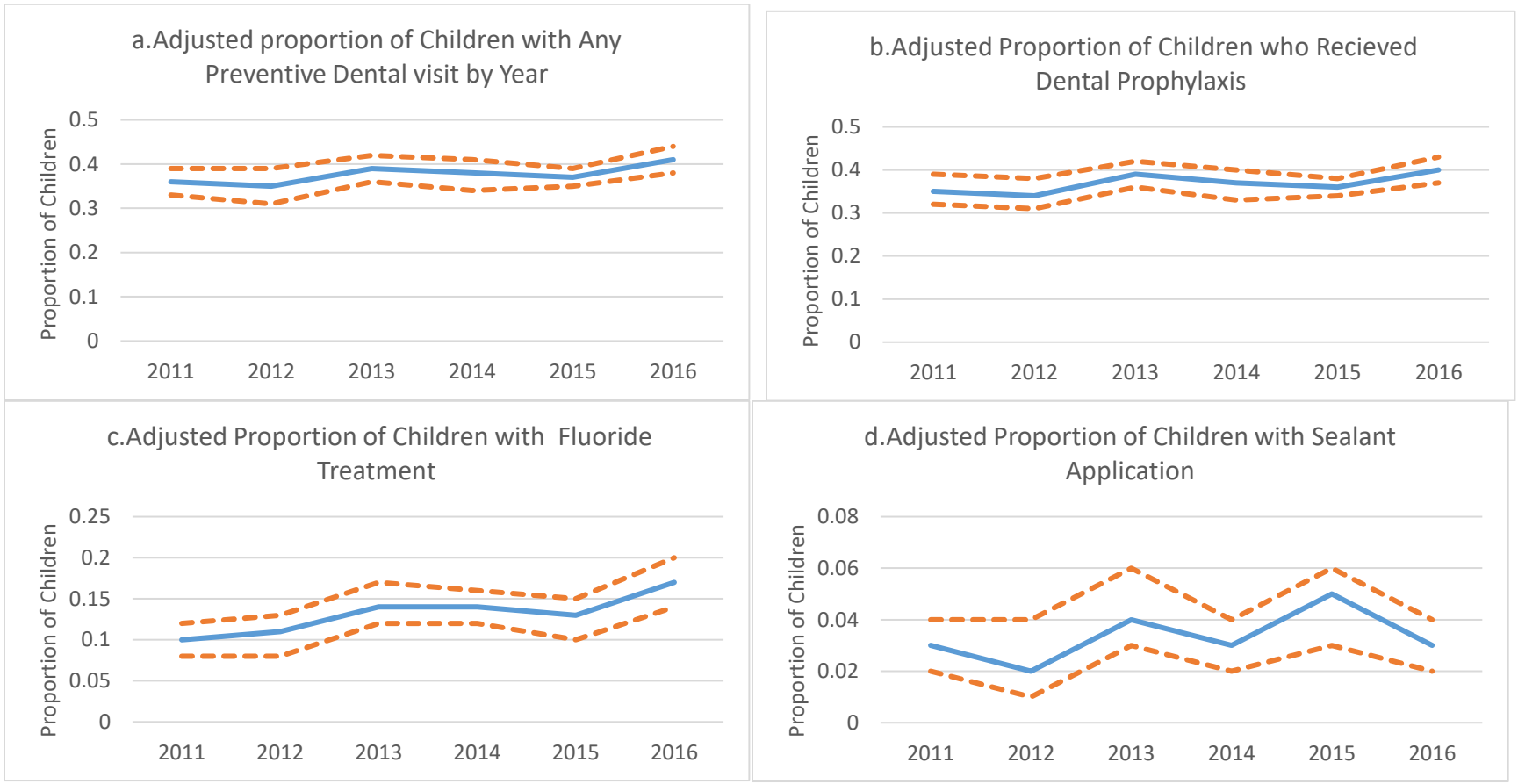
PA Guideline	Initial opioid use	Likelihood of pain low		Likelihood of pain moderate		Likelihood of pain high	
		Short term use	Long term use	Short term use	Long term use	Short term use	Long term use
Pre	13.89 [13.82-13.96]	2.04 [2.01-2.08]	2.13 [2.09-2.18]	3.39 [3.10-3.68]	3.38 [3.06-3.69]	8.50 [8.38-8.61]	6.34 [6.23-6.45]
Post	11.40 [11.33-11.48]	1.42 [1.38-1.45]	1.00 [0.96-1.03]	2.52 [2.13-2.90]	1.07 [0.82-1.32]	5.60 [5.50-5.71]	3.01 [2.92-3.09]

Predicted probabilities were derived from multivariable logistic regression models with random intercept, SE were clustered at the patient level. All models adjusted for demographic characteristics (age category, gender, race/ethnicity, region, category of assistance) and comorbidities. Comorbidities (pain, mental conditions, AUD, SUD, any AUD/SUD) and Benzodiazepine use were assessed in the pre-period.

Appendix A Supplemental Tables and Figures for Chapter Three



Appendix Figure 1 Derivation of Study Cohort



Appendix Figure 2 Trends in Preventive Dental Service Use Among Low Income Children Surveyed in MEPS 2011-2016

Estimate
95% CI intervals

Trends were estimated from a multivariable linear regression model controlling for child, parent, family-level characteristics and state and year fixed effects. Estimates were adjusted for family survey weights. 95% Confidence Intervals were constructed using standard errors that account for the complex sampling design of the MEPS. Displayed in the graphs are: a. any preventive visit; b. prophylaxis; c. fluoride treatment; and d. sealant application

Data and Methods

Imputation of selection criteria variables we pooled data from the 2003-2016 Medical Expenditure Panel Survey – Household Component (MEPS-HC). To study the effect of Medicaid adult dental policy changes on children's receipt of preventive dental services, we analyzed a subset of observations in the MEPS consisting of parent-child dyads in families with incomes below 200% of FPL.

Because pregnancy status was only reported for the years 2008-2016, we imputed missing pregnancy indicators for the years 2003 to 2007. We identified a pregnant woman as having either a child born in the same calendar year or by September of the next calendar year, or as having any pregnancy related inpatient visits over the same period. This measure was highly correlated with pregnancy status for the years in which this latter variable was included in the MEPS.

The supply of dentists was missing for 2003-2009 in the AHRF. We imputed missing values using linear regression models fitted to AHRF data for the years 2010-2016. We used these models to estimate the number of dentists in a county-year as a function of county fixed effects, total active medical doctors in the county, the size of the county's population, the percent of county residents with incomes below the Federal Poverty Level, and median household income. We applied regression coefficients from these models to impute the number of dentists in a county in each of the years 2003-2009. Our final measure was the number of dentists per 1000 county residents.

Medicaid dentist reimbursement was missing for some states over the study time period. We imputed missing values using linear regression models to estimate reimbursement rates in a state-year as a function of a linear time trend, state fixed effects, and an interaction term between

state fixed effects and linear time trends. Thus, our imputation model allows time trends in dental reimbursement rates to vary by state. Our final measure was the reimbursement rate by state and year.

Independent variables: Race and ethnicity was reported as non-Hispanic White, non-Hispanic Black, Hispanic and other. Parental educational attainment was categorized as less than high school, completed high school, any college education and not specified. An indicator for parental unemployment was created based on whether a person was unemployed for at least 2 of 3 MEPS rounds in a given survey year. Family size was categorized as follows: a family of 1 or 2 individuals, 3, 4, 5, or 6 individuals, or 7 or more individuals.

Dependent variables: The main dependent variable was an indicator of whether a child received any preventive dental visit in a year. Preventive dental visits were obtained from MEPS dental visit files. We defined any preventive visit as any dental prophylaxis (cleaning of the teeth) (CLENTETH), fluoride treatment (FLUORIDE) or sealant application (SEALANT). We ran a sub analysis to separately examine dental prophylaxis versus fluoride treatment or sealant applications (pooling the latter two into a combined measure).

Appendix Table1 Medicaid Adult Dental Policies by State, 2011-2016

State	2011	2012	2013	2014	2015	2016	ACA Medicaid expansion date
Alabama	0	0	0	0	0	0	N/A
Alaska	1	1	1	1	1	1	9/1/2015
Arizona	0	0	0	0	0	0	1/1/2014
Arkansas	1	1	1	1	1	1	1/1/2014
California	0	0	0	0	1	1	1/1/2014
Colorado	0	0	0	1	1	1	1/1/2014
Connecticut	1	1	1	1	1	1	1/1/2014
Delaware	0	0	0	0	0	0	1/1/2014
DC	1	1	1	1	1	1	1/1/2014
Florida	0	0	0	0	0	0	N/A
Georgia	0	0	0	0	0	0	N/A
Hawaii	0	0	0	0	0	0	1/1/2014
Idaho	0	0	0	0	0	0	N/A
Illinois	1	0	0	0	0	0	1/1/2014
Indiana	1	1	1	1	1	1	2/1/2015
Iowa	1	1	1	1	1	1	1/1/2014
Kansas	0	0	0	0	0	0	N/A
Kentucky	1	1	1	1	1	1	1/1/2014
Louisiana	0	0	0	0	0	0	7/1/2016
Maine	0	0	0	0	0	0	N/A*
Maryland	0	0	0	0	0	0	1/1/2014
Massachusetts	1	1	1	1	1	1	1/1/2014
Michigan	1	1	1	1	1	1	4/1/2014
Minnesota	1	1	1	1	1	1	1/1/2014
Mississippi	0	0	0	0	0	0	N/A
Missouri	0	0	0	0	0	1	N/A
Montana	0	0	0	0	0	1	1/1/2016
Nebraska	1	1	1	1	1	1	N/A
Nevada	0	0	0	0	0	0	1/1/2014
New Hampshire	0	0	0	0	0	0	8/15/2014
New Jersey	1	1	1	1	1	1	1/1/2014

Appendix Table 1 continued

State	2011	2012	2013	2014	2015	2016	ACA Medicaid expansion date
New Mexico	1	1	1	1	1	1	1/1/2014
New York	1	1	1	1	1	1	1/1/2014
North Carolina	1	1	1	1	1	1	N/A
North Dakota	1	1	1	1	1	1	1/1/2014
Ohio	1	1	1	1	1	1	1/1/2014
Oklahoma	0	0	0	0	0	0	N/A
Oregon	1	1	1	1	1	1	1/1/2014
Pennsylvania	1	1	1	1	1	1	1/1/2015
Rhode Island	1	1	1	1	1	1	1/1/2014
South Carolina	0	0	0	0	1	1	N/A
South Dakota	1	1	1	1	1	1	N/A
Tennessee	0	0	0	0	0	0	N/A
Texas	0	0	0	0	0	0	N/A
Utah	1	1	0	0	0	0	N/A
Vermont	1	1	1	1	1	1	1/1/2014
Virginia	0	0	0	0	0	0	N/A*
Washington	0	0		1	1	1	1/1/2014
West Virginia	0	0	0	0	0	0	1/1/2014
Wisconsin	1	1	1	1	1	1	N/A
Wyoming	1	1	1	1	1	1	N/A

1= state covered more than emergency Medicaid adult dental benefits, 0= state covered emergency only or did not cover adult Medicaid dental benefits

The table was constructed using information abstracted from the Medicaid and CHIP Payment and Advisory Commission((MACPAC). June 2015), Center for Health care Strategies(Center for Health Care Stratigies Inc., February 2015), the Kaiser Family Foundation(Kaiser Family Foundation), Medicaid state plan amendments filed with CMS(Centers for Medicare & Medicaid Services), and the peer-reviewed literature.(S. L. Decker & Lipton, 2015)

*Virginia expanded Medicaid on 1/1/2019 and Maine 1/10/2019 with coverage retroactive to 7/2/2018.

Appendix Table 2 Adjusted Association Between Implementation of the ACA Medicaid Expansion and Children's Receipt of Preventive Dental Services in States with vs. without Medicaid Dental Coverage for Adults (Full model estimates correspond to Table 3 in the main text)

Variable	Any preventive service	Dental prophylaxis	Fluoride treatment or sealant application
Adult Dental Coverage	-4.17 [-8.17, 0.27]	-5.16 [-10.27, -0.05]*	1.91 [-2.55, 6.37]
ACA State Medicaid expansion	3.03 [-2.76, 8.81]	3.69 [-1.76, 9.15]	-0.02 [-6.10, 6.07]
Adult Dental coverage ACA State Medicaid expansion*	-1.76 [-8.09, 4.56]	-1.88 [-8.20, 4.44]	-2.34 [-9.11, 4.43]
Child characteristics			
Female	0.69 [-2.74, 4.11]	0.77 [-2.69, 4.23]	0.21 [-2.23, 2.65]
Child age in years, categories			
6-9	10.61 [5.29, 15.94]**	10.46 [5.24, 15.67]**	6.64 [3.64, 9.64]**
10-14	17.94 [12.00, 23.88]**	16.78 [10.84, 22.71]**	10.94 [6.31, 15.57]**
15-18	Ref		
Child race and ethnicity			
White non- Hispanic	Ref		
Black non-Hispanic	-10.06 [-22.24, 2.13]	-9.63 [-21.86, 2.59]	-10.23 [-18.55, -1.9]*
Hispanic	-1.91 [-10.92, 7.09]	-1.15 [-10.34, 8.04]	-0.12 [-6.08, 5.83]
Other	4.43 [-8.62, 317.48]	4.43 [-8.44, 17.29]	2.78 [-5.90, 11.46]
Child in Medicaid	9.85 [5.58, 14.12]**	9.93 [5.82, 14.03]**	2.46 [-0.96, 5.88]
Parent Characteristics			
Female	0.69 [-2.74, 4.11]	0.20 [-5.38, 5.78]	0.43 [-4.30, 5.16]
Parent age in years	0.46 [0.16, 0.76]**	0.46 [0.16, 0.77]**	-0.03 [-0.27, 0.20]
Parent education			
Less than high school	Ref		
Completed high school	1.44 [-1.89, 4.78]	1.42 [-2.00, 4.84]	1.33 [-1.71, 4.36]
Any college	2.68 [-2.06, 7.43]	3.17 [-1.62, 7.96]	2.19 [-0.83, 5.21]
Not specified	-3.12 [-19.30, 13.05]	-2.72 [-18.71, 13.27]	-7.33 [-10.54, -4.12]**
Unemployment	-2.06 [-6.25, 2.13]	-1.99 [-6.18, 2.20]	-0.20 [-3.55, 3.15]
Parent comfortable with English language	7.26 [3.62, 10.91]**	7.33 [3.92, 10.74]**	6.21 [3.44, 8.97]**
Parent race and ethnicity			
White non- Hispanic	Ref		
Black non-Hispanic	4.12 [-8.33, 16.57]	4.50 [-7.94, 16.95]	4.01 [-4.83, 12.84]
Hispanic	7.53 [-0.37, 15.43]	7.53 [-0.50, 15.55]	1.56 [-3.89, 7.00]
Other	-6.81[-17.79, 4.18]	-5.58 [-16.91, 5.76]	-9.06 [-15.94, -2.18]
Parent smoker	-6.12 [-10.06, -2.18]**	-6.55 [-8.40, -3.79]**	-1.46 [-3.85, 0.93]

Appendix Table 2 Continued

Variable	Any preventive service	Dental prophylaxis	Fluoride treatment or sealant application
Family characteristics			
Family size			
2 or less	Ref		
3	-1.69 [-8.43, 5.05]	-1.17 [-7,88, 5.54]	-2.15 [-6.84, 2.55]
4	-3.53 [-9.92, 2.87]	-3.41 [-9.86, 3.05]	-1.86 [-6.02, 2.31]
5	-4.35 [-10.01, 1.31]	-3.88 [-9.57, 1.81]	-2.82 [-7.43, -1.78]
6	-8.79 [-16.51, -1.07]*	-8.32 [-16.10, -0.54]*	-5.45 [-10.66, -0.25]*
7 or more	-13.23 [-21.19, -5.26]**	-12.64 [-20.48,-4.80]**	-7.82 [-12.72, -2.93]**
Family income			
Less than 100%	Ref		
100% to less than 125%	0.17 [-3.69, 4.02]	0.59 [-3.28, 4.46]	0.30 [-2.80, 3.39]
Two parents	5.79 [2.56,9.02]*	5.67 [2.54, 8.81]**	3.12 [0.38, 5.85]*
Dentist Medicaid reimbursement rate	-0.96 [-.75, -0.18]*	-1.02 [-1.80, -0.25]*	-1.10 [-1.81, -0.39]**
County characteristics			
Urban	4.03 [0.40, 7.65]*	4.25 [-0.21, 8.71]	0.20 [-4.12, 4.51]
Dentists per 1000 population	-0.67 [-11.85,10.52]	-2.17 [-13.83, 9.50]	0.21 [-5.53, 5.96]
Percent people in poverty	-0.04 [-0.34, 0.26]	-0.06 [-0.36, 0.24]	-0.23 [-0.50, 0.04]

Estimates are percentage points and are derived from a multivariable linear regression model predicting child's receipt of preventive dental services as a function of Medicaid dental coverage for adults, controlling for child, parent, and family-level characteristics and state and year fixed effects. Estimates were adjusted for family survey weights. 95% Confidence Intervals were constructed using standard errors that account for the complex sampling design of the MEPS. Any preventive service was defined as any prophylaxis, fluoride treatment or sealant application visit.
*p<0.05 **p<0.001

Sensitivity Analysis

Event-study models

We estimated event-study models to conduct two supplementary analyses. First, we examined whether Medicaid expansions were associated with increases over time in children's receipt of preventive dental services when states consistently covered these services for adults. To do so, we used event-study models to estimate time-varying treatment effects of Medicaid expansions, separately in 24 states that covered dental services for adults in each year of our study period and in 19 states that did not cover these services in any study year. Second, to check whether we could isolate changes associated with Medicaid expansions from secular state trends, we used these event-study models to examine whether pre-expansion trends in children's preventive dental service use differed between expansion and non-expansion states categorized according to their adult dental coverage policies.

Our event study models had the following form:

$$y_{ist} = \alpha + \sum_{t \neq -1} \gamma_t (Years\_to\_expansion_t = t) + \sum_{t \neq -1} \theta_t (Years\_to\_expansion_t = t) * Expand_s + \beta X_{it} + \lambda Payment_{st} + \mu_s + \mu_t + \varepsilon_{ist}$$

where *i* indexes parent-child dyads, *s* states, and *t* years. In this model, the coefficient vector γ_t is the adjusted annual change in preventive dental service use among children relative to the omitted reference year (time period *t*=-1), which we define as the year preceding expansion in expansion states and 2013 in non-expansion states. The coefficient vector θ_t captures our difference-in-differences estimates of interest; it represents an adjusted differential change in preventive dental service use among children in expansion versus non-expansion states in each study year relative to the reference year.

We separately estimated models for the 24 states that covered dental services for adults in each year of our study period and for the 19 states that did not cover these services for adults in any study year. To assess time-varying treatment effects of Medicaid expansions, we examined the estimates $\hat{\theta}_1$, $\hat{\theta}_2$, and $\hat{\theta}_3$, which represent adjusted differential changes in the year of expansion, 1 year after expansion, and 2 years after expansion. For analyses of trends preceding Medicaid expansion, we focus on estimates of $\hat{\theta}_{-3}$ and $\hat{\theta}_{-2}$, which represent differential changes 3 years and 2 years prior to expansion. Results are reported in Table 3 below.

Appendix Table 3 Adjusted Trends in Children's Preventive Dental Care Use in States that Covered Medicaid Adult Dental Benefits in Each Year vs Did Not Cover Medicaid Adult Dental Benefits in Any Year From 2011-2016

Variable	States that covered adult dental benefits in each year from 2011-2016	States that did not cover adult dental benefits in any year from 2011-2016
Years relative to expansion		
3- years pre- expansion	-10.38 [-25.06, 4.29]	09.88 [-1.98, 21.73]
2- years pre- expansion	6.76 [-11.07, 24.59]	7.97 [1.44, 14.50]*
Year of expansion	1.61 [-12.39, 15.61]	-12.91 [-33.51-7.70]
1-year post-expansion	-1.91 [-27.54, 23.73]	23.52 [19.04, 28.01]**
2 years post-expansion	22.54 [0.70, 44.38]*	0.22 [-19.91, 20.34]
ACA State Medicaid expansion	-25.09 [-36.55,-13.64]**	-13.22 [-20.15,-6.28]
3- years pre- expansion* *ACA State Medicaid expansion*	10.10 [-3.29, 23.49]	1.14 [-17.27, 19.56]
2- years pre- expansion* *ACA State Medicaid expansion*	3.74 [-10.09, 17.58]	-2.25 [-13.81, 9.30]
Year of expansion * *ACA State Medicaid expansion*	4.21 [-6.28, 14.71]	9.11 [-10.99, 29.22]
1- year post- expansion* *ACA State Medicaid expansion*	13.53 [-6.85, 33.91]	4.00 [-12.98, 20.99]
2- year post- expansion* *ACA State Medicaid expansion*	0.29 [-10.59, 11.17]	1.48 [-4.87, 7.83]

To check whether we could isolate changes associated with Medicaid expansions from secular state trends, we examined whether pre-expansion trends in preventive service use differed between expansion and non-expansion states, and whether there were further differences between states categorized by whether they covered or did not cover Medicaid adult dental benefits from 2011 to 201.6

To calculate time to expansion, the exact expansion date was used for states that expanded Medicaid; for states that did not expand Medicaid, the date 1/1/2014 was used. During our study period 24 states continuously covered adult dental benefits in Medicaid while 19 states continuously did not cover adult dental benefits.

Trends are presented as percentage points and were estimated from a multivariable linear regression model. We estimated the probability that children received at least one preventive dental service (cleaning, fluoride treatment, or sealant application) as a function of the following variables: an interaction term between time to expansion and the state's Medicaid expansion status (which we used to assess pre-expansion differences in trends), year fixed effects, state fixed effects, and the child, parent, family-level

characteristics listed in Table 1 of the main manuscript. Estimates were adjusted for family survey weights. 95% Confidence Intervals were constructed using standard errors clustered at the state level. *p<0.05 **p<0.001

Appendix Table 4 Adjusted Associations Between Medicaid Expansions, Medicaid Dental Coverage for Adults, and Children's Enrollment in Medicaid or CHIP

Variable	Child enrolled in Medicaid or CHIP
Adult Dental Coverage	0.88 [-3.214.97]
ACA State Medicaid expansion	-1.09 [-6.484.31]
Adult Dental coverage* ACA State Medicaid expansion	-0.82 [-5.934.29]

Estimates are from a multivariable linear regression model predicting children's enrollment in Medicaid or CHIP as a function of Medicaid dental coverage for adults, Medicaid expansion, and an interaction between Medicaid expansion status and Medicaid dental coverage for adults, controlling for child, parent, and family-level characteristics and state and year fixed effects. Estimates were adjusted for family survey weights. 95% Confidence Intervals [in brackets] were constructed using standard errors clustered at the state level. Analysis of N= 39,028,587 weighted dyads (7,798 unweighted dyads) in families with income at or below 125% FPL surveyed in the 2011-2016 MEPS. Estimates are reported in percentage points.

Appendix Table 5 Adjusted Odds of Children's Receipt of Preventive Dental Services and ACA State Medicaid Expansions and Medicaid Adult Dental Coverage

	Any preventive service	Dental Prophylaxis	Fluoride treatment or sealant application
Odds of children's use of preventive dental services associated with:			
Adult Dental Coverage	0.83 [0.68, 1.01]	0.79 [0.64, 0.99]	1.19 [0.834, 1.70]
ACA State Medicaid expansion	1.16 [0.90, 1.49]	1.19 [0.94, 1.52]	1.00 [0.63, 1.59]
Adult Dental coverage* ACA State Medicaid expansion	0.91 [0.69, 1.21]	0.91 [0.68, 1.21]	0.79 [0.48, 1.30]

Estimates are from a multivariable logit model predicting children's receipt of preventive dental services as a function of Medicaid dental coverage for adults, Medicaid expansion, and an interaction between Medicaid expansion status and Medicaid dental coverage for adults, controlling for child, parent, and family-level characteristics and state and year fixed effects. Estimates were adjusted for family survey weights. Estimates were adjusted for family survey weights. 95% Confidence Intervals were constructed using standard errors clustered at the state level.

Appendix B Supplemental Tables and Figures for Chapter Four

Dental Benefits in PA Medicaid

In PA, Medicaid covers about 21% of the population. PA Medicaid provides comprehensive dental benefits for children under 21 years of age under the Early and Periodic Screening, Diagnostic and Treatment (EPSDT) benefit. For adults, dental benefits are optional in Medicaid and PA only covers limited dental benefits, comprehensive procedures such as root canal treatment, crowns and periodontal treatment are covered for adults only if a Dental Benefit Limit Exception Request is approved. Low-income adults have high oral healthcare needs,(K. Y. Li et al., 2018; Moeller et al., 2017) this was reflected in a survey of the Medicaid expansion group in PA, where oral health was reported among their top healthcare concerns. (Hom et al., 2016) Medicaid expansion in PA in 2015 provided an opportunity for many low-income adults to gain access to dental care services.

Appendix Table 6 ICD-9 and ICD-10 Codes for Opioid Use Disorders

	Opioid use disorder
ICD-9	304.0, 304.00, 304.01, 304.02, 304.03, 304.7, 304.70, 304.71, 304.72, 304.73, 305.5, 305.50, 305.51, 305.52, 305.53
ICD-10	F1110, F11120, F11121, F11122, F11129, F1114, F11150, F11151, F11159, F11181, F11182, F11188, F1119, F1120, F1121, F11220, F11221, F11222, F11229, F1123, F1124, F11250, F11251, F11259, F11281, F11282, F11288, F1129, F1190, F11920, F11921, F11922, F11929, F1193, F1194, F11950, F11951, F11959, F11981, F11982, F11988, F1199

ICD-9: International Classification of Diseases, 9th Revision

ICD-10: International Classification of Diseases, 10th Revision

Appendix Table 7 CDT Procedure Codes Used to Categorize Procedures Based on the Likelihood of Pain Associated with the Procedure

Likelihood of pain associated with the procedure	CDT codes
Likelihood of pain low	D0100-D0999 DIAGNOSTIC D1000-D1999 PREVENTIVE D2000-D2999 RESTORATIVE D5000-D5899 PROSTHODONTICS (removable D5900-D5999 MAXILLOFACIAL PROSTHETICS D6200-D6999 PROSTHODONTICS (fixed)* D8000-D8999 ORTHODONTICS D9000-D9999 ADJUNCTIVE GENERAL SERVICES EXCEPT for CDT codes D9110 and D9930
Likelihood of pain moderate	D3000-D3999 ENDODONTICS D4000-D4999 PERIODONTICS
Likelihood of pain high	D7000-D7999 ORAL & MAXILLOFACIAL SURGERY D 9110 Palliative (emergency) treatment of dental pain - minor procedure D9930 Treatment of complications (post-surgical) - unusual circumstances, by report

CDT code: American Dental Association Code on Dental Procedure and Nomenclature

PA Medicaid does not cover implant services, there were only 8 cases related to implant services over the study period (2012-2017)

Starting September 2011, PA Medicaid does not cover endodontic services, periodontal surgery and prosthodontics except with a benefit limit exception.

Appendix Table 8 ICD 9-10 diagnosis codes used to define comorbid conditions

		ICD-9/ICD-10 codes
Pain	Osteoarthritis	'711', '712', '713', '71500', '71504', '71509', '7151', '7152', '7153', '7158', '7159', '7161', '7270', '7212', '7213', '7219', '730', '731', '732', '733', '734', '735', '736', '737', '738', '739', 'M0000', 'M0010', 'M0020', 'M0080', 'M009', 'M00019', 'M00219', 'M00819', 'M00029', 'M00129', 'M00229', 'M00829', 'M118', 'M1480', 'M020', 'M150', 'M159', 'M151', 'M152', 'M150', 'M1991', 'M190', 'M1610', 'M1710', 'M1991', 'M1993', 'M192', 'M167', 'M175', 'M1990', 'M189', 'M169', 'M179', 'M158', 'M153', 'M159', 'M1990', 'M189', 'M169', 'M179', 'M125', 'M659', 'M6580', 'D481', 'M653', 'M654', 'M658', 'M651', 'M47814', 'M47817', 'M47819', 'M861', 'M862', 'M866', 'M869', 'M462', 'M896', 'M908', 'M463', 'M88', 'M906', 'M894', 'M905', 'M908', 'M42', 'M91', 'M92', 'M93', 'M81', 'M80', 'M84', 'M85', 'M87', 'M94', 'M89', 'S42', 'S49', 'S62', 'S72', 'S82', 'S92', 'S02', 'S12', 'S22', 'S32', 'S52', 'S68', 'M48', 'M214', 'M201', 'M203', 'M202', 'M204', 'M205', 'M206', 'M21', 'M200', 'M40', 'M962', 'M963', 'M964', 'M41', 'M438', 'M95', 'M8938', 'M8988', 'M999', 'M998', 'M430', 'M431', 'M99'

Appendix Table 9 Continued

		ICD-9/ICD-10 codes
	Rheumatoid arthritis	'714', 'M080', 'M082', 'M083', 'M088', 'M089', 'M120', 'M05', 'M06'
	Back pain	'720', '7214', '7215', '7216', '7217', '7218', '7221', '7222', '72230', '72232', '72252', '7226', '72270', '72273', '72272', '72280', '72282', '72283', '72290', '72292', '72293', '724', '7371', '7372', '7373', '7384', '7385', '7392', '7393', '7394', '75610', '75611', '75612', '75613', '75614', '75615', '75616', '75617', '75619', '75619', '8054', '8056', '8056', '8058', '8392', '83942', '846', '8471', '8473', '8472', '8479', 'M459', 'M4600', 'M461', 'M498', 'M465', 'M468', 'M469', 'M4714', 'M4715', 'M4716', 'M482', 'M481', 'M483', 'M489', 'M512', 'M519', 'M519', 'M5146', 'M5147', 'M5136', 'M5137', 'M513', 'M519', 'M5106', 'M5104', 'M5105', 'M961', 'M961', 'M961', 'M4640', 'M519', 'M4645', 'M518', 'M4647', 'M4800', 'M4804', 'M4806', 'M4808', 'M546', 'M545', 'M5430', 'M5414', 'M5415', 'M5416', 'M5417', 'M5489', 'M549', 'M4327', 'M4328', 'M5327', 'M533', 'M5328', 'M5408', 'M4389', 'M539', 'M4000', 'M40209', 'M962', 'M963', 'M40299', 'M404', 'M964', 'M405', 'M4120', 'M4100', 'M965', 'M4130', 'M4180', 'M419', 'M4300', 'M4310', 'M9983', 'M9984', 'M9902', 'M9903', 'M9904', 'Q7649', 'Q762', 'Q762', 'Q7649', 'Q7649', 'Q7649', 'Q761', 'Q760', 'Q76419', 'Q7649', 'S32009A', 'S3210A', 'S322A', 'S129A', 'S22009A', 'S32009A', 'S3210A', 'S322A', 'S33101A', 'S23101A', 'S332A', 'S338A', 'S336A', 'S339A', 'S233A', 'S238A', 'S338A', 'S335A', 'S239A'

Appendix Table 9 Continued

		ICD-9/ICD-10 codes
	internal orthopedic device implant and graft	'9964', 'T84498A', 'T84039A', 'T84029A', 'T84019A', 'M979A', 'T84059A', 'T84069A', 'T84099A', 'T84119A', 'T84129A', 'T84199A', 'T84498A'
	Neck pain	'7210', '7211', '7220', '72231', '7224', '72271', '72281', '72291', '723', '8390', '8391', '8470', '7210', '7211', '7220', '72231', '7224', '72271', '72281', '72291', '723', '8390', '8391', '8470', 'M47812', 'M4712', 'M5020', 'M5144', 'M5145', 'M5030', 'M5000', 'M961', 'M5080', 'M5090', 'M4802', 'M542', 'M530', 'M531', 'M5412', 'M5413', 'M436', 'M5402', 'M6788', 'M5382', 'S1190A', 'S13101A', 'S1190A', 'S13111A', 'S1190A', 'S13121A', 'S13131A', 'S13141A', 'S13151A', 'S1190A', 'S13161A', 'S13171A', 'S13181A', 'S13101A', 'S134A', 'S138A'
	Headache/migraine	'346', '30781', '7840', 'G43109', 'G43119', 'G43019', 'G43809', 'G43A', 'G43B', 'G43C', 'G43D', 'G43819', 'G43809', 'G43909', 'G43711', 'G43919', 'G44209', 'G441', 'R51'

Appendix Table 9 Continued

		ICD-9/ICD-10 codes
	Diseases of the musculoskeletal system and connective tissue	'710', '711', '712', '713', '714', '715', '716', '717', '718', '719', '720', '721', '722', '723', '724', '725', '726', '727', '728', '729', '730', '731', '732', '733', '734', '735', '736', '737', '738', '739', 'M3210', 'M340', 'M341', 'M349', 'M3500', 'M3501', 'M3390', 'M3320', 'M358', 'M355', 'M359', 'M1180', 'M11819', 'M11829', 'M11839', 'M11849', 'M11859', 'M11869', 'M11879', 'M1188', 'M1189', 'M1120', 'M11219', 'M11229', 'M11239', 'M11249', 'M11259', 'M11269', 'M11279', 'M1128', 'M1129', 'M119', 'M1480', 'M0200', 'M362', 'M363', 'M1280', 'M1460', 'M0220', 'M364', 'M029', 'M1480', 'M069', 'M0500', 'M0530', 'M0560', 'M061', 'M0800', 'M083', 'M0840', 'M1200', 'M0510', 'M064', 'M150', 'M159', 'M151', 'M152', 'M1991', 'M19019', 'M19029', 'M19039', 'M19049', 'M1610', 'M1710', 'M19079', 'M1991', 'M1993', 'M19219', 'M19229', 'M19239', 'M19249', 'M167', 'M175', 'M19279', 'M1993', 'M1990', 'M189', 'M169', 'M179', 'M158', 'M153', 'M1210', 'M12119', 'M12129', 'M12139', 'M12149', 'M12159', 'M12169', 'M12179', 'M1218',

Appendix Table 9 Continued

		ICD-9/ICD-10 codes
	Diseases of the musculoskeletal system and connective tissue	'M1219', 'M1250', 'M138', 'M1280', 'M130', 'M131', 'M128', 'M129', 'M23205', 'M23319', 'M23329', 'M23305', 'M23339', 'M23202', 'M232', 'M23359', 'M23369', 'M23009', 'M2340', 'M2240', 'M2350', 'M2389', 'M24', 'M25', 'M459', 'M4600', 'M461', 'M4980', 'M4680', 'M4690', 'M47812', 'M4712', 'M47814', 'M47817', 'M4714', 'M4716', 'M4820', 'M4810', 'M4830', 'M489', 'M47819', 'M4710', 'M5020', 'M512', 'M519', 'M514', 'M5030', 'M513', 'M519', 'M5000', 'M510', 'M961', 'M4640', 'M5080', 'M5090', 'M4645', 'M518', 'M4647', 'M4802', 'M542', 'M530', 'M531', 'M5412', 'M5413', 'M436', 'M5402', 'M6788', 'M5382', 'M4800', 'M4804', 'M4806', 'M4808', 'M546', 'M545', 'M5430', 'M5414', 'M5415', 'M5416', 'M5417', 'M5489', 'M549', 'M4327', 'M4328', 'M5327', 'M533', 'M5328', 'M5408', 'M4389', 'M539', 'M353', 'M750', 'M7510', 'M755', 'M753', 'M752', 'M758', 'M753', 'M754', 'M758', 'M25729', 'M7700', 'M7710'

Appendix Table 9 Continued

		ICD-9/ICD-10 codes
	Diseases of the musculoskeletal system and connective tissue	'M702', 'M703', 'M701', 'M7720', 'M706', 'M707', 'M7610', 'M7620', 'M705', 'M7640', 'M7650', 'M7040', '76899', 'M7740', 'M7660', 'M76829', 'M7730', 'M7750', 'M778', 'M779', 'M2570', 'M659', 'M6580', 'D481', 'M6530', 'M654', 'M65849', 'M65879', 'M6580', 'M2161', 'M2010', 'M2162', 'M70039', 'M7030', 'M7040', 'M7150', 'M7130', 'M6741', 'M6742', 'M6743', 'M6744', 'M6745', 'M6746', 'M6747', 'M6740', 'M7130', 'M6610', 'M7120', 'M6618', 'M669', 'M75120', 'M66829', 'M66239', 'M66249', 'M66339', 'M66349', 'M66259', 'M66269', 'M66369', 'M66879', 'M6688', 'M6700', 'M6520', 'M7140', 'M6750', 'M6500', 'M6780', 'M6788', 'M7100', 'M7180', 'M6790', 'M719', 'M60009', 'M619', 'M6110', 'M6100', 'M6140', 'M6159', 'M6250', 'M623', 'M6284', 'M6289' 'M2420', 'M357', 'M720', 'M722', 'M721', 'M724', 'M6010', 'M6020', 'M6210', 'M6200', 'M6240', 'M62838', 'M726','M6289', 'M629', 'M790', 'M609','M791', 'M797', 'M5410', 'M792', 'M793', 'M794','M729', 'M79609', 'M795', 'M7989', 'R252','R29898', 'M799', 'M7098', 'M7981', 'M861', 'M862', 'M866', 'M4620', 'M869', 'M896', 'M908', 'M869', 'M4630', 'M889', 'M9060', 'M8940', 'M8970', 'M9080', 'M4200', 'M9180', 'M93003', 'M9230', 'M9240', 'M9250', 'M9260', 'M9270', 'M928', 'M9320', 'M4210', 'M931', 'M9380', 'M9390', 'M81', 'M84', 'M85', 'M87', 'M4850A', 'M80', 'M940', 'M8900'

Appendix Table 9 Continued

		ICD-9/ICD-10 codes
	Diseases of the musculoskeletal system and connective tissue	'S42009P', 'S42209P', 'S4290P', 'S5290P', 'S5290Q', 'S5290R', 'S6290P', 'S7290P', 'S7290Q', 'S7290R', 'S82009P', 'S82009Q', 'S82009R', 'S8290P', 'S8290Q','S8290R', 'S92819P', 'S92909P', 'S92919P', 'S99209P', 'S99219P', 'S99229P', 'S99239P', 'S99249P', 'S99299P', 'S0291K', 'S0291K', 'S0292K', 'S12000K','S12001K', 'S12100K', 'S12101K', 'S12200K', 'S12201K', 'S12300K', 'S12301K', 'S12400K', 'S12401K', 'S12500K', 'S12501K', 'S12600K', 'S12601K', 'S229K','S329K', 'S42009K', 'S42209K', 'S4290K', 'S5290K', 'S5290M', 'S5290N', 'S6290K', 'S7290K', 'S7290M', 'S7290N', 'S8290K', 'S8290M', 'S8290N', 'S92819K','S92909K', 'S92919K', 'S99209K', 'S99219K', 'S99229K', 'S99239K', 'S99249K', 'S99299K', 'M89', 'M94', 'M484', 'M8930', 'M8989', 'M9489', 'M2140', 'M2010', 'M2030', 'M2020', 'M2040', 'M2059', 'M2060', 'M21939', 'M21029', 'M21129', 'M21839', 'M21339', 'M215', 'M20019', 'M20009', 'M20029','M20039', 'M20099', 'M21959', 'M21059', 'M21159', 'M21859', 'M21069', 'M21169', 'M21869', 'M21969', 'M2169', 'M21759', 'M21769', 'M2180', 'M2190','M4000', 'M40209', 'M962', 'M963', 'M40299', 'M4040', 'M964', 'M4050', 'M4120', 'M4100', 'M965', 'M4130', 'M4180', 'M419', 'M4389', 'M4010', 'M4140','M4150', 'M4389', 'M95', 'M8938', 'M8988', 'M4300', 'M4310', 'M9983', 'M9984', 'M99'

Appendix Table 9 Continued

	ICD-9/ICD-10 codes
Temporomandibular Disorder pain	'52460', '52461', '52462', '52463', '52469', 'M26601', 'M26602', 'M26603', 'M26609', 'M2669', 'M26611', 'M26612', 'M26613', 'M26619', 'M26621', 'M26622', 'M26623', 'M26629', 'M26631', 'M26632', 'M26633', 'M26639', 'M2669'
Abdominal pain/hernia	'78900', '78901', '78902', '78903', '78904', '78905', '78906', '78907', '78909', '53500', '541', '55092', '5770', '5409', '5531', '55320', '55321', '55329', '5533', '53390', '55090', '5641', '59080', 'R109', 'R1011', 'R1012', 'R1031', 'R1032', 'R1033', 'R1013', 'R1084', 'R1010', 'R102', 'R1030', 'K2900', 'K37', 'K4020', 'K8590', 'K8591', 'K8592', 'K3580', 'K3589', 'K429', 'K439', 'K432', 'K439', 'K469', 'K449', 'K279', 'K4090','K581', 'K582', 'K588', 'K589', 'N12'
Chest pain	'78650', '78651', '78652', '78659', '4139', 'R079', 'R072', 'R071', 'R0781', 'R0782', 'R0789', 'I208', 'I209'
Kidney stone/gallbladder stones	'57410', '57420', '57510', '5920', '5921', '5929', '5941', 'K8018', 'K8020', 'K819', 'N200', 'N201', 'N209', 'N210'
Menstrual/genital reproductive pain (females)	'6253', '6258', '6259', '6266', '6271', '6272', 'N946', 'N9489', 'R102', 'N921', 'N950', 'N951'
Fractures, contusions, injuries	'73313', '8020', '8052', '80700', '80701', '8072', '8088', '81000', '81200', '81209', '81220', '81240', '81301', '81301', '81305', '81341', '81381', '81400', '81401', '81500', '81600', '81602', '81610', '8208', '8220', '82300', '82380', '82381', '8240', '8240', '8242','8244', '8246', '8248', '8250', '82520', '82525', '8260', '8290', '83104', '8509', '8730', '87343', '8798', '88100', '88101', '8820', '8832',

Appendix Table 9 Continued

	ICD-9/ICD-10 codes
	'8860', '8910', '8910', '8920', '8930', '9100', '9130', '9140', '9160', '9190', '920', '9221', '9222', '92231', '92232', '92300', '92310', '92311', '92320', '92321', '9233', '9233', '9239', '92400', '92401', '92410', '92411', '92420', '92421', '9243', '9245', '9248', '9249', '9273', '95901', '95911', '95912', '95913', '95914', '95919', '9592', '9597', '9599', 'E887', 'E8880', 'E8881', 'E8888', 'E8889', 'E9060', 'E9063', 'E8859', 'M4850A', 'M8008A', 'M8448A', 'M8468A', 'S022A', 'S22009A', 'S2239A', 'S2239A', 'S2220A', 'S329A', 'S42009A', 'S42209A', 'S42293A', 'S42296A', 'S42309A', 'S42409A', 'S52023A', 'S52026A', 'S52123A', 'S52126A', 'S52539A', 'S52549A', 'S5290A', 'S62109A', 'S62009A', 'S62309A', 'S62509A', 'S62609A', 'S62523A', 'S62526A', 'S62639A', 'S62669A', 'S62509B', 'S62609B', 'S72009A', 'S82009A', 'S82109A', 'S82201A', 'S82401A', 'S8253A', 'S8256A', 'S8263A', 'S8266A', 'S82843A', 'S82846A', 'S82853A', 'S82856A', 'S82899A', 'S92009A', 'S99009A', 'S99019A', 'S99029A', 'S99039A', 'S99049A', 'S99099A', 'S92819A', 'S92909A', 'S92309A', 'S99109A', 'S99119A', 'S99129A', 'S99139A', 'S99149A', 'S99199A', 'S92403A', 'S92406A', 'S92503A', 'S92506A', 'T148A', 'S43109A', 'S0600A', 'S0100A','S01501A', 'S31000A', 'S51809A', 'S51009A', 'S61409A', 'S61109A', 'S61209A', 'S66529A', 'S68119A', 'S68129A', 'S68619A', 'S68629A', 'S81009A', 'S81809A','S91009A', 'S91309A', 'S91109A', 'S0001A', 'S0031A', 'S00419A', 'S00511A', 'S00512A', 'S0091A', 'S1011A', 'S1091A', 'S50319A', 'S50819A', 'S60819A',

Appendix Table 9 Continued

	ICD-9/ICD-10 codes
	'S60519A', 'S70219A', 'S70319A', 'S80819A', 'S90519A', 'T07A', 'S0093A', 'S1093A', 'S20219A', 'S301A', 'S300A', 'S300A', 'S40019A', 'S5010A', 'S5000A', 'S60229A', 'S60219A', 'S6000A', 'S60019A', 'S6010A', 'S40019A', 'S7010A', 'S7000A', 'S8010A', 'S8000A', 'S9030A', 'S9000A', 'S90119A', 'S90129A', 'S90229A', 'S7010A', 'T148A', 'T1490A', 'S6700A', 'S6710A', 'S098A', 'S0990A', 'S298A', 'S3981A', 'S39840A', 'S39848A', 'S3982A', 'S4980A', 'S4990A', 'S8980A', 'S8990A', 'S99819A', 'S99919A', 'T1490A', 'W19A', 'W01110A', 'W01198A', 'W1830A', 'W19A', 'W540A', 'W5501A', 'W1849A'
Neuropathies, excluding alcoholic neuropathy, drug-related neuropathy and optic neuropathies	'5313', '7272', '33700', '33701', '33709', '3560', '3562', '3564', '3569', '3572', '3573', '7234', 'B0223', 'B2684', 'G9009', 'G9001', 'G600', 'G603', 'G609', 'E0842', 'E1042', 'E1142', 'E1342', 'G63', 'M5412', 'M5413'
Fibromyalgia	'7291', 'M609', 'M791', 'M797'
Pain: others	'37991', '38022', '38023', '3829', '38870', '38181', '470', '5224', '5259', '5225', '5651', '56942', '60490', '61171', '61179', '71930', '725', '726', '727', '728','729', '7030', '7062', '78652', '8483', '8488', '8489', '87363', 'H5713', 'H60509', 'H60519', 'H60529', 'H60539', 'H60549', 'H60559', 'H60599', 'H6060', 'H6081', 'H6090', 'H6690', 'H9209', 'H6980', 'J342', 'K044', 'K089', 'K047', 'K603', 'K604', 'K605', 'K6289', 'N451', 'N452', 'N453', 'N644', 'N6451', 'N6452', 'N6453', 'N6459', 'M1230', 'M1240', 'M353', 'M750', 'M7510', 'M755', 'M753', 'M752', 'M758',

Appendix Table 9 Continued

		ICD-9/ICD-10 codes
	Pain: others	'M753', 'M754', 'M758', 'M25729', 'M7700 ', 'M7710', 'M702', 'M703', 'M701', 'M7720', 'M706', 'M707', 'M7610', 'M7620', 'M705', 'M7640', 'M7650', 'M7040', 'M76899', 'M7740', 'M7660', 'M76829', 'M7730', 'M7750', 'M778', 'M779', 'M2570', 'M659', 'M6580', 'D481', 'M6530', 'M654', 'M65849', 'M65879', 'M6580', 'M2161', 'M2010', 'M2162', 'M70039', 'M7030', 'M7040', 'M7150', 'M7130', 'M6741', 'M6742', 'M6743', 'M6744', 'M6745', 'M6746', 'M6747', 'M6740','M7130', 'M6610', 'M7120', 'M6618','M669', 'M75120', 'M66829', 'M66239', 'M66249', 'M66339', 'M66349', 'M66259', 'M66269', 'M66369', 'M66879', 'M6688', 'M6700', 'M6520', 'M7140', 'M6750', 'M6500', 'M6780', 'M6788', 'M7100', 'M7180', 'M6790', 'M719', 'M60009', 'M619', 'M6110', 'M6100', 'M6140', 'M6159', 'M6250', 'M623', 'M6284','M6289', 'M2420', 'M357', 'M720', 'M722', 'M721', 'M724', 'M6010', 'M6020', 'M6210', 'M6200', 'M6240', 'M62838', 'M726', 'M6289', 'M629', 'M790','M609', 'M791', 'M797', 'M5410', 'M792', 'M793', 'M794', 'M729', 'M79609', 'M795', 'M7989', 'R252', 'R29898', 'M799', 'M7098', 'M7981', 'L600','L723', 'R071', 'R0781', 'S2341A', 'S039A', 'S29019A', 'S39011A', 'T1490A', 'S025A','S025B'
	Cancer related pain	'3383', 'G893'
Mental disorders	adjustment disorders	'3090', '30924', '30928', '30929', '3093', '3094', '30982', '30983', '30989', '3099', 'F432'
	anxiety disorder	'29384', '3000', '30010', '3002', '3003', '3005', '30089', '3009', '308', '30981', '3130', '3131', '31321', '31322', '3133', '31382', '31383', 'F064', 'F41', 'F449', 'F40', 'F42', 'F488', 'F458', 'F488', 'F489', 'F99', 'F430', 'R457', 'F431', 'F938'

Appendix Table 9 Continued

		ICD-9/ICD-10 codes
	mood disorders	'29383', '2960', '2961', '2962', '2963', '2964', '2965', '2966', '2967', '29680', '29681', '29682', '29689', '2969', '311', 'F0630', 'F30', 'F32', 'F33', 'F31', 'F319', 'F308', 'F328', 'F3181', 'F39', 'F348', 'F329'
	personality disorders	'3010', '3011', '3012', '3013', '3014', '3015', '3016', '3017', '3018', '3019', 'F600', 'F340', 'F6089', 'F341', 'F601', 'F21', 'F603', 'F605', 'F604', 'F607', 'F602', 'F6081', 'F606', 'F603', 'F6089', 'F609'
	Mental: others	'29389', '2399', '30011', '30012', '30013', '30014', '30015', '30016', '30019', '3006', '3007', '30081', '30082', '302', '306', '3071', '3074', '3075', '3078', '3101', '316', '6484', 'V402', 'V403', 'V409', 'V673', 'F061', 'F53', 'D499', 'F444', 'F446', 'F440', 'F441', 'F4481', 'F449', 'F4489', 'F6811', 'F688', 'F481', 'F4521', 'F4522', 'F450', 'F451', 'F459', 'F66', 'F65', 'F641', 'Z87890', 'F64', 'R37', 'F520', 'F5221', 'F528', 'F5231', 'F458', 'F525', 'F458', 'F59', 'F459', 'F5000', 'F519', 'F5102', 'F5109', 'F5101', 'F5103', 'F5119', 'F5111', 'F5112', 'F518', 'F509', 'F502', 'F983', 'F9821', 'F508', 'F9829', 'F4541', 'G44209', 'F4542', 'F070', 'F54', 'O9934', 'O906', 'F489', 'F69', 'Z9183', 'F69', 'Z09'
	Drug-induced mental disorders/sleep disorders	'2921', '2928', '2929', 'F12121', 'F12122', 'F1215', 'F12180', 'F12221', 'F12222', 'F1225', 'F12280', 'F12921', 'F12922', 'F1295', 'F12980', 'F13121', 'F1314', 'F1315', 'F13180', 'F13182', 'F13221', 'F13231', 'F13232', 'F1324', 'F1325', 'F1326', 'F1327', 'F13280', 'F13282', 'F13921', 'F13931', 'F13932', 'F1394', 'F1395', 'F1396', 'F1397', 'F13980', 'F13982', 'F14121', 'F14122', 'F1414', 'F1415', 'F14180',

Appendix Table 9 Continued

		ICD-9/ICD-10 codes
	Drug-induced mental disorders/sleep disorders	'F14182', 'F14221', 'F14222', 'F1424', 'F1425', 'F14280', 'F14282', 'F14921', 'F14922', 'F1494', 'F1495', 'F14980', 'F14982', 'F15121', 'F15122', 'F1514', 'F1515', 'F15180', 'F15182', 'F15221', 'F15222', 'F1524', 'F1525', 'F15280', 'F15282', 'F15921', 'F15922', 'F1594', 'F1595', 'F15980', 'F15982', 'F16121', 'F16122', 'F1614', 'F1615', 'F16180', 'F16183', 'F16221', 'F1624', 'F1625', 'F16280', 'F16283', 'F16921', 'F1694', 'F1695', 'F16980', 'F18121', 'F1814', 'F1815', 'F18180', 'F18221', 'F1824', 'F1825', 'F1827', 'F18280', 'F18921', 'F1894', 'F1895', 'F1897', 'F18980', 'F19121', 'F19122', 'F1914', 'F1915', 'F1916', 'F1917', 'F19180', 'F19182', 'F19221', 'F19222', 'F19231', 'F19232', 'F1924', 'F1925', 'F1926', 'F1927', 'F19280', 'F19282', 'F19921', 'F19922', 'F19931', 'F19932', 'F1994', 'F1995', 'F1996', 'F1997', 'F19980', 'F19982'
	Alcohol-induced mental disorders	'291', 'F10121', 'F1014', 'F1015', 'F10180', 'F10182', 'F10221', 'F10231', 'F10232', 'F1024', 'F1025', 'F1026', 'F1027', 'F10280', 'F10282','F10921', 'F1094', 'F1095', 'F1096', 'F1097', 'F10980', 'F10982'
	Other nonorganic psychoses	'2980', '2981', '2982', '2983', '2984', '2988', '2989', 'F323', 'F333', 'F28', 'F4489', 'F23', 'F29'
	Delusional disorders	'2970', '2971', '2972', '2973', '2978', '2979', 'F22', 'F24', 'F23'
	Schizophrenic disorders	'2950', '2951', '2952', '2953', '2954', '2955', '2956', '2957', '2958', '2959', 'F2089', 'F201', 'F202', 'F200', 'F2081', 'F2089', 'F205', 'F259', 'F209'

Appendix Table 9 Continued

	ICD-9/ICD-10 codes
Substance use disorders (SUD)	'3041', '3042', '3043', '3044', '3045', '3046', '3048', '3049', '3052', '3053', '3054', '3056', '3057', '3058', '3059', 'F121', 'F122', 'F131', 'F132', 'F141', 'F142', 'F151', 'F152', 'F161', 'F162', 'F181', 'F182', 'F191', 'F192'
Alcohol use disorders (AUD)	'291', '303', '3050', 'F101', 'F102'
Any history of SUD/AUD	'965', '966', '967', '968', '969', '970', '971', '972', '973', '975', '977', '980', '989', '303', '304', '305', 'F10', /*'F11',*/ 'F12', 'F13', 'F14', 'F15', 'F16', 'F17', 'F18', 'F19', 'T39', 'T40', 'T41', 'T42', 'T43', 'T48', 'T51', 'T65'

ICD-9: International Classification of Diseases, 9th Revision

ICD-10: International Classification of Diseases, 10th Revision

Appendix Table 9 Predicted Probabilities for Initial Opioid Fill among PA Medicaid Beneficiaries 2012-2017

Variable	Predicted probability [95% CI]
Likelihood of pain low	2.43 [2.40-2.47]
Likelihood of pain moderate	8.27 [7.90-8.64]
Likelihood of pain high	31.76 [31.63-31.90]
Gender	
Female	12.72 [12.64-12.81]
Male	12.79 [12.73-12.85]
Age in years, categories	
12-15	3.30 [3.23-3.37]
16-22	13.85 [13.73-13.97]
22-29	17.60 [17.46-17.74]
30-39	16.72 [16.58-16.86]
40-49	15.08 [14.91-15.25]
50-59	13.49 [13.31-13.67]
60-64	11.56 [11.29-11.82]
Race and ethnicity	
White non- Hispanic	12.87 [12.80-12.95]
Black non-Hispanic	13.93 [13.82-14.03]
Hispanic	10.99 [10.85-11.12]
Other	10.26 [10.06-10.46]
Categories of Assistance	
Children and families, no	12.46 [12.36-12.56]
Children and families, yes	13.02 [12.93-13.12]
Disabled/ Chronically ill, no	13.01 [12.94-13.09]

Appendix Table 10 Continued

Variable	Predicted probability [95% CI]
Disabled/ Chronically ill, yes	12.22 [12.09-12.35]
Expansion, no	12.63 [12.56-12.70]
Expansion, yes	13.10 [12.97-13.23]
Region	
South east	11.07 [11.00-11.15]
South west	14.98 [14.86-15.11]
Lehigh/ Capitol	13.25 [13.12-13.37]
North east	12.27 [12.12-12.42]
North west	14.65 [14.49-14.81]
Comorbidities	
Musculoskeletal pain conditions, no	12.73 [12.67-12.79]
Musculoskeletal pain conditions, yes	12.84 [12.75-12.92]
Mental conditions no	12.77 [12.71-12.82]
Mental conditions yes	12.75 [12.62-12.88]
Alcohol use disorder no	12.77 [12.72-12.82]
Alcohol use disorder yes	12.24 [11.86-12.61]
Substance use disorder no	12.81 [12.76-12.86]
Substance use disorder yes	11.32 [11.02-11.63]
Any history of AUD/SUD no	12.61 [12.56-12.66]

Appendix Table 10 Continued

Any history of AUD/SUD yes	14.36 [14.16-14.56]
Benzodiazepine use no	12.69 [12.63-12.74]
Benzodiazepine use yes	13.59 [13.41-13.77]

Predicted Probabilities were derived from multivariable logistic regression models that allow for clustering at the patient level. All models controlled for year fixed effects.

Comorbidities were measured in the 180 days prior to the index date

Appendix Table 10 Predicted Probabilities for Subsequent Short-term Opioid Use (4-90 days Post Index Procedure) Stratified by Likelihood of Pain Associated with the Procedure, Likelihood of Pain Moderate and High were Combined into the High Category (N=436,500)

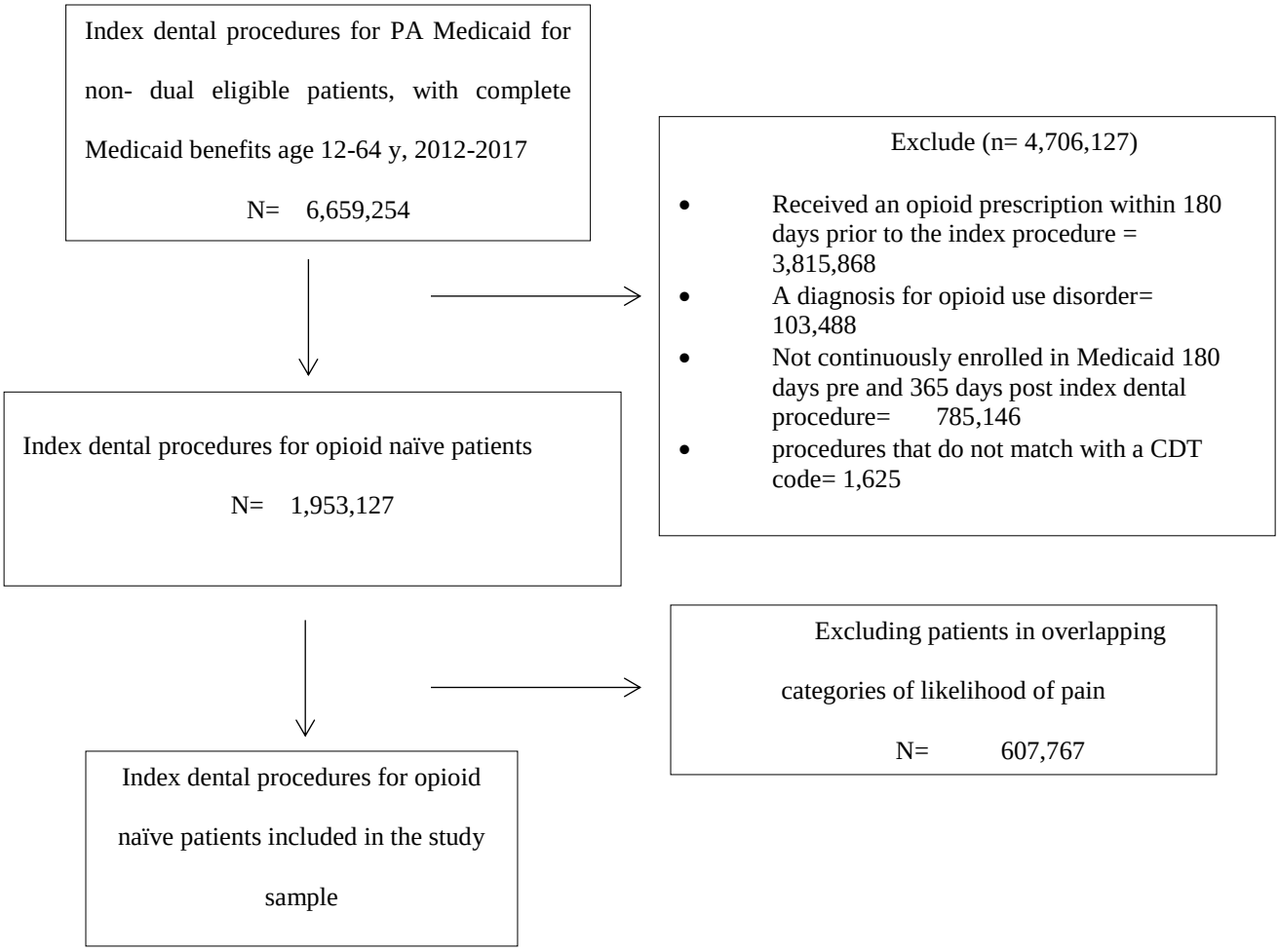
Variable	Likelihood of pain low	Likelihood of pain high
	Predicted probability [95% CI]	Predicted probability [95% CI]
Initial opioid fill, No	0.93 [0.91-0.956]	2.80 [2.74- 2.87]
Initial opioid fill, Yes	25.03 [24.47-25.60]	13.53 [13.34-13.70]
Male	1.76 [1.72-1.81]	6.98 [6.89-7.15]
Female	1.76 [1.73-1.79]	7.02 [6.89-7.15]
Age in years, categories		
12-15	0.30 [0.28-0.33]	1.94 [1.82-2.07]
16-21	1.49 [1.43-1.54]	4.64 [4.50-4.77]
22-29	2.54 [2.46-2.63]	7.98 [7.80-8.16]
30-39	2.67 [2.58-2.76]	9.11 [8.91-9.30]
40-49	2.44 [2.33-2.55]	9.00 [8.75-9.22]
50-59	2.38 [2.26-2.50]	8.73 [8.47-9.00]
60-64	2.05 [1.87-2.22]	7.63 [7.22-8.04]
Race and ethnicity		
White non- Hispanic	1.93 [1.90-1.97]	7.34 [7.23-7.65]
Black non-Hispanic	1.74 [1.69-1.78]	7.06 [6.92-7.20]
Hispanic	1.33 [1.27-1.40]	5.77 [5.55-5.98]
Other	1.31 [1.22-1.41]	5.32 [5.02-5.63]

Appendix Table 11 Continued

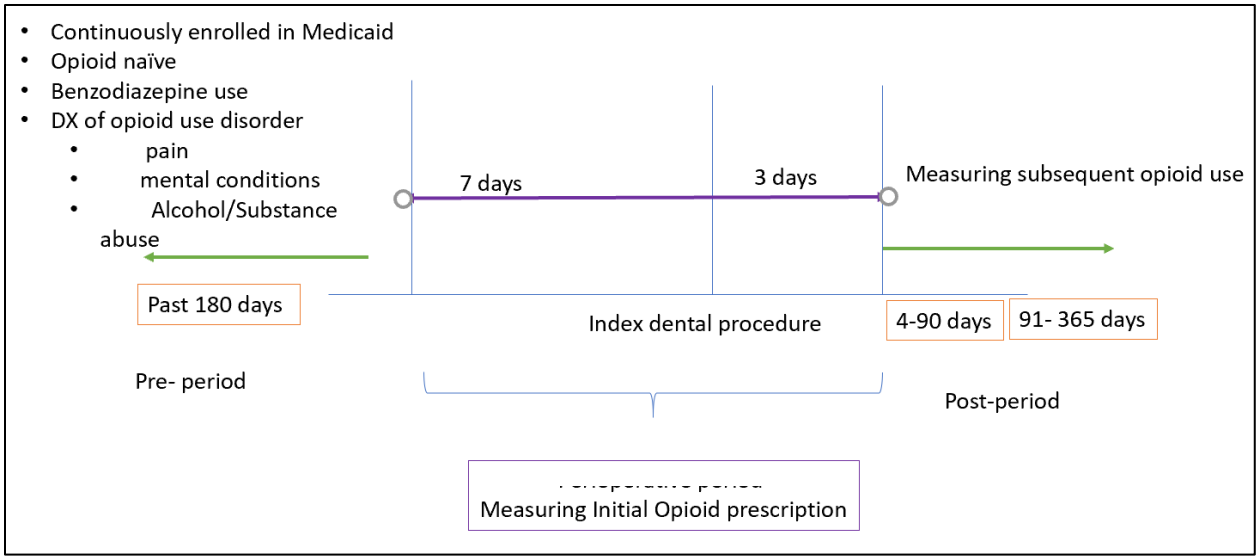
Variable	Likelihood of pain low	Likelihood of pain high
	Predicted probability [95% CI]	Predicted probability [95% CI]
Category of assistance		
Children and families no	1.76 [1.71-1.82]	7.00 [6.75-7.03]
Children and families yes	1.76 [1.72-1.81]	7.10 [6.95-7.24]
Disabled/ Chronically ill no	1.81 [1.77-1.84]	7.04 [6.92-7.16]
Disabled/ Chronically ill yes	1.67 [1.61-1.74]	6.91 [6.72-7.10]
Expansion no	1.72 [1.67-1.74]	6.94 [6.84-7.04]
Expansion yes	1.93 [1.86-2.00]	7.13 [6.94-7.32]
Region		
South east	1.50 [1.46-1.54]	6.82 [6.69-6.95]
South west	2.30 [2.23-2.37]	8.76 [8.59-8.94]
Lehigh/ Capitol	1.72 [1.66-1.77]	5.56 [5.39-5.72]
North east	1.65 [1.58-1.72]	5.83 [5.62-6.03]
North west	2.01 [1.92-2.09]	7.28 [7.07-7.49]
Musculoskeletal pain conditions no	1.71 [1.68-1.74]	6.91 [6.82-7.00]
Musculoskeletal pain conditions yes	1.87 [1.83-1.92]	7.14 [7.02-7.27]

Appendix Table 11 Continued

Variable	Likelihood of pain low	Likelihood of pain high
	Predicted probability [95% CI]	Predicted probability [95% CI]
Mental conditions no	1.76 [1.73-1.79]	6.93 [6.85-7.04]
Mental conditions yes	1.79 [1.72-1.85]	7.29 [7.10-7.48]
Alcohol use disorder (AUD) no	1.76 [1.74-1.79]	6.97 [6.90-7.05]
Alcohol use disorder (AUD) yes	1.72 [1.54-1.90]	7.90 [7.32-8.41]
Substance use disorder (SUD) no	1.76 [1.74-1.79]	6.97 [6.90-7.05]
Substance use disorder (SUD) yes	1.75 [1.59-1.90]	7.54 [7.08-8.00]
Any history of AUD/SUD no	1.72 [1.70-1.75]	6.91 [6.83-6.99]
Any history of AUD/SUD yes	2.17 [2.06-2.28]	7.66 [7.39-7.92]
Benzodiazepine use no	1.76 [1.73-1.79]	6.90 [6.82-6.97]
Benzodiazepine use yes	1.80 [1.72-1.88]	7.82 [7.57-8.07]



Appendix Figure 3 Cohort Build



Appendix Figure 4 Defining the periprocedural period

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