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Dissertação de Mestrado

Inequalities in dental pain: Evidences from a systematic review and a longitudinal study

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Notas Preliminares

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Resumo

A dor dental, uma condição debilitante influenciada por diversos determinantes sociais, é um problema significativo de saúde pública, com impactos profundos na qualidade de vida dos indivíduos. Esta dissertação examinou o efeito das desigualdades sociais, raciais e de gênero na prevalência de dor dental por meio de uma revisão sistemática com meta-análise e uma análise longitudinal utilizando dados da coorte de nascimentos de 1982 de Pelotas. A revisão incluiu 18 estudos observacionais, identificados em seis bases de dados até fevereiro de 2024, e mostrou que indivíduos de baixa renda têm 79% maior chance de relatar dor dental (OR=1,79; IC 95%: 1,39–2,30), enquanto baixa escolaridade aumentou o risco em 27% (OR=1,27; IC 95%: 1,06–1,52). Minorias raciais enfrentaram um risco 26% maior (OR=1,26; IC 95%: 1,18–1,33), com diferenças significativas entre subgrupos. A análise longitudinal, com dados de 607 participantes da coorte de 1982 de Pelotas, identificou duas trajetórias de dor dental: baixa prevalência (46,7%) e alta prevalência (53,5%). Homens apresentaram maior probabilidade de seguir a trajetória de baixa prevalência (56,2%) em comparação às mulheres (48,8%), enquanto negros (58,1%) e indígenas (70,0%) tiveram maior prevalência de dor, em contraste com brancos (54,5%). Medidas de desigualdade indicaram reduções significativas na dor dental associadas à renda familiar (SII: −0,17; IC 95%: −0,31 a −0,04; p=0,012; CIX: −0,06; IC 95%: −0,11 a −0,01; p=0,013) e escolaridade materna (SII: −0,15; IC 95%: −0,29 a −0,01; p=0,036; CIX: −0,06; IC 95%: −0,10 a −0,01; p=0,024). Assim, esta dissertação fornece evidências robustas sobre os mecanismos que influenciam as inequidades na dor dental. Os resultados evidenciam que políticas públicas com o objetivo de melhorar a saúde bucal da população não podem deixar de enfrentar as inequidades produzidas pelo sistema de exploração que estamos inseridos para obter êxitos na melhora das condições de saúde bucal.

Palavras chaves: Dor dental, Desigualdades sociais, Disparidades em saúde, Estudo longitudinal, Revisão sistemática.

Abstract

Dental pain, a debilitating condition influenced by various social determinants, represents a significant public health issue with profound impacts on individuals' quality of life. This dissertation examined the effect of social, racial, and gender inequalities on the prevalence of dental pain through a systematic review with meta-analysis and a longitudinal analysis using data from the 1982 Pelotas Birth Cohort. The review included 18 observational studies, identified across six databases up to February 2024, and revealed that individuals with low income were 79% more likely to report dental pain (OR=1.79; 95% CI: 1.39–2.30), while low education increased the risk by 27% (OR=1.27; 95% CI: 1.06–1.52). Racial minorities faced a 26% higher risk (OR=1.26; 95% CI: 1.18–1.33), with significant differences observed between subgroups. The longitudinal analysis, which utilized data from 607 participants of the 1982 Pelotas Cohort, identified two trajectories of dental pain: low prevalence (46.7%) and high prevalence (53.5%). Men were more likely to follow the low-prevalence trajectory (56.2%) compared to women (48.8%), whereas Black (58.1%) and Indigenous (70.0%) participants experienced higher prevalence of dental pain in contrast to White participants (54.5%). Measures of inequality indicated significant reductions in dental pain associated with household income (SII: −0.17; 95% CI: −0.31 to −0.04; p=0.012; CIX: −0.06; 95% CI: −0.11 to −0.01; p=0.013) and maternal education (SII: −0.15; 95% CI: −0.29 to −0.01; p=0.036; CIX: −0.06; 95% CI: −0.10 to −0.01; p=0.024). Thus, this dissertation provides robust evidence on the mechanisms influencing inequalities in dental pain, highlighting that public policies aimed at improving oral health cannot succeed without addressing the inequities perpetuated by the systemic structures of exploitation.

Key-words: Dental pain, Social inequities, Health disparities, Longitudinal study, Systematic review.

Summary

Introduction

Dental pain is a debilitating condition and a significant public health concern due to its high prevalence and negative impact on physical, psychological, and social well-being. Globally, it affects a considerable proportion of individuals, particularly children and adolescents, with prevalence estimates reaching 32.7% (Pentapati et al., 2021). The repercussions of dental pain extend beyond physical discomfort, encompassing reduced academic performance (Ab Malek et al., 2024), increased reliance on emergency services (Yang et al., 2016), and high treatment costs (Pentapati et al., 2021). These impacts are more pronounced among vulnerable and marginalized groups, including ethnic and racial minorities, low-income individuals, and those with lower educational attainment (Costa et al., 2022; Silva de Pinho et al., 2012).

Social and structural determinants play a pivotal role in perpetuating inequalities in oral health, with dental pain often associated with poverty, racial discrimination, and limited education (Constante et al., 2012; Bastos et al., 2020). Children from impoverished families are more likely to grow up in substandard housing conditions, which negatively affect their overall development and health, with consequences that persist into adulthood (Ghorbani et al., 2017). Furthermore, individuals with lower income and formal education levels are less likely to seek preventive care, exacerbating adverse oral health outcomes (Constante et al., 2016).

Racism, as a fundamental determinant of health inequities, operates at structural, individual, and psychosocial levels, reflecting deeply entrenched historical processes. It impacts oral health through factors such as chronic stress, social exclusion, discrimination, and unequal access to healthcare services (Phelan & Link, 2015; Calvasina, Muntaner & Quiñonez, 2015). Studies consistently demonstrate that racial and ethnic minorities exhibit higher prevalence rates of dental pain, highlighting the disproportionate burden of these inequalities (Rauber et al., 2021; Goes et al., 2007). Similarly, prolonged exposure to poverty and socioeconomic deprivation contributes to worsening disparities over the life course (Kuh, Ben Shlomo & Ezra, 2004; Ghorbani et al., 2017).

Longitudinal approaches, such as trajectory analyses, provide valuable tools for examining how cumulative life-course exposures shape health outcomes

(Jamieson, Steffens & Paradies, 2013). Despite this, few studies have comprehensively explored how social, racial, and gender inequalities interact to influence the prevalence of dental pain in adults, particularly in low- and middle-income contexts (Celeste et al., 2013). Most research focuses on single time points or short-term outcomes, failing to capture the dynamic and cumulative nature of oral health disparities (Santos et al., 2022).

In this context, the present study aims to investigate dental pain in adults by examining how social, racial, and gender inequalities influence its prevalence over the life course, using data from the Pelotas birth cohort in Brazil and a systematic review. By exploring these associations, the study seeks to provide evidence to inform the development of interventions and policies that promote greater equity in health.

2 Dissertation Proposal

2.1 Introduction

Dental pain is described as the painful sensation resulting from the loss of integrity in dental tissues (**Trowbridge**, 1986), usually caused by the progression of dental caries (Y**u**; **Abott**, 2018). This condition affects approximately 32.7% of the worldwide population (**Pentapati**; Y**eturu**; S**iddiq**, 2021). Dental pain prevalence is not equally distributed among the general population, showing higher rates in vulnerable social groups. This asymmetric distribution is directly associated with social and ethnic-racial inequalities, which play a crucial role in the manifestation of dental pain (B**astos**; G**igante**; P**eres**, 2008).

The relationship between the high prevalence of dental pain and socially vulnerable groups underscores the need to understand the mechanisms that inequities influence dental pain (B**astos** et al., 2007). This understanding is essential for the development of public policies directed to reduce inequities and consequently improve the oral health of marginalized individuals. The reduction of dental pain can positively impact the quality of life of these populations since that is associated with difficulties in eating and chewing, reduced sleep (P**inho** et al., 2012), lower academic performance, and school absenteeism (R**uff** et al., 2019) and related to frequent visits to emergency services (C**urrie** et al., 2017).

Although several studies evaluate dental pain through cross-sectional studies (Costa et al., 2022; García-Cortés et al., 2020; Salehi et al., 2023), there are still few longitudinal studies assessing the effect of inequities on dental pain throughout life (Riley; Gilbert; Heft, 2003; Tickle; Blinkhorn; Milsom, 2008; Vargas et al., 2022). In this context, a life course approach can offer valuable insights into the pathways that inequalities influence dental pain in the life course. This approach integrates temporal aspects across one’s lifespan, providing a comprehensive perspective on oral health (Buka; Rosenthal; Lacy, 2017). Therefore, this study aims to analyze the impact of social, ethnic-racial, and gender inequities on dental pain through different analytical and study design approaches.

2.2 Objective

Analyze the effect of social, racial, and gender inequities on dental pain.

2.2.1 Specific Objectives

- Summarize the available evidence about the effect of social, racial, and gender inequities on dental pain in adults through a systematic review and meta-analysis.

- Investigate the effect of inequalities (social, racial, and gender) on dental pain trajectory from 24 to 40 years old in a birth cohort in Brazil.

2.3 Justification

Several studies have investigated dental pain across different age groups using cross-sectional approaches (Costa et al., 2022; García-Cortés et al., 2020; Salehi et al., 2023) and few studies (Riley; Gilbert; Heft, 2003; Tickle; Blinkhorn; Milsom, 2008; Vargas et al., 2022) assess the effect of inequalities on dental pain through longitudinal designs. Also, two systematic reviews have estimated the prevalence of dental pain without investigating the potential effects of inequalities on this outcome (Santos et al., 2021; Porporatti et al., 2023).

Life course epidemiology represents a crucial methodological approach for longitudinally understanding dental pain. Through this methodology, it becomes feasible to construct theoretical models that establish connections between physical and psychosocial exposures experienced at various life stages and their subsequent impact on health outcomes (Ben-Shlomo; Kuh, 2002; Kuh et al., 2003). Therefore, the use of a life course approach can improve the level of evidence about the effect of inequalities in dental pain experience. Dental pain is a debilitating condition that significantly reduces an individual's daily quality of life (Goes et al., 2008; Pinho et al., 2012), deeply influencing the social and economic aspects of many individuals (Pentapati; Yeturu; Siddiq, 2021). Therefore, individuals exposed to disadvantaged groups such as social, racial, and gender minorities can be disproportionately affected by dental pain (Braveman, 2006). Specific racial groups (Pascoe; Richman, 2009), distinct socioeconomic status (Sabbah et al., 2009), and gender differences (Read; Gorman, 2010) are linked to a wide range of psychosocial stressors in the life course that negatively impact the health and oral health outcomes.

We expected that our study improve the literature knowledge about effects of inequalities on dental pain and provide evidence to support policies to decrease any inequality detected

2.4 Literature Review

2.4.1 Physiology of Dental Pain

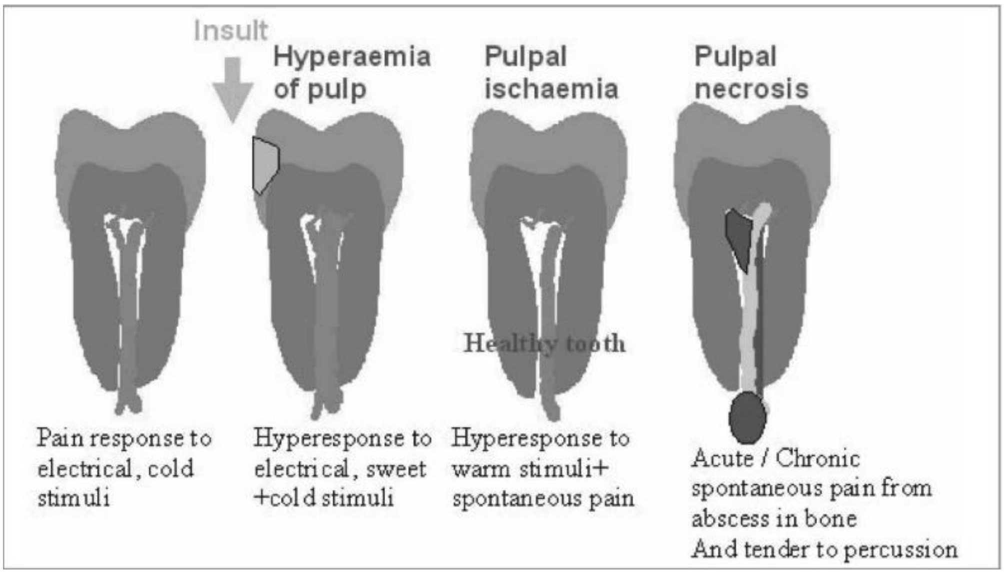
Toothache, also known as dental pain, originates from tissue, cellular, and biochemical processes that transduce nociceptive stimuli for pain recognition in the central nervous system (Trowbridge, 1986). The dentin-pulp complex, responsible for generating these painful stimuli, has an anatomy recognized for housing an extensive network of nerve fibers (A fibers, Aβ fibers, Aδ fibers, and C fibers) (Yu; Abbott, 2018). Type A fibers are found in the coronal odontoblastic layer, predentin, and internal dentin, while C fibers reside within the dental pulp proper and are frequently adjacent to the pulp's blood vessels; due to their variations, various forms of nerve impulse conduction are performed. This variety of fibers has a direct reflection on the clinical presentation of the painful sensation manifested by the affected individual (Yu; Abbott, 2018).

Pain is a complex experience influenced by social, psychological, and physiological circumstances. Pain can be described as a distressing experience associated with actual or potential tissue damage, encompassing sensory, emotional, cognitive, and social aspects (Williams; Craig, 2016). Thus, the mechanism culminating in the painful sensation results from the accumulation of various individual factors, compromising the integrity of the individual experiencing this condition (Rachlin, 2010).

2.4.2 Epidemiology of Dental Pain

Dental pain is predominantly triggered by the loss of dental tissue integrity or compromise of the neurovascular bundle in the periapical region due to pathological processes such as caries lesions or trauma (Yu; Abbott, 2018). The progression of caries lesions, when not reversed by preventive measures or dental interventions, leads to inflammation of the dental pulp, which can result in clinical manifestations of pain and edema, as exemplified by Figure 1, elaborated by (Renton, 2011), illustrating the evolution and consequent painful symptomatology related to caries disease, from transient and provoked pain to spontaneous pains.

Figure 1 - Diagram of caries lesion progression proposed by Renton, 2011



The implications of dental pain are wide, encompassing personal, economic, and social aspects. In children and adolescents, dental pain can affect their daily activities, with children suffering from toothache having a higher likelihood of lower academic performance (Goes et al., 2007), as well as experiencing disruptions in sleep and eating (Shepherd; Nadanovsky; Sheiham, 1999). It is also associated with family repercussions, such as caregivers missing work and financial complications (Goes et al., 2008). In adults, dental pain is linked to difficulties in eating and chewing, reduced sleep, as well as a considerable impact on social and functional roles (Pinho et al., 2012), leading to frequent visits to emergency services (Currie et al., 2017). There is a variation in the prevalence of dental pain among age groups; studies describe that in some samples, adults exhibit twice the dental pain compared to the elderly (Vargas; Macek; Marcus, 2000).

The incidence of dental pain emerges as a significant indicator of oral health, as this symptom can guide the development of strategies for dental treatment and prevention (Shepherd; Nadanovsky; Sheiham, 1999). High prevalence rates of dental pain are recognized in the Brazilian population, as evidenced by various studies: 33.9% in school populations (Goes et al., 2007), 22.0% in children (Ferreira-Júnior et al., 2015), and 24.3% in adult populations (Pinho et al., 2012). A systematic review on toothache demonstrated a global prevalence of 32.7% (Pentapati; Yeturu; Siddiq, 2021), as well as a meta-analysis has shown an overall prevalence of dental pain of approximately 36% in children and adolescents (Santos et al., 2022). Furthermore, the high prevalence rates of dental caries worldwide are reported by the WHO in 2022, with a rate of 42% in deciduous dentition and 29% in permanent dentition. In total terms, 2 billion people suffer from dental caries, affecting 514 million children in deciduous dentition (World Health Organization, 2022). These facts are intrinsically associated with the prevalence of dental pain, as it is highly linked to dental caries, some associations are described, like children and adolescents with dental caries presented a 3.49 times greater chance of experiencing dental pain than those without dental caries.

Epidemiological studies commonly establish correlations between dental pain and sociodemographic characteristics. It is well documented that in economically disadvantaged cities, there exists a heightened prevalence of dental pain. This prevalence is attributed to citizens facing elevated risks of oral diseases due to poorer dietary habits, inadequate oral hygiene practices, limited access to and utilization of fluorides, low rates of education, reduced access to and utilization of dental services (Ferreira-Júnior et al., 2015; Goes et al., 2007; Pentapati; Yeturu; Siddiq, 2021; Peres et al., 2012; Pinho et al., 2012). This highlights the relevance of social determinants for dental caries and consequently for dental pain in these population groups. A recent systematic review with meta-analysis identified an association between dental pain and a decrease in quality of life in adolescents and children (Barasuol et al., 2020). This relationship highlights the potential impact of dental pain on daily activities and the quality of life of individuals.

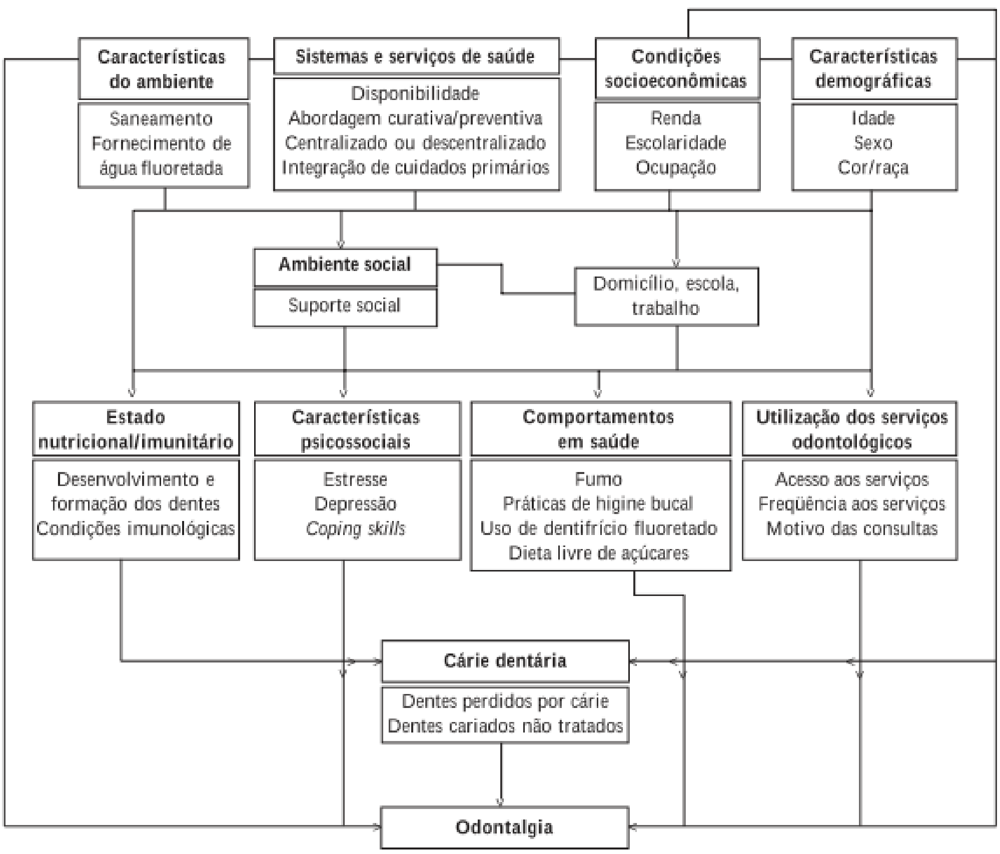
2.4.3 Social Determinants and Dental Pain

The transition of models understanding the health-disease process has increasingly led to the understanding that social characteristics influence the occurrence of diseases (Giovanella et al., 2012). Social determinants contribute to inequalities in exposure to health conditions, living circumstances, and access to the healthcare system (Bueno et al., 2014).

Actions aimed at oral health must be grounded in the principles of universality, comprehensiveness, equity, participatory management, ethics, access, welcoming, bond, and professional responsibility (Brasil; Ministério da Saúde, 2004). It is necessary to adopt a comprehensive approach, transitioning from a paradigm centered on disease and free demand to a comprehensive healthcare model, focusing on health promotion initiatives (Brasil; Ministério da Saúde, 2004). In this context, it is crucial to identify priority groups by understanding the epidemiological characteristics and social conditions of the population, known as Social Determinants of Health (SDH) (Brasil; Ministério da Saúde, 2004).

Theoretical formulations that reflect the complexity of social processes and a network of causes between aspects of social structure and health/disease are necessary to understand and combat health inequities. Studies have already developed conceptual and theoretical models for general health (World Health Organization, 2010), dental caries (Foley; Akers, 2019; Holst et al., 2001), and dental pain (Bastos et al., 2007), exemplified by Figure 2.

Figure 2 - Conceptual Model for Toothache by BASTOS et al 2007.



In this model that integrates dimensions of previously proposed models, it is considered that aspects of social structure, such as environment, health, socioeconomic conditions, and demography, influence the occurrence of dental pain. The social environment is an indirect pathway through which the social structure can affect dental pain. Additionally, there are other ways in which the social structure can influence the outcome, not represented in the figure, such as social influence, person-to-person contact, and social embedding. A direct pathway through which social structure can influence dental pain is through sanitation and the supply of fluoridated water, known to prevent dental caries. Demographic characteristics can modify social environments and directly impact dental pain through biological mechanisms, such as hormonal differences between men and women that can affect pain perception. The influence of healthcare systems and services on dental pain is mediated by the social environment in contexts such as home, school, and work. The conceptual model engages with previously elucidated concepts, contrary to the existing tendency to associate social conditions with individual diseases through isolated mechanisms at specific moments, resulting in the neglect of multifaceted and dynamic processes through which social factors can affect health, consequently leading to an incomplete understanding and underestimation of the influence of social factors on health (Link; Phelan, 1995). Therefore, this conceptual model denotes a complex influence of a variety of circumstances responsible for altering individuals affected by dental pain.

Negative influences due to discriminatory social patterns may be associated with worse quality-of-life relationships. It has been proposed that routine discrimination can become a chronic stressor that can erode an individual's protective resources and increase vulnerability to physical illnesses (Gee et al., 2007). Like other forms of accumulated stress, the perception of discrimination can lead to body wear and tear, as chronic overactivity or underactivity of allostatic systems produces an allostatic load (Seeman et al., 1997).

Dealing with experiences of discrimination can leave individuals with less energy or resources to make healthy behavioral choices (Pascoe; Richman, 2009). Research examining these pathways suggests that the perception of discrimination is related to health behaviors that have clear links to disease outcomes, such as smoking (Landrine; Klonoff, 1996), alcohol and substance abuse (Bennett et al., 2005), as well as non-participation in behaviors that promote good health, such as cancer screening, diabetes control, and condom use (Ryan; Gee; Griffith, 2008; Yoshikawa et al., 2004). Hence, inferring discriminatory situations in daily life may be associated with worse general health conditions and habits and consequently allied with poorer oral health habits and conditions.

2.4.4 Ethnic-Racial Inequalities and Dental Pain

It is important to highlight the conceptual differences associated with the discussion about race and ethnicity in epidemiological studies for a better characterization of the topic. Conceptually, the term "race" is mainly—and not adequately—used to refer to phenotypic characteristics that differentiate individuals, particularly emphasizing skin color (Kabad; Bastos; Santos, 2012). However, this categorization lacks many cultural and hereditary dimensions and even presents a significant limitation in considering additional characteristics (Alves; M Fortuna; Betânia Toralles, 2005). Furthermore, the concept of race does not apply to the human species, as there is no plausibility in the relationship of genetic variations sufficiently different for such classification (National Human Genome Research Institute, 2005). Therefore, race is a social construct used to distinguish individuals with differences in sociocultural backgrounds. Also, race does not present a relevant relationship with biological aspects and is understood only in a social aspect (Ford; Airhihenbuwa, 2010; Maio; Monteiro, 2005). In the present study, we will always consider race as a social construct.

The category of race should not be confused or equated with ethnicity. Racial groupings have their origins in geographic divisions determined by natural barriers such as oceans and mountains. In contrast, ethnic groups emerged within these racial categories due to variations in religion, cultural tradition, and/or language (Alves; M Fortuna; Betânia Toralles, 2005). Data related to ethnicity are of great utility for researchers in obtaining information about geographical provenance, migration patterns, residency, dietary choices, cultural elements, environmental circumstances, and ancestry, as these patterns can often imply different outcomes in analyses (Alves; M Fortuna; Betânia Toralles, 2005).

In the Brazilian context, the officially used ethnic-racial classification is based on the "race/color" criterion in the demographic census conducted by the Brazilian Institute of Geography and Statistics (IBGE), where people are categorized into five groups: white, black, brown, yellow, and indigenous (Osório, 2003). Many epidemiological studies are oriented based on this classification.

Racial discrimination stems from this racial construct and, as indicated in other studies, is associated with higher physiological stress responses, more negative psychological stress responses, increased engagement in unhealthy behaviors, and decreased participation in healthy behaviors due to a system perpetuating this discrimination (Pascoe; Richmann, 2009).

Racial inequalities in oral health refer to health disparities among groups defined based on ethnic-racial characteristics, often correlated with racial minorities experiencing worse overall health and oral health conditions (Guiotoku et al., 2012).

Moreover, these inequalities are frequently addressed in epidemiological studies on dental pain. Through these studies, a higher prevalence of dental pain in racialized groups can be observed. Higher prevalence rates of dental pain have been found in individuals with darker skin tones, including black, brown, and indigenous groups when compared to white individuals (Freire et al., 2012). There are also higher prevalence rates of seeking dental consultations due to pain among black individuals compared to white individuals (Cunha et al., 2022). A population-based cross-sectional study in Brazil identified a 50% higher prevalence in black individuals compared to white individuals (Kuhnen et al., 2009). It has also been noted that black individuals had a 30% higher prevalence of toothache compared to white individuals, regardless of the socioeconomic status indicator adopted for control in the analysis (Bastos; Gigante; Peres, 2008). More pronounced negative effects in daily life were also observed in groups that included black or multiracial individuals (Pinho et al., 2012).

When analyzing overall oral health conditions in racialized individuals, Bastos et al. (2009) described an unequal distribution of unfavorable oral health conditions in their study. They found an association where the darker the skin color, the higher the prevalence of unfavorable oral health conditions. These results support the need to investigate the distribution of health issues in epidemiological studies based on ethnic-racial characteristics, an approach previously highlighted by Chor and Lima (2005). Besides that, some authors highlighted a possible difference based on skin color may partially stem from residual confusion with socioeconomic variables or insufficient collection and analysis of race/skin color-associated factors along with socioeconomic conditions. However, they could also signal inequities in terms of racial access to and utilization of healthcare services, highlighting potential disparities in healthcare based on race (Peres et al., 2012). Hence, a longitudinal analysis could effectively mitigate residual confounding issues often associated with certain observational studies.

While analyzing these perspectives on inequities in racialized populations, there is extensive discussion regarding the implementation of policies and considerations of a history of policies for the better and appropriate confrontation of conditions and combating racism (Maio; Monteiro, 2005). However, there is still a considerable need to create new policies to reduce or eliminate these disparities.

2.4.5 Sex and Dental Pain

Gender refers to a social construct based on cultural conventions, attitudes, and relationships between men and women. Therefore, it is not a static category but is produced and reproduced through people's actions (Borrel; Artazcoz, 2007). Gender can vary from one society to another and also over time throughout history. On the other hand, sex refers to the physical, anatomical, and physiological differences between men and women (Krieger, 2001). Both gender and sex are interconnected with health, and this interaction occurs simultaneously. People do not live solely as one "gender" or one "sex," but rather as both simultaneously (Krieger, 2003).

Health inequalities can also involve gender and sex characteristics when considering oral health quality, access to oral health services, and the prevalence of dental pain. Women, when evaluated for positive oral health habits, exhibit better practices and oral health behaviors (Fukai; Takaesu; Maki, 1999), showing higher frequency in dental visits, use of dental floss, oral cancer examinations, restorations, and adherence to dentist recommendations (Su et al., 2022).

When evaluating the prevalence of dental pain, a higher prevalence of dental pain in the female sex compared to the male sex has been found (Bastos; Gigante; Peres, 2008; Kuhnen et al., 2009; Peres et al., 2010). In adolescents, it has been reported that females, both dark-skinned and light-skinned black individuals, as well as those with parents of low income and education levels, and those attending public schools, exhibited a higher prevalence of dental pain than their counterparts (Peres et al., 2010). It has also been found that females were more likely to report toothache across all age groups when compared to males; however, this relationship between sex and the prevalence of dental pain remains inconclusive (Bastos; Gigante; Peres, 2008). This inconclusive relationship is highlighted when examining other studies describing dental pain reports that did not find a statistically significant difference between males and females (Barrêtto; Ferreira, 2009; Vargas; Macek; Marcus, 2000). Moreover, this inconclusive relationship regarding gender also aligns with uncertainty about the association between a specific gender and increased susceptibility to dental caries (Martinez-Mier; Zandona, 2013).

To justify the difference between genders, there is a leaning among anthropologists towards explanations for the increased risk of caries in women related to behavioral factors, such as the division of labor by sex (Lukacs; Largaespada, 2006).

2.4.6 Socioeconomic Status and Dental Pain

The term "socioeconomic status" commonly refers to the relative positioning of individuals, families, or groups within stratified social systems (Hoff; Laursen; Tardif, 2002). Defined in this manner, the concept is encompassed by sociological principles such as social stratification and social inequality. Social inequality pertains to the fact that in nearly all societies, essential social values like education, occupation, economic resources, prestige, power, and information are not evenly distributed. On the other hand, social stratification relates to the arrangement of social systems (e.g., societies) where individuals, families, and groups are classified into hierarchies (e.g., social classes) based on their access to or control of education, wealth, prestige, power, and similar factors (Ribas et al., 2003).

Socioeconomic status covers more than just income; it also includes educational achievement, occupational prestige, and subjective perceptions of social status and class. It significantly influences health by shaping the environments where individuals live, work, and age, consequently impacting their vulnerability to different diseases. These intermediary factors involve living and working conditions, social networks and support systems (social capital), psychological aspects such as stress, and access to healthcare services (Peres et al., 2019).Furthermore, socioeconomic status can manifest in health behaviors, as elucidated by the Health Lifestyle Model formulated by Cockerham. This model suggests that lifestyle is influenced not only by individual choices but also by social structural elements like social class circumstances, gender, age, race, living conditions, and other factors (Cockerham, 2010). A healthy lifestyle denotes a collection of behavioral patterns individuals embrace to sustain and improve their overall well-being. These behaviors are influenced by specific norms, skills, and knowledge related to practices that contribute to good health, stress management, and personal satisfaction (Wang; Geng, 2019). Associations have been identified wherein poorer health-related behaviors tend to be more prevalent among individuals with lower levels of education and lower socioeconomic status (Sabbah et al., 2009). Some studies report income as the best single indicator of material living standards in health research (Galobardes et al., 2006). This is because income is indicative of the standard of living and life chances that individuals and households experience through sharing goods and services (Duncan et al., 2002).

The etiology of commonly prevalent oral conditions involves behavioral risk factors like inadequate diet, tobacco use, and increased stress levels, which exhibit variations based on income (Laaksonen et al., 2003; Lynch; Kaplan; Salonen, 1997). Income is recognized as a facilitator for accessing healthcare services (Van Doorslaer; Masseria; Koolman, 2006). Consequently, higher socioeconomic conditions are likely associated with improved health habits, lifestyle, and subsequently, better quality of life. Studies suggest that individuals with higher incomes tend to have better quality of life and oral health compared to those with lower salaries (Sfreddo et al., 2019).

As observed, a variety of characteristics contribute to an individual's condition, reflecting upon their oral health. Epidemiological surveys evaluating dental pain prevalence indicate that lower age, family income, and years of schooling correspond to higher reported rates of toothache (Kuhnen et al., 2009).

Furthermore, several other studies (Aranha et al., 2020; Barrêtto; Ferreira, 2009; Costa et al., 2022; Ferreira-Júnior et al., 2015; Hafner et al., 2013; Peres et al., 2010) have established a significant association between lower incomes and increased prevalence as well as a heightened risk of dental pain. Therefore, it is crucial to consider sociodemographic characteristics in the investigation of dental pain, as they markedly influence its prevalence and distribution within populations.

2.4.7 Measures of Health Inequality

Some definitions exist to assess what would be health inequities. In short, health inequities refer to the avoidable, unfair, and unjust differences that adversely affect 'disadvantaged nations and groups' within nations. This definition can be effectively communicated to policymakers, the public, and the lay press, at least where there is some degree of underlying consensus that not all groups in society have equal opportunities to be healthy (Braveman, 2006).

Given the unequal distribution of dental pain across society (Santos et al., 2022), quantifying this health inequality numerically holds the potential to greatly enhance evidence-based policymaking processes. Through the utilization of data to understand the impact of these inequalities on diverse populations, research can play a pivotal role in informing policy decisions (Brownson; Chriqui; Stamatakis, 2009).

In health inequality assessment, there exist both simple and complex measures. Simple measures include basic calculations like difference and ratio, while complex measures are applied to inequality dimensions involving more than two population subgroups. These complex measures take into consideration the circumstances across all population subgroups and may also consider the population share of each subgroup (Schlotheuber; Hosseinpoor, 2022).

Among the complex measures, the "Slope Index of Inequality" (SII) serves as an absolute measure calculated through regression analysis to assess inequality. It quantifies the disparity in estimated indicator values between the most advantaged and disadvantaged subgroup. This measurement accounts for circumstances across all other subgroups by employing a suitable regression model. Additionally, subgroups are weighted based on their respective shares within the population (Schlotheuber; Hosseinpoor, 2022).

Indeed, the Slope Index of Inequality (SII) has a range of potential values: positive, negative, or zero. A value of zero signifies the absence of inequality. Higher absolute values of the SII indicate increased levels of inequality. When the SII is positive, it indicates a concentration of the indicator among the advantaged group, while negative values indicate a concentration of the indicator among the disadvantaged group (Schlotheuber; Hosseinpoor, 2022).

The Relative Concentration Index (RCI) is a relative measure used to assess inequality, depicting the gradient observed across various subgroups within a population on a relative scale. It serves to illustrate the degree of concentration of an indicator among disadvantaged or advantaged subgroups, with the weighting of subgroups determined by their respective shares in the population (Schlotheuber; Hosseinpoor, 2022).

Interpretation of the RCI falls within the range of -1 to +1 (or between -100 and +100, when multiplied by 100), assuming a value of zero in the absence of inequality. Positive RCI values indicate a concentration of the indicator among advantaged subgroups, while negative values signify a concentration among disadvantaged subgroups. The magnitude of the RCI's absolute value correlates with the level of inequality: the greater the absolute value of RCI, the higher the inequality observed (Schlotheuber; Hosseinpoor, 2022).

The Absolute Concentration Index (ACI) represents an absolute measure employed to quantify inequality across population subgroups, portraying the degree of concentration of an indicator among disadvantaged or advantaged subgroups on an absolute scale. The weighting of subgroups is determined by their respective shares within the population (Schlotheuber; Hosseinpoor, 2022).

The interpretation of the ACI involves a value of zero indicating the absence of inequality. Positive ACI values suggest an indicator concentration among advantaged subgroups, while negative values imply a concentration among disadvantaged subgroups. Additionally, the magnitude of the ACI's absolute value correlates positively with the level of observed inequality: a higher absolute value of ACI signifies a greater level of inequality (Schlotheuber; Hosseinpoor, 2022).

These approaches are valuable for assessing the extent of socioeconomic health disparities, facilitating comparisons across multiple groups, accounting for changes in group sizes over time, and reflecting both absolute levels of a health indicator and relative differences among social groups (Braveman, 2006).

2.4.8 Life Course Epidemiology

Life Course Epidemiology investigates how socially structured exposures during childhood, adolescence, and early adulthood affect the risk of diseases in later adulthood. Therefore, this approach can explain social inequalities in adult health and mortality (Kuh et al., 2003). A life course approach to health offers a conceptual and methodological framework to understand the multiple determinants of health and disease at different levels, integrated temporally throughout life (Buka; Rosenthal; Lacy, 2017). Thus, through life course epidemiology, it is possible to develop theoretical models that propose connections between physical and psychosocial exposures at different stages of life and their subsequent health outcomes (Ben-Shlomo; Kuh, 2002).

The epidemiology of dental caries can be analyzed through the life course epidemiology approach because it is a chronic disease with cumulative characteristics, measured in a valid and reliable manner, with high prevalence in the population, and is of great interest to public health (Nicolau et al., 2007). It is associated with the prevalence of odontogenic pain, as it reflects the aggravation of dental caries.

Dental caries, a prevalent dental condition, can affect individuals from early childhood to old age. Widely considered the most prevalent chronic disease during childhood, caries' prevalence tends to escalate with age due to its cumulative nature (Bernardi; Spini; Oris, 2015). The Global Burden of Disease (GBD) 2010 Study highlighted untreated caries in permanent teeth as the most widespread global condition, impacting around 35% of the world's population (Marcenes et al., 2013).

Despite their high prevalence, caries are largely preventable but display a distinct social pattern, disproportionately impacting disadvantaged and lower-income groups (Hobdell et al., 2003). Significantly, consistent and gradual social gradients are observed in both clinical and subjective oral health outcomes across an individual's lifespan (Sheiham et al., 2011). Thus, the application of Life Course Epidemiology methodology could effectively assess and elucidate patterns of dental pain occurrence throughout individuals' lives..

2.5 Methodology

2.5.1 Article 1 - **Iniquities in the prevalence of dental pain in adults: A systematic review and meta-analysis**

Introduction

Justification for the Review

The repercussions of dental pain are widely recognized, encompassing physical, social, financial, and psychological aspects (PINHO et al., 2012). Additionally, the literature has described the association between dental pain and factors such as socioeconomic deprivations, ethnic-racial differences, and gender inequalities (PAU et al., 2003; BASTOS et al., 2008; CONSTANTE et al., 2012; ARANHA et al., 2020).

While some systematic reviews, such as that by (SANTOS et al. 2021), focused on the prevalence of dental pain in children, we note an ongoing systematic review protocol (PORPORATTI et al., 2023) aimed at evaluating the prevalence of dental pain in adults. However, to date, no study has proposed to analyze how social, racial, and gender inequities specifically affect the prevalence of dental pain in adults. Therefore, it is essential to conduct a comprehensive analysis of available evidence to understand how these inequities impact the prevalence of dental pain in adults and to identify the most affected groups. This will contribute to directing the development of specific and effective public policies in this area.

Objectives

To systematically review the literature to investigate how social, racial, and gender inequities are related to the prevalence of dental pain in adults and the elderly.

Methodology

Review Question

What is the effect of inequities (social, racial, and gender) on the prevalence of dental pain in adults?

Participants/Population

Inclusion:

- Adults (≥ 18 years old)

Exposure

Disadvantaged Groups: For racial exposure, we will consider dark skin color as well as the grouped category of all racial minorities. For gender, exposure will be considered as the female sex. Regarding socioeconomic factors, we will focus on groups with lower socioeconomic levels, and for educational level, exposure will refer to strata with fewer years of schooling.

Comparison/Control

As comparison groups, we will consider the most advantaged social groups and create a category encompassing all strata that are not disadvantaged. Thus, for racial characteristics, the control will be individuals with white skin color; for gender, it will be male; for socioeconomic and educational factors, it will be the most advantaged groups with higher levels and in the upper strata.

Context

The prevalence of dental pain and related experiences can substantially vary based on individuals' sociodemographic, socioeconomic, racial, and gender characteristics. These social inequities in oral health have increasingly become the focus of research to understand and address disparities that may impact access to dental services and oral health across different population groups.

Outcome

Odontogenic dental pain.

This protocol was drafted following reporting recommendations according to PRISMA-P (MOHER et al., 2015) and will be registered on the PROSPERO platform.

Eligibility Criteria

This systematic review will include observational studies, including cross-sectional and cohort studies, addressing the prevalence of dental pain in individuals aged 18 years or older (adults and the elderly), provided they are representative of the studied population. For studies employing sample analysis, only those reporting the sampling process and its representativeness of the population will be included. Exclusion criteria encompass studies exclusively assessing dental pain prevalence in children, studies conducted on animals, those where the prevalence of dental pain is not clearly reported or calculable, studies not specifically focused on assessing dental pain (such as those investigating overall orofacial pain, mouth pain, or gum pain), and study types not falling under the category of observational studies, such as reviews, case reports/series, protocols, expert opinions, letters, and protocols. There will be no language, publication location, or publication date restrictions.

Sources of Information

Electronic searches will be conducted in December 2023 across the following databases: PubMed (National Library of Medicine), Web of Science (Clarivate Analytics), Scopus (Elsevier), Embase (Elsevier), LILACS (Biblioteca Virtual em Saúde), and SciELO (Scientific Electronic Library Online). Grey literature will be reviewed using Google Scholar, filtering the first 100 results listed by relevance. Additionally, abstracts and proceedings from the last 5 years of the International Association for Dental Research (IADR) will be assessed. After the complete reading and selection of included articles, an analysis of the reference lists of the included articles and relevant reviews found during the search will be conducted. Their titles will be evaluated, and those deemed by the reviewers to meet the inclusion criteria will subsequently be analyzed by reading the abstract and full text. Articles meeting the inclusion criteria that have not been included through the database search will be added for review. For studies where full texts are unavailable for analysis, the authors of the studies will be contacted via the corresponding author's email up to 3 times, with intervals of 1 month between contact attempts, to potentially obtain the studies.

Search Strategy

The search strategy was developed according to the PECO acronym. Keywords and related terms were selected and combined using boolean operators. The following search strategy will be tailored for each database involving specific descriptors related to the research question. The blocks #1, #2, #3 e #4 will be combined using the boolean operators "AND" for the research process.

Boolean operator	Search terms	Blocks
-	(Adult) OR (Adults) OR (Young Adult) OR (Older Adult) OR (Middle Aged) OR (Middle Age) OR (Aged) OR (Elderly)	#1
AND	(Toothache) OR (Toothaches) OR (Odontalgia) OR (Odontalgias) OR (Dental pain)	#2
AND	(Observational Study) OR (Prevalence) OR (Prevalences) OR (Incidence Proportion) OR (Incidence Proportions) OR (Proportion, Incidence) OR (Retrospective studies) OR (Studies, Retrospective) OR (Study, Retrospective) OR (Retrospective Study) OR (Prospective studies) OR (Prospective Study) OR (Studies, Prospective) OR (Study, Prospective) OR (Cohort Studies) OR (Cohort Study) OR (Studies, Cohort) OR (Study, Cohort) OR (Incidence Studies) OR (Incidence Study) OR (Studies, Incidence) OR (Study, Incidence)	#3

Data Management

After conducting the search in each database, the articles' listings containing the title and abstract will be imported into the reference manager Mendeley Desktop® (Mendeley Ltda, Relx Group™ Elsevier, London, UK). Upon importing all lists, these will be compared, and duplicates will be removed, generating a single file that will be imported into the Rayyan application (Ouzzani et al., 2016).

Study Selection Process

The selection will occur in two phases, individually, by two researchers simultaneously (1R and 2R). In the first phase, both researchers, using the Rayyan application (Ouzzani et al., 2016), will independently review titles and abstracts of all references, applying eligibility criteria. If the title/abstract meets the criteria, the study will proceed to the second phase, where criteria will be applied to the full text of the articles. Disagreements between reviewers will be resolved through discussion with a third researcher (LAC). The second phase will involve a full-text reading, and reapplying the eligibility criteria; any disagreements between researchers will again be resolved by another researcher (LAC). Reasons for exclusion will be recorded at each phase.

Obtaining the full text for analysis will be done through the University Federal de Pelotas proxy; when not possible, a request for the text will be made using the COMUT system. If the text is still unavailable after the system's request, contact with the authors will be attempted. Reasons for exclusion will be recorded at each phase. Additionally, Cohen's kappa values for agreement between reviewers will be obtained in both phases.

Data Collection Process

Two researchers will independently and simultaneously collect data from the included articles in duplicate into a spreadsheet using Microsoft® Excel® software for Microsoft 365 MSO (Version 2310 Build 16.0.16924.20054). Upon completing the data collection, the authors will compare the information, and in case of disagreement during the data verification, a third researcher will resolve it. If any relevant information is unavailable in the study, contact with the authors will be made. For duplicated studies or those evaluating the same population, they will be analyzed based on publication date and sample size. For selection, only the study with the largest sample size will be included for analysis, and if the sample sizes are equal, the most recent publication will be included. In cases where the selected study does not contain all exposure variables, the study with a smaller sample size for that exposure may be included, while maintaining the larger sample study for other exposures.

Data Items

The following data, when available, will be obtained from each included study: author, study design, year, country of publication, country of study application, sample size, and prevalence ratio of dental pain according to sex, income, race, and level of education, diagnostic criteria, overall prevalence of dental pain, and the timeframe in which this pain was evaluated. We will consider all the different instruments used to measure the outcome. Typically, odontogenic dental pain is collected through a closed question where the participant is asked if they had dental pain (yes or no) in a specific period (last week, last month, last six months, for example). We will consider all periods presented in the studies and conduct subgroup analysis, if possible, to stratify the results by different periods. When necessary, means and measures of error will be approximated from presented numbers. If prevalence ratios are not provided, they will be manually calculated. If Odds Ratios are presented, the prevalence ratio will be estimated using the formula: PR = Odds Ratio / (1 - risk0 + risk0 × Odds Ratio), where risk0 is the prevalence of dental pain among unexposed individuals.

Risk of Bias Assessment

The analysis of methodological quality and bias control of eligible studies will be performed using the ROBINS-E tool, suitable for all epidemiological studies independently and concurrently by two reviewers (1R and 2R). Any disagreements between the two examiners will be resolved by a third reviewer (3R).

Data Synthesis

The data will be presented through qualitative descriptions, and when possible, a meta-analysis will be conducted. Quantitative synthesis will be performed through meta-analyses using RStudio 3.3.0 software (RStudio Team, MA, USA). For the meta-analysis, absolute and relative prevalence values of dental pain between exposed and unexposed groups will be extracted from the included studies. Since socioeconomic and demographic variables often belong to the same hierarchical level in multivariate analysis, raw data of variables will be included to avoid collinearity effects in the measure of association. If hierarchical models present results by blocks, adjusted results will be included. The combined results will be presented as prevalence ratios with their respective 95% confidence intervals. Estimates or absolute values will be appropriately converted into prevalence ratios if necessary. In longitudinal studies, only the most recent outcome will be included in the analysis. A meta-analysis will be conducted for each exposure (sex, race, education, and socioeconomic level). The extremes of dental pain within each group will be graphically presented using an equiplot (http://www.equidade.org/equiplot). The prevalence of dental pain will also be estimated through a meta-analysis using random effects.

Prevalence ratios will be grouped using random models since epidemiological studies present substantial heterogeneity. Meta-analyses may be stratified (subgroup analysis) by the duration of dental pain assessment and the population (adults and the elderly). Sensitivity analyses will investigate the influence of each study on the pooled result. A funnel plot and Egger's test will be used to assess any possible publication bias. Meta-regression analysis will be conducted to identify and explain potential sources of heterogeneity among the included studies. Meta-regression analyses will be performed using a random-effects model. Methodological characteristics will be included in the multivariate regression model. Variable selection will be performed using a backward stepwise approach, and those with a p-value <0.20 will be retained in the final model.

Assessment of the Certainty of Evidence

The evaluation of evidence quality for all outcomes will be conducted using the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) working group methodology. Evidence quality will be assessed considering the following domains: risk of bias, consistency, direction, precision, and publication bias. Additional domains may be considered in appropriate situations. The quality of evidence will be categorized into four levels: high, moderate, low, or very low. All studies included in the meta-analysis will be evaluated for the quality of evidence.

2.5.3 Article 2 – **Inequalities in the life course on dental pain trajectory in adults: A birth cohort study**

The present study will be reported according to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) for cohort studies.

Study design, setting, and participants

The information that will be utilized in this study is from oral health studies originating from follow-ups conducted at the ages of 15, 24, 31, and 40 years within the 1982 birth cohort from the city of Pelotas-RS, Brazil. In 1982, all children born in the three existing maternity hospitals in Pelotas were identified. The 5,914 live-born children underwent measurements and weighing at the maternity ward, while their mothers were assessed and interviewed through a structured questionnaire containing inquiries about socioeconomic and demographic factors, as well as pregnancy and maternal health data.

The initial oral health assessment started in 1997, during which 70 out of the 265 census tracts in the city were systematically selected, constituting approximately 27% of households. Subsequently, a systematic search was conducted for adolescents born in 1982 within the chosen sectors, resulting in the identification of 1076 individuals. From this pool, a probabilistic sample of 900 adolescents was randomly extracted. Within this survey, oral health examinations, comprising a questionnaire and dental assessments, were conducted on 888 adolescents. Subsequent oral health surveys within this sub-sample of the cohort took place at the ages of 24 (720 members examined), 31 (539 members examined), and 40 years (463 members examined).

Outcome:

The outcome of the present study will be the trajectory of the dental pain occurrence in the last four weeks collected in each wave of the study (15, 24, 31, and 40 years). Dental pain was collected through the questions: “Have you had a toothache in the last 4 weeks?” (yes/no). The dental pain collected at the studied ages was organized as a dichotomous variable a group-based trajectory modeling was used to identify groups with similar trajectories of dental pain in the life course. The model will be estimated using the command “traj” in Stata 16.0 (Dennis et al., 1981; Jones; Nagin, 2007; Silva et al., 2018) to identify the similarity of the trajectory among evaluated individuals. The parameters for the model trajectory will be determined based on the maximum likelihood by the quasi-Newton method (Jones; Nagin, 2007). The number of trajectories will be determined by sequential comparisons of the Bayesian information criterion (BIC) and its fit criteria when substantial differences between the K and K + 1 trajectory model will not be produced in the k + 1 model BIC score.

Co-variables

Sex was collected at birth (male/female). Self-reported skin was assessed at 24 years according to the official classification of the Brazilian Institute of Geography and Statistics (IBGE - Instituto Brasileiro de Geografia e Estatística) (REFERENCE) through the question: “What is your color or race?” a) White, b) Black, c) Brown, d) Yellow, and e) American Indigenous and will be dichotomized into: a) white, and b) racial minorities (black, brown, yellow, and american indigenous).

The educational level at 31 years of age was collected in years and later categorized into three groups (≥ 12; 9 to 11 and ≤ 8 years). The maternal educational level at birth was collected in years and will be categorized into three groups (≥ 12; 9 to 11 and ≤ 8 years). The variable 'family income at birth' was recorded using the Brazilian minimum wage as the unit, and will be categorized into groups (≤1, 1.1-3.0, 3.1-6.0, 6.1-10, and >10).

Statistical Analysis

The statistical analysis will be performed utilizing Stata 16.0 Software (StataCorp., College Station, TX, USA). This study will employ a descriptive analysis, presenting frequencies of the outcome based on sex, skin color self-reported, education level at 31 years, maternal education at birth, and family income at birth using equiplots (http://www.equidade.org/equiplot) and Fisher's exact statistical test.

Two inequality indicators (Slope Index of Inequality and Concentration Index) will be used for ordinal stratifies, i.e., Education level at 31 years, Maternal education at birth, and Family income at birth. The Slope Index of Inequality (SII) is an absolute inequality index and the Concentration Index (CIX) is a measure of relative inequality. The SII quantifies absolute inequality in percentage points (pp), representing the absolute difference in predicted values of a health indicator between the most and least favored individuals in terms of socioeconomic indicators. The SII considers the entire distribution through an appropriate regression model. On the other hand, the CIX gauges relative inequality, akin to the Gini index for income concentration. It indicates the extent to which a distribution deviates from complete equality. Statistical significance will be set at $p < 0.05$, where the p-value signifies the likelihood that the index differs from zero (indicating no inequality), along with 95% confidence intervals (95% CI).

Discriminant ability through the Decision Trees algorithm will be performed using a decision trees model (GLMM trees) (Fokkema 2020) in Rstudio software. This approach will be employed for modeling the discriminative ability of the co-variables to discriminate the trajectory of dental pain. We will use the following co-variables in this model: sex, skin color self-reported, education level at 31 years, maternal education at birth, and family income. We anticipate encountering imbalanced classes in our outcome. If this is confirmed in the data, we plan to address it by applying Random Over-Sampling Examples (ROSE) to our training data. To evaluate the discriminant accuracy of pruned trees, we will employ a 10-fold cross-validation procedure. The dataset will be randomly divided into training sets ($n = 9$) for model training, and a testing set will be reserved to assess the predictive performance of the tree model. Each of the 10 folds (sets) will serve as the testing set during specific iterations.

The performance of decision trees will be assessed through predictions, and the receiver operating characteristic (ROC) curve (AUROC) statistic will be subsequently calculated. An AUROC between 0.7 and 0.79 was considered useful, while ≥0.8 was deemed excellent (Giannini et al., 2006). Additional evaluations, including ROC curves, sensitivity, and specificity, will be conducted. In alternative analyses, rather than using the 10-fold cross-validation, we will employ an external validation approach by randomly dividing the dataset into separate subsets, with one designated for model training (70% of the data) and the other for validation (30%).

Ethical approval

Approval for the study was granted by the Human Research Ethics Committee of the Faculty of Medicine of the Federal University of Pelotas under protocol number 384.332. All participants provided informed consent, and measures were in place to ensure participant anonymity.

2.6 Schedule

Project Stages	**2nd Semester 2023**	**1st Semester 2024**	**2nd Semester 2024**	**1st Semester 2025**
Topic selection	X			
Literature review and analysis	X			
Project writing	X			
Dissertation proposal qualification	X			
Data collection		X		
Data evaluation		X		
Statistical and computational analysis		X		
Dissertation and scientific article writing			X	X
Dissertation defense				X

2.7 Financing

This dissertation project was developed with the support of the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES), and the resources required for the next stages are described below.

2.8 Budget

Material	Quantity	Unit price	Total
Computer	1	**R$ 3.500,00**	**R$ 3.500,00**
English language revision	1	**R$ 400,00**	**R$ 400,00**
Commute	10	**R$ 5,00**	**R$ 50,00**
A4 sheet	2 packs of 500 sheets	**R$ 10,00**	**R$ 20,00**
Printing	200 folhas	**R$ 0,20**	**R$ 40,00**

* The above costs will be covered by the researchers themselves..

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3. Field Report

During the development of the systematic review, a change was made to the tool used for risk of bias assessment. Initially, the ROBINS-E tool was adopted for this purpose. However, after a thorough re-evaluation, it was decided to replace it with the Critical Appraisal Tools from the Joanna Briggs Institute (JBI) to ensure better methodological alignment with other studies and current best practices.

Regarding the decision tree analysis conducted using data from the Pelotas Birth Cohort, significant limitations were identified. After constructing the model, its predictive performance was evaluated using the area under the ROC curve (AUC). The AUC value obtained was below 0.7, which is considered inadequate for a reliable predictive model. Due to this unsatisfactory performance, the analysis was discarded, as it did not meet the minimum criteria required to support valid or relevant conclusions within the context of the study.

4. Article 1

Iniquities in the prevalence of dental pain in adults: A systematic review and meta-analysis[1]

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Abstract

This systematic review and meta-analysis aim to investigate the influence of social, racial, and gender inequities on the prevalence of dental pain in adults and the elderly. Observational studies (cross-sectional, longitudinal, and cohort) reporting the effect of inequalities (income, education, race, and gender) on dental pain prevalence in individuals aged 18 years or older were included. A comprehensive search was conducted in six databases (PubMed/Medline, Scopus, Web of Science, LILACS, SciELO, and Embase) up to February 2024. Out of 2,944 identified records, 18 studies were included in the review and meta-analysis, comprising 145.253 participants. Most of the studies presented a cross-sectional design (n=16; 90%), and all studies presented low bias risk. Meta-analysis revealed that individuals from lower income groups had 79% higher odds of dental pain (OR=1.79; 95% CI: 1.39–2.30), while lower educational levels increased the odds by 27% (OR=1.27; 95% CI: 1.06–1.52). Racial minorities showed 26% higher odds of experiencing dental pain (OR=1.26; 95% CI: 1.18–1.33), with significant variations across subgroups. No statistical difference was observed between the groups for sex (OR=1.06, CI 95% [0.98–1.14]). Egger's test shows no reporting bias for income (p=0.074), education level (p=0.429), race (0.206), and sex (p=0.162). In meta-regression, income heterogeneity was fully explained by country of study application and sample size (R^2=100.0%); education by year and design (R^2=39%); sex by country (R^2=76.5%). These findings highlight the substantial impact of inequities on oral health and emphasize the need for targeted interventions and policies to address dental pain disparities.

Keywords: Systematic Review, Toothache, Inequalities

1-This article will be submitted for review to the journal *Community Dentistry and Oral Epidemiology*. The manuscript has been prepared in accordance with the journal's submission guidelines.

Introduction

Dental pain is a significant public health issue with a high prevalence (1) often leading to an increased demand for dental services (2) and adversely affecting individuals' quality of life (3,4). Its prevalence is markedly higher among vulnerable and marginalized social groups (5,6). The repercussions of dental pain are broad and multifaceted, encompassing physical, social, financial, and psychological dimensions (7). Moreover, the literature has consistently highlighted its association with social determinants such as socioeconomic deprivations, and ethnic-racial differences (8–10).

Social and racial factors are identified as distal variables to explain the inequalities in dental pain (11). These inequalities are rooted in centuries of exploitation systems of unfavored populations, leading nowadays to a low family socioeconomic status (12,13) which can persist in the life course (13). It explains part of the social and racial segregation observed in modern societies (14). Children from impoverished families are more likely to grow up in substandard housing conditions, which detrimentally impact their development and health (15), with consequences that extend into adulthood (16). These associations are partly explained by the prolonged latency periods of chronic diseases, including oral conditions, and their multifactorial etiology (17).

Racism is known as a fundamental cause of inequalities in health (18). It functions across structural, individual, and social-psychological levels, reflecting deep-rooted socio-historical processes such as slavery (19). The link between racism and health inequities extends beyond socioeconomic status, incorporating factors such as power, prestige, neighborhood dynamics, stigmatization, discrimination, autonomy, and social connections, all of which independently shape disparities in oral health (19). These mechanisms likely influence the prevalence of dental pain, with recent studies (20–22) suggesting that discrimination acts as a psychological stressor underpinning racial inequalities.

While systematic review (23) has focused on the prevalence of dental pain in children, an ongoing systematic review protocol (24) aims to evaluate the prevalence of dental pain in adults, the interplay between social, racial, and gender inequities, and dental pain remains underexplored. To date, no study has comprehensively examined how these inequities shape the prevalence of dental pain in adults, leaving a critical gap in understanding the broader societal and structural determinants of oral health disparities. This gap is particularly significant given the well-documented impact of social determinants on health outcomes, which disproportionately affect vulnerable populations (25). By systematically analyzing the relationship between social, racial, and gender inequities and the prevalence of dental pain, this review seeks to provide evidence that can inform targeted interventions and policies. Understanding these associations is essential to addressing oral health disparities and improving health equity, particularly in the context of aging populations and increasingly diverse societies. Therefore, this systematic review aims to investigate if social, racial, and gender inequities influence the prevalence of dental pain in adults and the elderly.

Methodology

Protocol and registration

This systematic review was registered to PROSPERO (registration number: CRD42024499902). This systematic review was drafted according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses/Scoping Reviews) guidelines (26).

Review question

The research question - "What is the effect of inequities (social, racial, and gender) on the prevalence of dental pain in adults?" - was structured following the PECO model:

Population: Individuals aged 18 years or older.

Exposition: We considered four expositions in the study: income, education, race, and gender. For income, the exposition was the group with a lower income level. For education, the exposure was defined as the strata with fewer years of schooling. For race, it was considered each skin color as well as the grouped category of all racial minorities. For gender, exposure was considered as the female sex.

Comparison: For income, was considered the most advantaged income group. For education, the strata with higher years of education. For race, the control was individuals with white skin color. For gender, the control was the male group.

Outcome: The outcome of dental pain was considered when assessed through structured questionnaires conducted via interviews. All times interval were considered for the analysis, and were grouped for the statiscal analysis.

Eligibility criteria

This systematic review included observational studies, including cross-sectional, longitudinal, and cohort studies, addressing the prevalence of dental pain in individuals aged 18 years or older (adults and the elderly), provided they were representative of the studied population. Only population-based studies reporting the sampling process were included. Exclusion criteria encompassed studies where the prevalence of dental pain was not clearly reported or calculable, and studies not specifically focused on assessing dental pain (such as those investigating overall orofacial pain, mouth pain, or gum pain). There were no language or publication period restrictions.

Information Sources

A comprehensive electronic search was carried out up to February 2024 across six databases, including PubMed, Web of Science, Scopus, Embase, LILACS, and SciELO. Following the complete review of included articles, reference lists from these articles and relevant reviews were analyzed. Titles meeting the inclusion criteria were further assessed through abstract and full-text readings. Additional articles not found in the initial search but meeting inclusion criteria were included. For studies lacking available full texts, authors were contacted up to three times, at one-month intervals. The search results were imported into Mendeley Desktop®, duplicates were removed, and the final list was processed in the Rayyan application.

Search Strategy

The search strategy was designed following the PECO acronym, utilizing keywords and related terms combined with Boolean operators. A tailored search strategy was created for each database, incorporating specific descriptors relevant to the research question. The blocks #1, #2, #3, and #4 were combined using the boolean operator "AND" as detailed in **supplementary table 1**.

Study Selection Process

The selection process was conducted in two phases by two researchers (AM and LF) independently. In the first phase, titles and abstracts were reviewed using the Rayyan application (27) and applied eligibility criteria. Studies meeting these criteria advanced to the second phase, where the full text was assessed. Disagreements were resolved with a third researcher (LC).

Data Collection Process

Two researchers independently collected data from the included articles, recording the information in duplicate using Microsoft Excel. Afterward, they compared the data, and any disagreements were resolved by a third researcher. If relevant information was missing, the study authors were contacted. For duplicated studies or those involving the same population, the selection was based on publication date and sample size. The study with the largest sample size was included; if sizes were equal, the most recent publication was selected. If the selected study lacked certain exposure variables, a smaller sample study might be included for those variables, while retaining the larger sample study for other exposures.

Data Items

The following data, when available, were obtained from each included study: author, study design, year, country of publication, country of study application, sample size, and prevalence ratio of dental pain according to sex, income, race, and level of education, diagnostic criteria, the overall prevalence of dental pain, and the timeframe in which this pain was evaluated. It was considered all the different instruments used to measure the outcome. Typically, odontogenic dental pain is collected through a closed question where the participant is asked if they had dental pain (yes or no) in a specific period (last week, last month, last six months, for example). When necessary, means and measures of error were approximated from presented numbers. If prevalence ratios are not provided, they will be manually calculated. If Odds Ratios are presented, the prevalence ratio will be estimated using the formula: PR = Odds Ratio / (1 - risk0 + risk0 × Odds Ratio), where risk0 is the prevalence of dental pain among unexposed individuals (28)

Risk of Bias Assessment

The analysis of methodological quality and bias control of eligible studies were performed using the Joanna Briggs Critical Appraisal Tools for each type of study design (Cross-sectional, longitudinal, and cohort by two reviewers (AM and LF.). Any disagreements between the two examiners will be resolved by a third reviewer (L.C.).

Data Synthesis

The data were analyzed qualitatively through meta-analyses using R language (RStudio Team, MA, USA). Since socioeconomic and demographic variables often belonged to the same hierarchical level in multivariate analysis, raw data of variables were included to avoid collinearity effects in the measure of association. If hierarchical models presented results by blocks, adjusted results were included. Prevalence ratios with 95% confidence intervals were calculated, converting estimates as needed. For longitudinal studies, only the most recent outcome was analyzed. Separate meta-analyses were done for each exposure (income, education, race, sex). Random-effects models were used due to a priori heterogeneity known in observational studies. Subgroup analysis was performed to stratify skin color for each racial group. Sensitivity analyses evaluated each study's impact, while a funnel plot and Egger's test assessed publication bias. Meta-regression was performed using random effects to identify potential heterogeneity sources; variable selection was based on a p-value <0.20.

Assessment of the Certainty of Evidence

The quality of evidence for all outcomes was assessed using the GRADE methodology, focusing on the risk of bias, consistency, direction, precision, and publication bias, with additional domains considered when relevant. Evidence was classified into four levels: high, moderate, low, or very low, and all studies in the meta-analysis underwent this evaluation.

Results

Study selection

The study selection flow diagram is shown in **Supplementary figure 1**. The search process identified a total of 2,944 studies, after the full assessment of eligibility criteria only 21 studies were included in this review, and only 18 studies were included in the meta-analysis. Although three studies met the inclusion criteria, the prevalence of dental pain for each inequity individually could not be calculated due to insufficient information, and attempts to contact the authors were unsuccessful; therefore, these studies were excluded (29–31). All the excluded articles by the full assessment were presented in **supplementary table 4.** Cross-sectional studies (n=16; 90%) were the most prevalent, followed by longitudinal (n=2; 14%). Most of the studies were from Brazil (n=6; 33%), followed by the United States (n=2; 11%), Iran (n=2; 11%), and South Korea (n=2; 11%). A total of 145.253 individuals were included. Characteristics and data extracted from of each included study are provided in **Supplementary table 1**.

Risk of bias assessment

The methodological quality of the studies is displayed **in Table 1** (cross-sectional studies) and **Table 2** (longitudinal studies). All the included studies showed a low risk of bias.

Table 1 - Risk of Bias Assessed by the Joanna Briggs Institute Critical Appraisal Checklist for prevalence studies

Authors	Q.1	Q.2	Q.3	Q.4	Q.5	Q.6	Q.7	Q.8	Q.9
Aranha et al., 2020	Y	Y	Y	Y	Y	Y	Y	Y	Y
Ardila & Agudelo-Suárez, 2016	Y	Y	Y	Y	Y	Y	Y	Y	Y
Bastos et al., 2008	Y	Y	Y	Y	Y	Y	Y	Y	Y
Chung et al., 2004	Y	Y	Y	Y	Y	Y	Y	Y	Y
Constante et al., 2012	Y	Y	Y	Y	Y	Y	Y	Y	Y
Constante et al., 2015	Y	Y	Y	Y	Y	Y	Y	Y	Y
Echeverria et al., 2020b	Y	Y	Y	Y	Y	Y	Y	Y	Y
Hafner et al., 2013	Y	Y	Y	Y	Y	Y	Y	Y	Y
Kakoei et al., 2013	Y	Y	Y	Y	Y	Y	Y	Y	Y
Kuhnen et al., 2009	Y	Y	Y	Y	Y	Y	Y	Y	Y
Leung et al., 2008	Y	Y	Y	Y	Y	Y	Y	Y	Y
Ligthart et al., 2014	Y	Y	Y	Y	Y	Y	Y	Y	Y
Momeni et al., 2016	Y	Y	Y	Y	Y	Y	Y	Y	Y
Vargas et al., 2000	Y	Y	Y	Y	Y	Y	Y	Y	Y
Wan et al., 2021	Y	Y	Y	Y	Y	Y	Y	Y	Y
Yang et al., 2016	Y	Y	Y	Y	Y	Y	Y	Y	Y

*The risk of bias was classified as high when the study reached up to 49% 'yes' scores, moderate when the study reached 50% to 69% 'yes' scores, and low when the study reached over 70% 'yes' scores. U: indicates unclear, S: yes, N: no. Q.1: Was the sample frame appropriate to address the target population? Q.2: Were study participants sampled in an appropriate way? Q.3: Was the sample size adequate? Q.4: Were the study subjects and the setting described in detail? Q.5: Was the data analysis conducted with sufficient coverage of the identified sample? Q.6: Were valid methods used for the identification of the condition? Q.7: Was the condition measured in a standard, reliable way for all participants? Q.8: Was there appropriate statistical analysis? Q.9: Was the response rate adequate, and if not, was the low response rate managed appropriately?

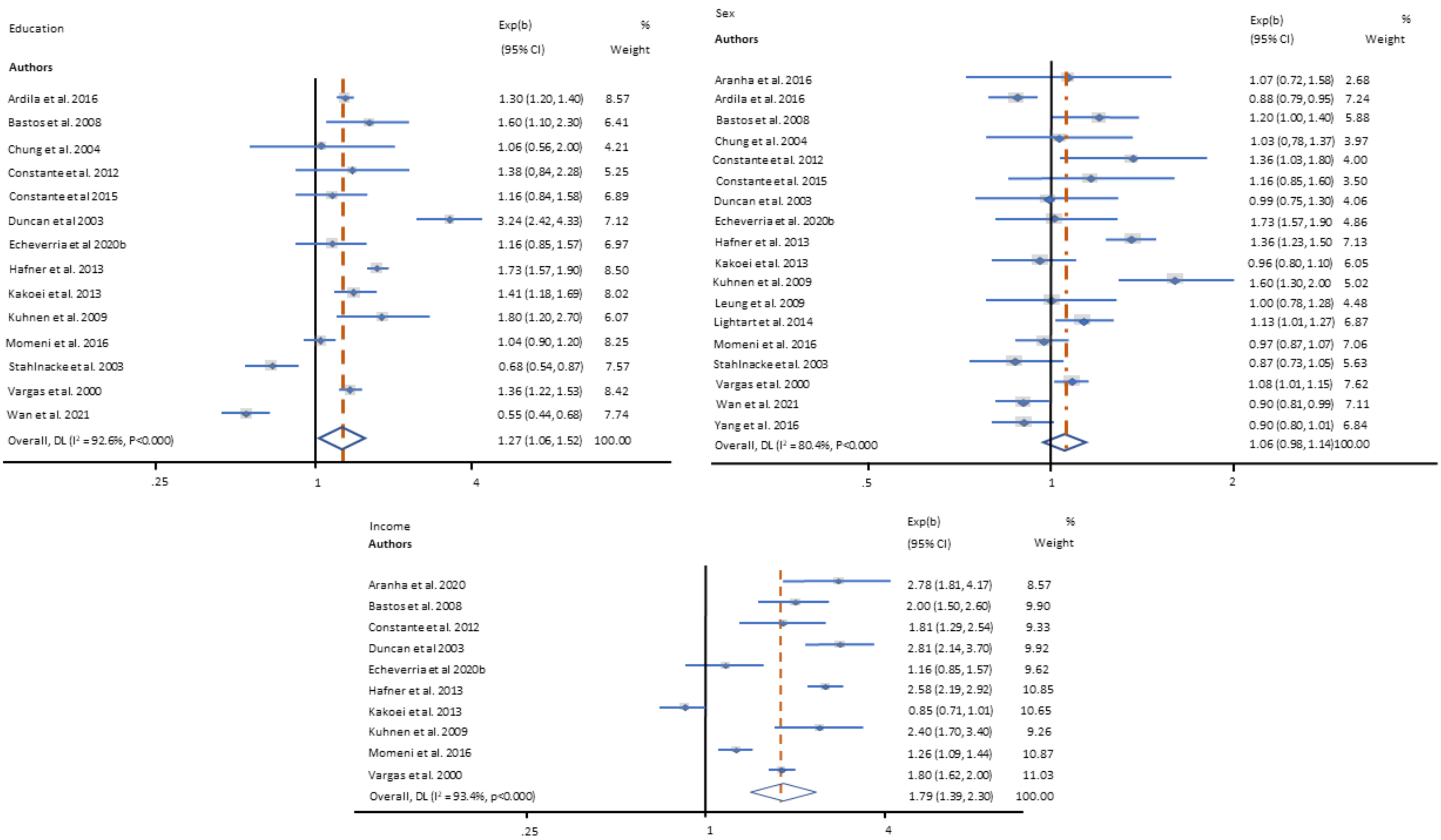
Table 2 - Risk of Bias Assessed by Joanna Briggs Institute critical appraisal checklist for cohort studies

Author/Year	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11
Duncan et al., 2003	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Stahlnacke et al., 2003	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

The risk of bias was classified as high when the study reached up to 49% 'yes' scores, moderate when the study reached 50% to 69% 'yes' scores, and low when the study reached over 70% 'yes' scores. U: indicates unclear, S: yes, N: no. Q.1: Were the two groups similar and recruited from the same population? Q.2: Were the exposures measured similarly to assign people to both exposed and unexposed groups? Q.3: Was the exposure measured in a valid and reliable way? Q.4: Were confounding factors identified? Q.5: Were strategies to deal with confounding factors stated? Q.6: Were the groups/participants free of the outcome at the start of the study (or at the moment of exposure)? Q.7Were the outcomes measured in a valid and reliable way? Q.8: Was the follow up time reported and sufficient to be long enough for outcomes to occur? Q.9Was follow up complete, and if not, were the reasons to loss to follow up described and explored? Q.10: Were strategies to address incomplete follow up utilized? Q.11: Was appropriate statistical analysis used?

Result of synthesis

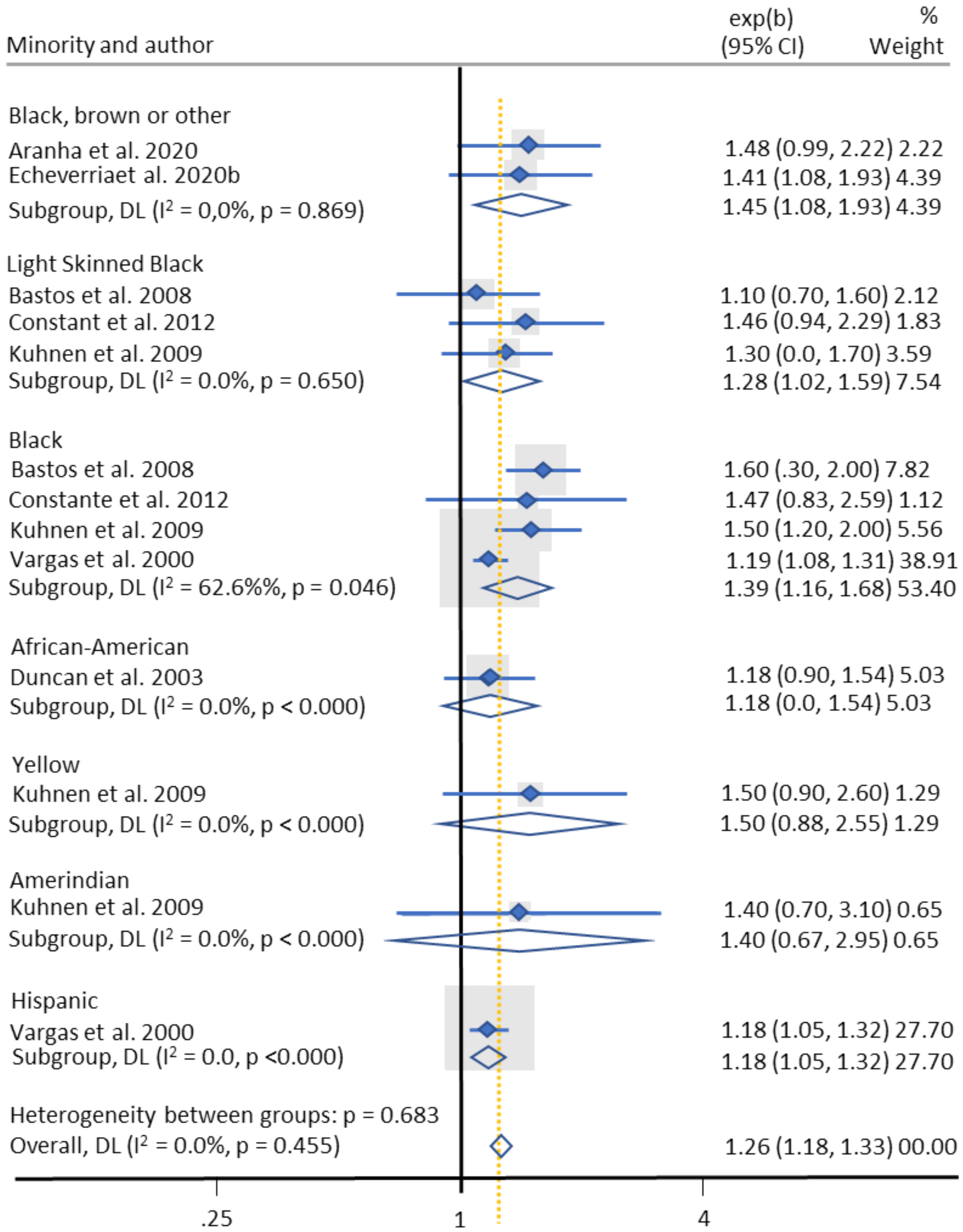
Figure 1: Forest Plot of Meta-Analysis Showing Odds Ratios (OR) and 95% Confidence Intervals (95% CI) for the Effects of Education, Sex, and Income on Dental Pain Prevalence in Adults and



Elderly Individuals.Interval (95%CI) of the effect of a) education, b) sex, and c) income on dental pain prevalence in adults and elders.

Figure 2: Forest Plot of Meta-Analysis Showing Odds Ratios (OR) and 95% Confidence Intervals

(95% CI) for the Effects of Race on Dental Pain Prevalence in Adults and Elderly Individuals stratified by different racial minorities.



Synthesis of results (meta-analysis)

Individuals from the lower income group were found to have 79% higher odds of experiencing dental pain compared to those in the highest income group (OR=1.79, CI 95% [1.39–2.30]). For income, sensitivity analysis showed that the pooled estimate remained stable upon excluding any individual study. Funnel plot analysis (**Supplementary figure 2**) suggested potential reporting bias, though this was not statistically confirmed by Egger's test (p=0.074).

Individuals with lower educational attainment were found to have 27% higher odds of experiencing dental pain compared to those in the highest income group (OR=1.27, CI95% (1.06–1.52). Sensitivity analysis for education showed that the pooled estimate changed upon the exclusion of any study.

Funnel plot analysis (Figure S2) suggested potential reporting bias, though this was not statistically confirmed by Egger's test (p=0.429).

For race, considering all the polls of racial minorities, we observed that racial minority groups presented 26% higher odds of dental pain compared to white individuals (OR=1.26 (1.18, 1.33). Moreover, in subgroup analysis considering each racial group, we observed that when individuals were Black, Brown, and other had 45% higher odds of dental pain than white individuals (OR=1.45, CI95%[1.08 -.193]), light-skinned Black had 28% higher odds of dental pain than white individuals (OR=1.28, CI95%[1.02 – 1.59]), Black individuals had 39% higher odds of dental pain than white individuals (OR=1.39, CI95%[1.16 – 1.68]). Sensitivity analysis for racial inequalities revealed that the pooled estimate remained consistent even after the removal of any individual study. Funnel plot analysis (Figure S2) indicated no reporting bias, a finding further corroborated by Egger's test (p=0.206).

No statistical difference was observed between the groups for sex (OR=1.06, CI 95% [0.98 – 1.14]). Funnel plot analysis (Figure S2) indicated some reporting bias for this group, although Egger's test (p=0.162) did not statistically confirm this.

Metaregression

The meta-regression for income demonstrated that the analyzed covariates (Country of study application and Sample size) fully accounted for the heterogeneity in the effects (R^2 = 100.0%). For education, “year” and “study design” accounted for 39.0% of heterogeneity (R^2 = 39.04%). No metareggression was performed for race group since I^2 was zero. For sex, the “country” explained 76.5% of the heterogeneity. The meta-regression is shown in **supplementary table 3.**

Certainty of evidence

The certainty of evidence analysis revealed low certainty for all findings, indicating significant uncertainty regarding their accuracy and reliability. The limitations arose from the observational nature of our studies, potentially limiting the applicability of the results.

Discussion

This study represents a significant step forward in understanding the complex relationship between social, racial, and educational inequities and the prevalence of dental pain. By systematically analyzing data from 21 studies, we provide robust evidence that individuals from lower income and education groups, as well as racial minorities, face disproportionately higher odds of experiencing dental pain. Sensitivity analyses strengthen the robustness of our results for income and race showing a consonance between data with low bias risk. Although most of the evidence was provided from cross-sectional studies, all included studies were population-based, which strengthens the external validity of the review's conclusions. These findings underscore the unfair impact of structural inequalities on oral health outcomes (32). The results highlight that public policies aimed at decreasing dental pain in adults must address also the social and racial inequities to achieve success.

This study has several limitations that should be acknowledged. First, most included studies analyzed racial characteristics using broad categories, such as "non-white individuals," which may oversimplify the complex and diverse experiences of racial groups and mask significant intra-group variations. To address this limitation, we conducted a subgroup analysis to differentiate between racial groups and quantify the effect for each group individually. Similarly, while the studies captured the variable of sex, they did not concurrently consider gender, potentially obscuring inequities across diverse gender identities and expressions. The reliance on observational studies introduces the possibility of residual confounding, as unmeasured variables may have influenced the reported associations. The cross-sectional design of the majority of included studies further limits causal inference. Geographically, most of the studies were conducted in South America, North America, and Europe, which restricts the generalizability of the findings to countries outside these regions. Sensitivity analysis highlights the significant influence of each included study, which should be taken into consideration during data interpretation, as the exclusion of even a single study could alter the results. It was not possible to assess the intersectionality within the samples, which represents a significant limitation, as inequities rarely occur in isolation but rather as a result of complex interactions among various social, economic, and cultural factors. Furthermore, varying time intervals were consolidated for the evaluation of dental pain, as certain studies examined the preceding six months, the past year, and the previous day. Additionally, the findings related to educational level do not appear to be particularly robust, as the sensitivity analysis showed that excluding any single study would alter the observed result.

Despite these limitations, the study presents strengths that enhance its value and impact. It provides a systematic and comprehensive synthesis of data from 18 studies, offering robust evidence on the associations between social determinants, such as income, education, and race, and the prevalence of dental pain. By integrating sensitivity analyses and rigorous risk-of-bias assessments, the review ensures a high degree of methodological rigor, bolstering the reliability of its findings. Moreover, the inclusion of multiple dimensions of inequality allows for a wide perspective, addressing gaps left by previous reviews that often focused narrowly on singular factors or specific populations. The study may also contribute actionable insights that can inform targeted interventions and policy changes, with the ultimate goal of reducing oral health inequities and promoting health equity on a global scale. This integrative approach positions the study as a valuable resource for guiding public health strategies and advancing the field of oral health research.

Our findings reveal that income is significantly associated with the experience of dental pain, corroborating existing literature (5,10,28). Poorer individuals face greater challenges in accessing dental services and tend to use them less frequently (29). These economic disparities contribute to unhealthy behaviors, creating and perpetuating a cycle of poor health outcomes among low-SES populations (30). In contrast, higher income facilitates access to health services, and on a global scale, countries with higher per capita income allocate more resources to oral health (31). This pattern is reflected at the individual level, where economically vulnerable populations encounter significant barriers to regular dental service use. Moreover, limited access to fluorides and infrequent dental service utilization within this group increase their susceptibility to severe dental caries and, consequently, dental pain (32).

Education, on the other hand, plays a crucial role in fostering skills and traits that promote improved health outcomes (33). Conversely, poor health often disrupts educational attainment due to challenges such as learning disabilities, absenteeism, and cognitive disorders (34). Higher educational levels are particularly beneficial for oral health, as they are associated with better hygiene practices, healthier habits, and greater access to dental care (35). Education also influences the utilization of dental services, with individuals possessing higher educational attainment more likely to seek preventive care, which aids in early problem detection and reduces the risk of pain. In contrast, those with lower educational levels often rely on emergency dental services, a pattern linked to a higher prevalence of pain and adverse oral health conditions (36).

The findings of our study underscore the persistence of ethnic and racial inequities in the prevalence of dental pain (6). The meta-analysis further revealed that individuals with darker skin tones experience a higher prevalence of dental pain, emphasizing how health systems often mirror societal structures and perpetuate the health inequities faced by populations subjected to racial discrimination (37). Contributing factors to these disparities include the limited availability and high costs of quality health services (38), language barriers (39), and lack of cultural competence among healthcare providers (40). Discrimination exacerbates these challenges by negatively affecting patient trust, preferences, and service utilization, with ethnic minorities frequently encountering mistrust and discouragement in healthcare settings (41). Racism impacts oral health by restricting access to quality care, inducing psychosocial stress that influences behaviors and clinical outcomes, and weakening the provider-patient relationship (42). Addressing these inequities requires equity-oriented health systems that actively confront racial discrimination while promoting multisectoral actions to dismantle systemic barriers. For racial health inequalities to emerge, societal structures must devalue certain groups by appropriating their contributions, assigning dehumanizing labels, and denying access to positions of power and symbolic resources (43).

Although the protocol aimed to assess gender inequities, all included studies evaluated only biological sex. None of the studies addressed gender as a broader construct. The measurement of sex inequities in these studies relied on data related to biological sex, which, while highlighting certain disparities, does not adequately capture the experiences of diverse gender identities. (44). Gender functions as a social system that defines men and women as different and allocates power, resources, and status based on these distinctions (45). The results of this review showed no statistically significant difference in the prevalence of dental pain between genders. This finding appears robust, supported not only by the meta-analysis but also by the absence of reporting bias and the sensitivity test. Despite this topic having been controversial in the literature, the data provided by this systematic review indicate that such differences may not exist in dental pain prevalence. Through the aggregation provided by the meta-analysis, we were able to synthesize this information and observed that there seems to be no association. Although this study did not observe statistical differences between sexes, gender inequalities are widely acknowledged as a significant challenge in global health (46). Restrictive gender norms influence health outcomes through differential exposures, health-related behaviors, and access to care, while gender-biased health research and healthcare systems further reinforce these inequities, often with severe implications for health (47). Women and gender minorities are particularly affected, as health systems frequently neglect their specific needs, thereby perpetuating disparities (48). Moreover, intersectionality compounds these issues by layering additional forms of discrimination, such as racism and classism, creating more complex disadvantages (49). Deeply entrenched gender norms are continuously reinforced, presenting significant obstacles to promoting gender equality and improving health outcomes (50).

Understanding the drivers of poor oral health and oral health inequalities at the population level is essential for developing effective policy responses. The association between socioeconomic factors and dental pain underscores the significant role of social inequalities in health care, as dental pain is closely tied to oral diseases, particularly dental caries (51). The high prevalence and intensity of reported pain among adults highlight the urgent need to raise awareness and foster early recognition of dental problems, shifting the focus toward prevention rather than the current reliance on emergency curative care in this segment of the population. Additionally, dental pain often serves as a reliable indicator of barriers to accessing costly dental services, further emphasizing the importance of addressing these structural challenges (52,53).

Health behaviors reflect a complex interplay between individuals and their contextual environments, shaped by social determinants such as societal institutions, prevailing ideologies, and entrenched inequalities. These behaviors not only contribute to health outcomes but also embody and reflect biosocial processes, illustrating the intricate relationship between individual actions and broader social dynamics (54).

Conclusion

This study demonstrates that dental pain is disproportionately experienced by social groups adversely affected by inequities. These inequities, rooted in structural determinants such as race, socioeconomic status, and educational attainment, underscore the critical need for the development of targeted public policies. Addressing these social and racial disparities through well-designed interventions is essential to mitigating the burden of dental pain.

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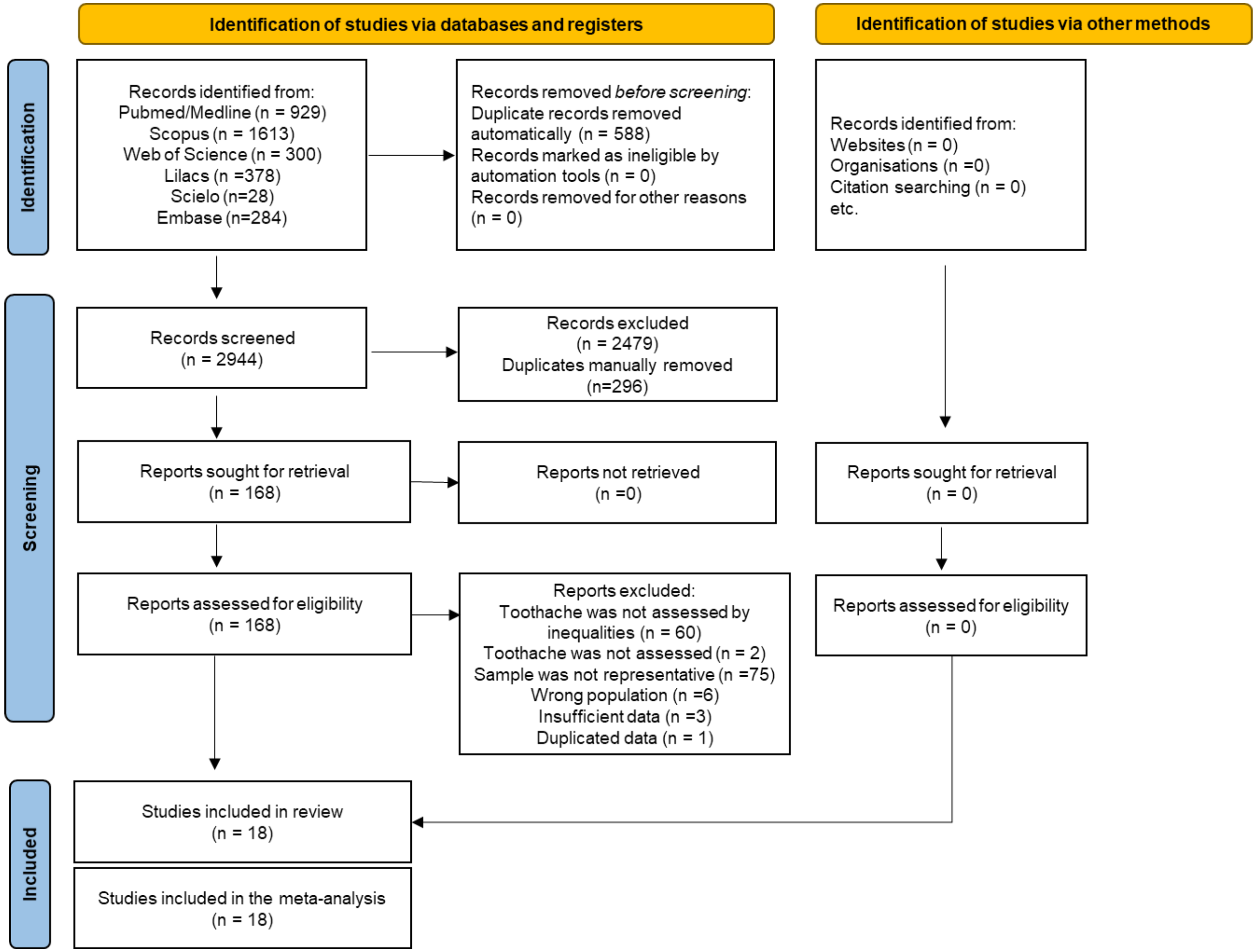
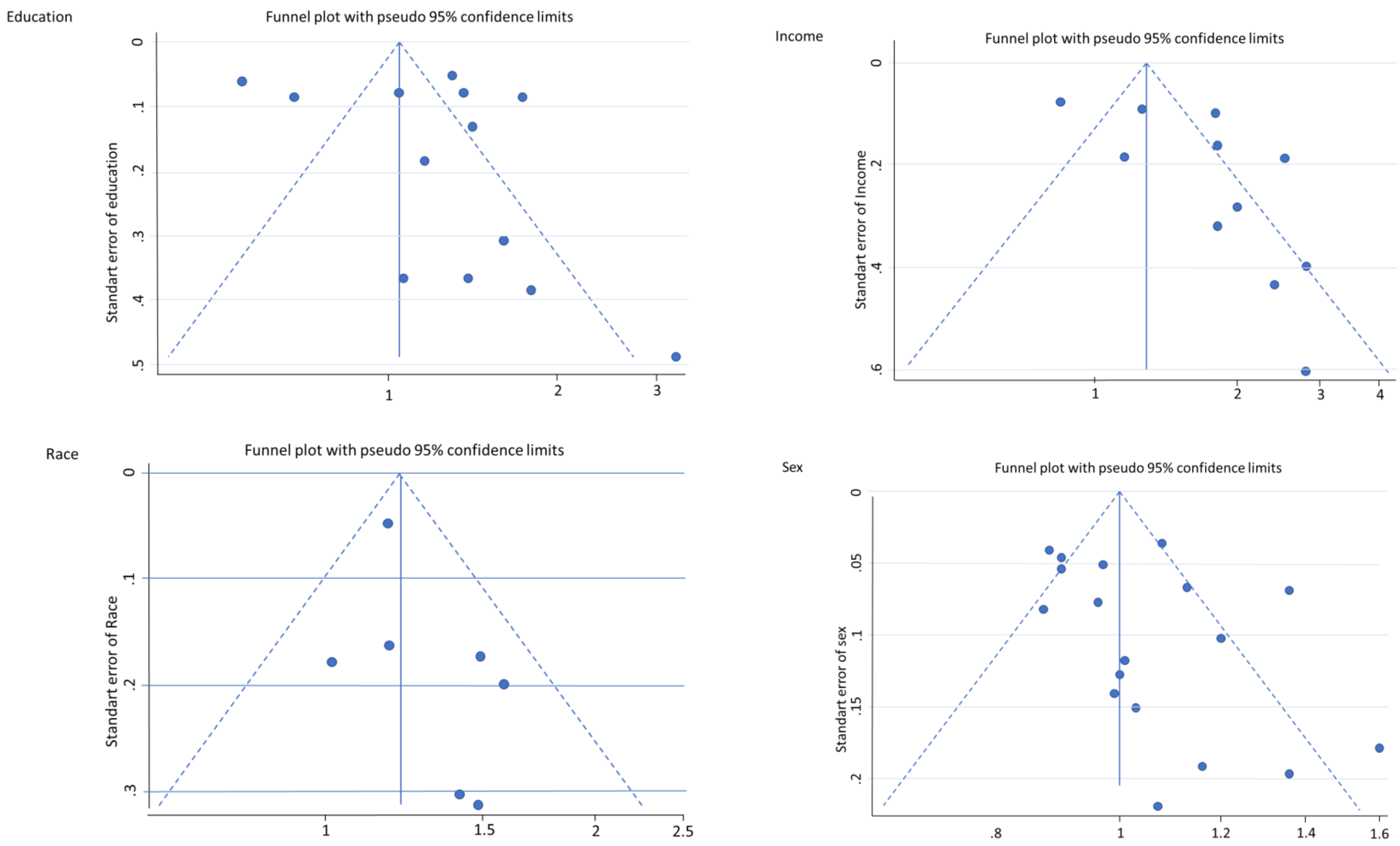
Supplementary Material

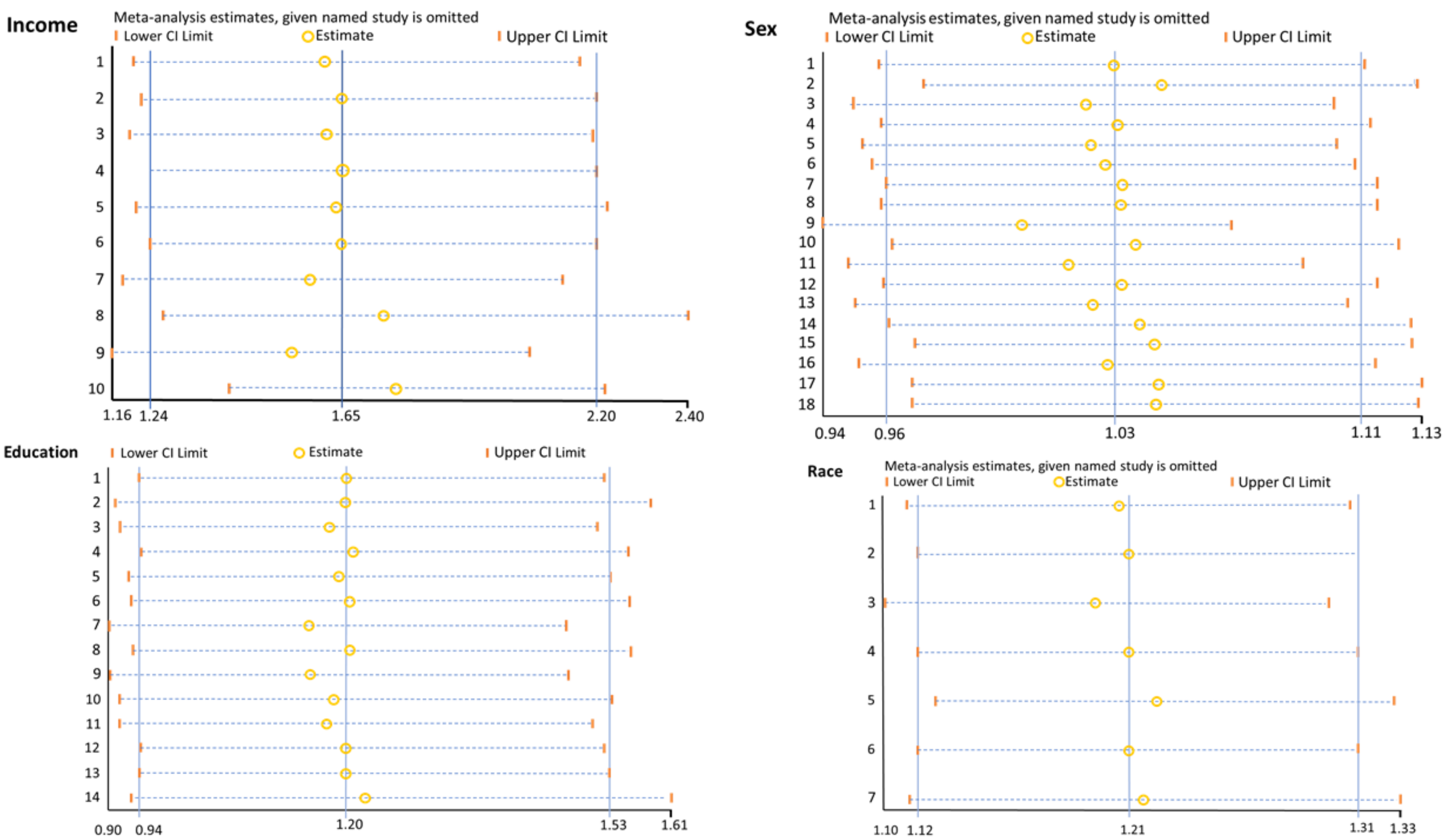
Supplementary Figure 1: Flowchart of Study Selection in the Systematic Review



Supplementary Figure 2: Funnel Plot Analysis for Reporting Bias Across Different Inequalities



Supplementary Figure 3: Sensitivity analysis for each inequality



Supplementary table 1 : Search Strategies for Each Database in the Systematic Review

Database	Search Strategy
PubMed	(Adult) OR (Adults) OR (Young Adult) OR (Older Adult) OR (Middle Aged) OR (Middle Age)) AND (“Toothache” OR “Odontalgia” OR “Dental Pain”) AND ((Observational Study) OR (Prevalence) OR (Prevalences) OR (Incidence Proportion) OR (Incidence Proportions) OR (Proportion, Incidence) OR (Retrospective studies) OR (Studies, Retrospective) OR (Study, Retrospective) OR (Retrospective Study) OR (Prospective studies) OR (Prospective Study) OR (Studies, Prospective) OR (Study, Prospective) OR (Cohort Studies) OR (Cohort Study) OR (Studies, Cohort) OR (Study, Cohort))
Scopus	((Adult) OR (Adults) OR (Young Adult) OR (Older Adult) OR (Middle Aged) OR (Middle Age)) AND ((Toothache) OR (Odontalgia) OR (Dental Pain)) AND ((Observational Study) OR (Prevalence) OR (Prevalences) OR (Incidence Proportion) OR (Incidence Proportions) OR (Proportion, Incidence) OR (Retrospective studies) OR (Studies, Retrospective) OR (Study, Retrospective) OR (Retrospective Study) OR (Prospective studies) OR (Prospective Study) OR (Studies, Prospective) OR (Study, Prospective) OR (Cohort Studies) OR (Cohort Study) OR (Studies, Cohort) OR (Study, Cohort))
Web of Science	ALL=("Adult") OR ALL=("Adults") OR ALL=("Young Adult") OR ALL=("Older Adult") OR ALL=("Middle Aged") OR ALL=("Middle Age") OR ALL=("Aged") OR ALL=("Elderly") AND ALL=("Toothache") OR ALL=("Toothaches") OR ALL=("Odontalgia") OR ALL=("Odontalgias") OR ALL=("Dental pain") AND ALL=("Observational Study") OR ALL=("Prevalence") OR ALL=("Prevalences") OR ALL=("Incidence") OR ALL=("Incidences") OR ALL=("Incidence, Cumulative") OR ALL=("Incidence Rate") OR ALL=("Incidence Rates") OR ALL=("Cohort Studies") OR ALL=("Cohort Study")
Lilacs	((adult) OR (adults) OR (young adult) OR (older adult) OR (middle aged) OR (middle age)) AND ((“toothache”) OR (“odontalgia”) OR (“dental pain”)) AND ((observational study) OR (prevalence) OR (prevalences) OR (incidence proportion) OR (incidence proportions) OR (proportion, incidence) OR (retrospective studies) OR (studies, retrospective) OR (study, retrospective) OR (retrospective study) OR (prospective studies) OR (prospective study) OR (studies, prospective) OR (study, prospective) OR (cohort studies) OR (cohort study) OR (studies, cohort) OR (study, cohort))

Database	Search Strategy
Scielo	((Adult) OR (Adults) OR (Young Adult) OR (Older Adult) OR (Middle Aged) OR (Middle Age)) AND ((“Toothache”) OR (“Odontalgia”) OR (“Dental Pain”)) AND ((Observational Study) OR (Prevalence) OR (Prevalences) OR (Incidence Proportion) OR (Incidence Proportions) OR (Proportion, Incidence) OR (Retrospective studies) OR (Studies, Retrospective) OR (Study, Retrospective) OR (Retrospective Study) OR (Prospective studies) OR (Prospective Study) OR (Studies, Prospective) OR (Study, Prospective) OR (Cohort Studies) OR (Cohort Study) OR (Studies, Cohort) OR (Study, Cohort))
Embase	('adult':ti,ab,kw OR 'adults':ti,ab,kw OR 'young adult':ti,ab,kw OR 'older adult':ti,ab,kw OR 'middle aged':ti,ab,kw OR 'middle age':ti,ab,kw OR 'aged':ti,ab,kw OR 'elderly':ti,ab,kw) AND ('toothache':ti,ab,kw OR 'toothaches':ti,ab,kw OR 'odontalgia':ti,ab,kw OR 'odontalgias':ti,ab,kw OR 'dental pain':ti,ab,kw) AND ('observational study':ti,ab,kw OR 'prevalence':ti,ab,kw OR 'prevalences':ti,ab,kw OR 'incidence':ti,ab,kw OR 'incidence proportion':ti,ab,kw OR 'incidence proportions':ti,ab,kw OR 'proportion, incidence':ti,ab,kw OR 'retrospective studies':ti,ab,kw OR 'studies, retrospective':ti,ab,kw OR 'study, retrospective':ti,ab,kw OR 'retrospective study':ti,ab,kw OR 'prospective studies':ti,ab,kw OR 'prospective study':ti,ab,kw OR 'studies, prospective':ti,ab,kw OR 'study, prospective':ti,ab,kw OR 'cohort studies':ti,ab,kw OR 'cohort study':ti,ab,kw OR 'studies, cohort':ti,ab,kw OR 'study, cohort':ti,ab,kw OR 'incidence studies':ti,ab,kw OR 'incidence study':ti,ab,kw OR 'studies, incidence':ti,ab,kw OR 'study, incidence':ti,ab,kw)

Suppplementary table 2 : Descriptive Table of Findings from Included Studies

Author Study Design Year of Publication Country of study application	Diagnostic criteria Overall prevalence Timeframe of pain evaluation Sample size	Prevalence (Sex)	Odds Ratio /95%CI (Sex)	Prevalence (Income)	Odds Ratio /95%CI (Income)	Prevalence (Race)	Odds Ratio /95%CI (Race)	Prevalence (Level of Education)	Odds Ratio /95%CI (Level of education)
Aranha Cross-sectiontal 2020 Brazil	Interview 21.1% Past 6 months 1207	-	1.07 (1.58 - 0.72)	-	2.78 (1.81 - 4.17)	-	1.48 (0.99 - 2.22)	-	-
Ardila Cross-sectional 2016 Colombia	Interview 10% Past 6 months 34 843	-	0.88 (0.95 -0.79)	-	-	-	-	-	1.3 (1.4 -1.2)
Bastos Cross-sectional 2008 Brazil	Interview 17.7% Past 6 months 3136	M = 15.8 (13.7-17.9); F = 19.2% (17.1–21.4)	1.2 (1.0–1.4)	H = 12.4% (10.1–14.8); L= 24.8% (19.8–29.8)	2.0 (1.5–2.6)	W= 16.5%; N.W.= 23.81	1.58 (2.02 - 1.24)	L= 18.8% (14.8–22.7); H = 11.7 % (8.6–14.8);	1.6 (1.1–2.3)
Chung Cross-sectional 2004 South Korea	Interview 26.8% Past 6 months 1032	M= 26.8; F =26.8	1.03 (0.78–1.37)	-	-	-	-	L=27.2%; H= 27%	1.06 (2.0 - 0.56)
Constante Cross-sectional 2012 Brazil	Interview 14.8% Past 6 months 1720	M = 12.7%. F = 16.5%	1.36 (1.8 - 1.03)	H = 19.2% (15.8–22.6); L =11.6% (8.3–14.8)	1.81	W =13.8%; N.W. = 19%	1.02 (1.04 - 0.7)	L= 17.0 % (10.9–23.0); H = 12.9% (10.5–15.4)	1.38 (2.28 - 0.84)
Constante Cross-sectional 2015 Brazil	Interview 17.5% Past 6 months 1099	M = 16.2% (12.8–20.2); F =18.6 % (15.3–22.3)	1.16 (1.6 -0.85)	-	-	-	-	L= 18.5% (15.5–21.9); H= 16.4% (12.7–20.8)	1.16 (1.58 - 0.84)

Duncan Longitudinal 2003 USA	Interview 11.5% At the same day 873	M = 11.4%; F = 11.5%;	0.99 (1.30 - 0.75)	H = 8.3%; L= 20.3%	2.81 (3.70 - 2.14)	W = 11.0%; N.W. = 2.7%	1.18 (1.54 - 0.9)	L= 19.1%; H = 6.8%	3.24 (4.33 - 2.43)
Echeverria Cross-sectional 2020b Brazil	Interview 18% Past 6 months 1.099	M = 17.9; F 18.1	1.01 (1.27 - 0.81)	H= 16.3%; L= 18.8%	1.16 (1.57 - 0.85)	W=16.9%; N.W.= 23.8%	1.41 (2.13 - 0.94)	L=19.8%; H = 14.8%	1.16 (1.57 - 0.85)
Hafner Cross-sectional 2013 Brazil	Interview 21% Past 6 months 9779	M= 26.7%; F= 26.3%	1.36 (1.50 - 1.23)	L= 34.2% H= 17.02%	2.53 (2.92 - 2.19)	-	-	L= 29.9% H 19.7%	1.73 (1.90 - 1.57)
Kakoei Cross-sectional 2013 Iran	Interview 55.1% Past 6 months 1850	M= 56.3%; F= 55.3%	0.96 (1.1 - 0.8)	H=57.9%; L= 54%	0.85 (1.01 - 0.71)	-	-	L=59.7% H= 50%	1.41 (1.69 - 1.18)
Kuhnen Cross-sectional 2009 Brasil	Interview 18% Past 6 months 2051	M= 13%. F= 21.4%	1.60 (2.0 - 1.3)	L= 27.4% H= 11.1%	2.4 (3.4- 1.7)	W=15.9%. N.W.= 22.0%	1.49 (1.87 - 1.19)	L= 22.9. H= 12.8%	1.8 (2.7 - 1.2)
Leung Cross-sectional 2008 Chi-	Interview 27.5% Past 6 months 1.352	M= 27%; F=27%	1.00 (1.28 - 0.78)	-	-	-	-	-	-
Ligthart Cross sectional 2014 Holand	Interview 24% last year 11787	M= 13.1%; F= 14.6%	1.13 (1.27 - 1.01)	-	-	-	-	-	-
Momeni Cross sectional 2016 Iran	Interview 19.8% Last year 19465	M= 14.2%; F= 13.8%	0.97 (1.07 - 0.87)	L= 15.6% H=12.8%	1.26 (1.44 - 1.09)	-	-	L= 13.7% H= 13.2%	1.04 (1.2- 0.9)

Stahlnacke Cohort prospective 2003 Sweden	Interview . . 4971	-	0.87 (1.05 - 0.73)	-	-	-	-	-	0.68 (0.87 - 0.54)
Vargas Cross-sectional 2000 USA	Interview 13.6% Past 6 months 33 073	M=13.2%; F=13.9%	1.08 (1.15 - 1.01)	L= 21.2%; H= 13.0%	1.80 (2.0 - 1.62)	W= 12.7%; N.W.= 14.75	1.18 (1.28- 1.09)	L=16.1%; H =12.3%	1.36 (1.53 - 1.22)
Wan Cross-sectional 2021 China	interview 15.3% Past 6 months 11050	M=15.4%; F=16.8%	0.90 (0.99-0.81)	-	-	-	-	L= 12.7%; H= 21%;	0.55 (0.68 - 0.44)
Yang Cross-sectional 2016 Korea	interview 35.5% - 4866	M=53.1%; F=46.9%	0.90 (1.01 - 0.80)	-	-	-	-	-	-

Supplementary Table 3: Results of Meta-Regression for Individual Inequalities

Inequities	Exp(b)	Std. error	p	Confidence Interval	R^2
Sex					76.46%
Country of study application	0.96	0.01	0.00	(0.94 - 0.98)	
Income					100.00%
Country of study application	0.87	0.02	0.00	(0.83 - 0.93)	
Sample size	1.37	0.12	0.00	(1.11- 1.69)	
Education					39.04%
Year	0.64	0.12	0.04	(0.42 - 0.98)	
Study design	0.71	0.11	0.06	(0.50 – 1.01)	

*Study design and year were excluded because of collinearity. Race was not included in the meta-regression because the I^2 value was 0.

Supplementary Table 4: Excluded Studies During Full-Text Review and Justifications

Author/Year of Publication	Reason for Exclusion
Ahmad 2015	Wrong population
Akbar 2019	Does not assess toothache by inequalities
Alkhatib 2002	Sample was not representative
Almohaimeed 2022	Does not assess toothache by inequalities
AlTuraiki 2021	Does not assess toothache by inequalities
Ankkuriniemia 1997	Does not assess toothache by inequalities
Antunovic 2021	Does not assess toothache by inequalities
Aranha 2018	Sample was not representative
Arantes 2018	Does not assess toothache by inequalities
Ardila 2016a	Same sample from Ardila, 2020
Ayo-Yusuf 2016	Does not assess toothache by inequalities
Azlan 2018	Does not assess toothache by inequalities
Azodo 2013	Does not assess toothache by inequalities
Azodo1 2013	Sample was not representative
Bae 2006	Does not assess toothache by inequalities
Bastos 2005	Sample was not representative
Bolenge 2016	Does not assess toothache by inequalities
Bomfim 2023	Sample was not representative
Borges 2023	Does not assess toothache by inequalities
Brandão 2012	Sample was not representative
Broughton 1991	Does not assess toothache by inequalities
Bulgareli 2018	Does not assess toothache by inequalities
Cavalcanti 2020	Does not assess toothache by inequalities
Cavalheiro 2015	Does not assess toothache by inequalities
Chi 2008	Does not assess toothache by inequalities
Cohen 2009	Sample was not representative
Comassetto 2021	Sample was not representative
Constante 2020	Does not assess toothache by inequalities
Cunha 2020	Does not assess toothache
Curie 2016	Sample was not representative
da Silva 2016	Sample was not representative
Daly 2010	Sample was not representative
Dar-Odeh 2018	Does not assess toothache by inequalities
de Pinho 2012	Does not assess toothache by inequalities
de Siqueira 2013	Does not assess toothache by inequalities
Delgado-Angulo 2019	Wrong population
Dias-da-Costa 2010	Does not assess toothache by inequalities
Diesburg-Stanwood 2004	Does not assess toothache by inequalities
Echeverria 2020a	Does not assess toothache by inequalities
Ekback 2009	Does not assess toothache by inequalities
Eilershaw	Sample was not representative
Farmakis 2016	Sample was not representative
Figueiredo 2013	Does not assess toothache by inequalities
Foester 1998	Does not assess toothache by inequalities
Fonseca 2020	Does not assess toothache by inequalities

Author/Year of Publication	Reason for Exclusion
Fonseca 2020a	Does not assess toothache by inequalities
Freire 2021	Sample was not representative
Freitas 2020a	Does not assess toothache by inequalities
Freitas 2020	Sample was not representative
Gaber 2017	Does not assess toothache
Garcia-Córtes 2020	Sample was not representative
Gelberg 1990	Sample was not representative
Gomes 2007	Sample was not representative
Ha 2018	Sample was not representative
Huang 2022	Sample was not representative
Jaiswal 2015	Sample was not representative
Jamieson 2009 (!)	Sample was not representative
Jamieson 2009	Does not assess toothache by inequalities
Jamieson 2010	Sample was not representative
Jamieson 2011	Sample was not representative, Does not assess toothache by inequalities
Jamieson 2021	Does not assess toothache by inequalities, wrong population (age >15 years)
Jarwan 2023	Does not assess toothache by inequalities
Joseph 2023	Does not assess toothache by inequalities, sample was not representative
Joury 2018	Does not assess toothache by inequalities
Karam 2020	Does not assess toothache by inequalities
Kida 2007	Does not assess toothache by inequalities
Kruger 2015	Sample was not representative
Lacerda 2004	Sample was not representative
Laslett 2008	Sample was not representative
Lidell 1997	Does not assess toothache by inequalities
Lipton 1993	Insufficient data
Locker 1987	Does not assess toothache by inequalities
Locker 1998	Does not assess toothache by inequalities
Lorencini 2019	Sample was not representative
Luo & McGrath 2006	Sample was not representative
Luo & McGrath 2008	Sample was not representative
Marques-Vidal & Milagre 2006	Sample was not representative
Matsuyama 2021	Sample was not representative
Mauricio & Moreira 2014	Sample was not representative
Medina-Solís 2019	Does not assess toothache by inequalities
Meija 2014	Does not assess toothache by inequalities
Miller 1975	Sample was not representative
Miotto 2012	Sample was not representative
Miotto 2013	Sample was not representative
Miranda 2021	Does not assess toothache by inequalities
Misrohmasari 2022	Wrong population
Moeller & Quinonez 2016	Does not assess toothache by inequalities
Montero 2015	Does not assess toothache solely
Morgan 2013	Does not assess toothache by inequalities

Author/Year of Publication	Reason for Exclusion
Morita 2006	Insufficient data
Mudassar 2015	Sample was not representative
Muirhead 2009	Does not assess toothache by inequalities
Nazir 2018	Sample was not representative
Newton 2002	Sample was not representative
Ocwia 2021	Does not assess toothache by inequalities
Pattussi 2010	Does not assess toothache by inequalities
Pei 2021	Sample was not representative
Pengpid 2023	Does not assess toothache by inequalities
Peres 2012	Sample was not representative
Peres 2014	Insufficient data
Peres 2019	Wrong population
Pinto 2012	Does not assess toothache by inequalities
Pires 2019	Does not assess toothache by inequalities
Raittio 2016	Does not assess toothache by inequalities
Raittio 2016	Insufficient data
Raittio 2020	Wrong population
Raskiliene 2020	Sample was not representative
Ravaghi 2013	Wrong population
Richards 2009	Sample was not representative
Riley 1998	Sample was not representative
Riley 2001	Sample was not representative
Riley 2002	Sample was not representative
Riley 2002a	Sample was not representative
Riley 2002b	Sample was not representative
Riley 2002c	Sample was not representative
Riley 2003	Sample was not representative
Riley 2006	Sample was not representative
Ringland 2004	Sample was not representative
Salim 2021	Sample was not representative
Santiago 2013	Wrong population
Schwarz 1994	Does not assess toothache by inequalities
Sebring 2017	Sample was not representative
Silva-Junior 2017	Does not assess toothache by inequalities
Sipila 2001	Does not assess toothache by inequalities
Sipila 2015	Sample was not representative
Soares 2019	Sample was not representative
Souza 2022	Does not assess toothache by inequalities
Touré 2011	Does not assess toothache by inequalities
Vega-López 2018	Sample was not representative
Vega-López 2020	Sample was not representative
Verma 2014	Does not assess toothache by inequalities
Vigoa 2021	Sample was not representative
Wang 2023	Sample was not representative
Yang 2016a	Does not assess toothache by inequalities
Zlotnick 2014	Does not assess toothache by inequalities
Zusman 2016	Does not assess toothache by inequalities

5. Article 2

Inequalities in the life course on dental pain trajectory in adults: A birth cohort from Pelotas, RS, Brazil [2]

André Luiz Rodrigues Mello[1], Kaue Farias Collares[2], Francine dos Santos Costa[3], Luiz Alexandre Chisini[4].

Abstract

This prospective study analyzed dental pain trajectories at 24, 31, and 40 years using data from a birth cohort in Pelotas, Brazil. Socioeconomic inequalities were assessed through maternal education and family income using the slope index of inequality (SII) and concentration index (CIX). 607 participants were included, and two linear trajectories were identified (BIC =1856.45): low prevalence (46.7%) and high prevalence (53.5%). Significant associations were observed for sex (p= 0.040) and race (p=0.030). Males were more likely to follow the low prevalence trajectory (56.2%) compared to females (48.8%) (p = 0.040). Racial disparities were also significant, with Whites predominantly in the low prevalence trajectory (54.5%), while Blacks (58.1%) and Amerindians (70.0%) were more likely to follow the high prevalence trajectory (p = 0.030). Significant reductions in dental pain trajectories were observed for family income (SII: −0.17, 95% CI −0.31 to −0.04, p = 0.012) and maternal schooling (SII: −0.15, 95% CI −0.29 to −0.01, p = 0.036). Relative inequalities (CIX) showed reductions for family income (−0.06, 95% CI −0.11 to −0.01, p = 0.013) and maternal schooling (−0.06, 95% CI −0.10 to −0.01, p = 0.024). This study highlights that socioeconomic, racial, and gender inequalities significantly influence dental pain trajectories. These findings underscore the importance of public policies to reduce disparities and promote oral health equity.

Keywords: Health Inequities, Dental pain, Toothache, group-based trajectory modeling

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Introduction

Dental pain is a debilitating condition that significantly impacts both physical and psychological well-being. Globally, it affects 32.7% of children and adolescents leading to high treatment costs (58), reduced academic performance (59), and increased reliance on emergency care (60). The burden of dental pain is not evenly distributed, disproportionately affecting vulnerable and marginalized populations (6). In particular, Black and Brown individuals, as well as those with lower educational attainment, bear the greatest burden of the disease (61). Furthermore, oral diseases exhibit a clear social gradient, shaped by intersecting factors such as race (62), income (63), and educational level (64).

Racism, a fundamental driver of health inequities, operates across structural, individual, and socio-psychological dimensions, is deeply rooted in historical and social processes, and significantly contributes to racial disparities in oral health (19,65). Ethnic and racial minorities consistently exhibit a higher prevalence of dental pain, highlighting their disproportionate burden (6,8,10,11,13). Similarly, low income is strongly associated with poor oral health outcomes, including higher rates of dental caries, tooth loss, and periodontal disease (66) Like race, income is frequently identified as a key factor linked to a greater prevalence of dental pain (67,68). Furthermore, individuals with lower levels of formal education are less likely to seek preventive dental care compared to their more educated peers, a behavior that likely exacerbates the prevalence of dental pain within this group (40).

Life course epidemiology provides a comprehensive framework for examining how exposures throughout life influence health outcomes (69). Longitudinal approaches, such as trajectory analysis, are particularly valuable for identifying vulnerable populations, describing heterogeneity in health profiles, and elucidating pathways to optimal health outcomes (70). These methodologies yield critical evidence to support the development of personalized healthcare strategies targeted to specific subpopulations. Despite these advancements, limited research has investigated how early-life inequalities influence dental pain trajectories across the life course, particularly in low- and middle-income countries (15). Most studies focus on single time points or short-term outcomes, failing to capture the dynamic and cumulative nature of oral health disparities over time (10,23). This gap in the literature underscores the need for studies that explore long-term trajectories of dental pain within the context of social inequities (71)

In this context, the present study aims to investigate dental pain trajectories in a birth cohort from Pelotas, Brazil. By examining the predictive role of inequalities in shaping dental pain outcomes, this study seeks to provide a deeper understanding of the long-term consequences of early-life disparities on oral health in older adults.

Methodology

This study was reported following the STROBE checklist for observational studies (72).

Study design, study size, setting, participants

This study utilized data from oral health assessments conducted at ages 24, 31, and 40 within the 1982 birth cohort from Pelotas, RS, Brazil. In 1982, all 5,914 live births in the city's three maternity hospitals were recorded, with newborns measured and weighed, and their mothers interviewed using a structured questionnaire on socioeconomic, demographic, and maternal health factors.

The first oral health assessment began in 1997, with 70 of the city's 265 census tracts systematically selected, covering approximately 27% of households. A systematic search identified 1,076 adolescents born in 1982, from which a probabilistic sample of 900 was randomly selected. Oral health examinations, including questionnaires and dental assessments, were conducted on 888 participants. Follow-up oral health surveys within this sub-sample were completed at ages 24 (720 participants, 81%), 31 (539 participants, 61 %), and 40 years (463 participants, 49 %). In this study, we included only participants who attended at least two follow-up assessments (n=607). The trajectory estimation command automatically imputes missing data for participants absent from a follow-up, ensuring the continuity and integrity of the longitudinal analysis.

Outcome

The outcome of this study is the trajectory of dental pain occurrence over the last four weeks, assessed at ages 24, 31, and 40. At 24 years, dental pain was measured using the question: “Have you had a toothache in the last 4 weeks?” (yes/no). At 31 and 40 years dental pain was assessed by the question: “In the past 6 months, have you experienced tooth pain?” (yes/no). The collected data was organized as a dichotomous variable, and group-based trajectory modeling was applied to identify groups with similar dental pain trajectories over the life course.

The model was estimated using the "traj" command in Stata 16.0,(73) which determines trajectory similarity among individuals. Estimates were performed considering a Logit model due to data distribution. Model parameters were estimated through maximum likelihood using the quasi-Newton method (Jones & Nagin, 2007). The number of trajectories was defined through sequential comparisons of the Bayesian Information Criterion (BIC), stopping when no substantial differences were observed between the K and K+1 trajectory models. Finally, 2 trajectories (low and high) of dental pain were produced, including the 607 individuals.

Variables

Sex was recorded at birth as male or female. Self-reported skin color was assessed at age 24 using the official classification of the Brazilian Institute of Geography and Statistics (IBGE) through the question: “What is your color or race?” with five options: a) White, b) Black, c) Brown, d) Asiatic, and e) Indigenous.

Maternal education at birth was also collected in years and categorized into the same three groups. Family income at birth, measured in Brazilian minimum wages, was categorized into five groups: ≤1, 1.1–3.0, 3.1–6.0, 6.1–10, and >10.

2.4 Statistical Methods

The statistical analysis was performed utilizing Stata 16.0 Software (StataCorp., College Station, TX, USA). The descriptive analysis was performed by presenting frequencies of the outcome based on sex, skin color self-reported, maternal education at birth, and family income at birth using chi-square and Fisher's exact statistical test. We investigated the attrition level comparing the analyzed sample with the full birth cohort. Equiplots were also built to illustrate inequalities (http://www.equidade.org/equiplot).

Two inequality indicators, the Slope Index of Inequality (SII) and the Concentration Index (CIX) were applied to ordinal stratifiers: Maternal education at birth, and family income at birth. The Slope Index of Inequality (SII) is an absolute measure of inequality, while the Concentration Index (CIX) assesses relative inequality. The SII quantifies inequality in percentage points (pp), reflecting the absolute difference in predicted health indicator values between the most and least advantaged individuals based on socioeconomic factors. It accounts for the entire distribution using an appropriate regression model.

In contrast, the CIX measures relative inequality, comparable to the Gini index for income distribution, indicating deviations from complete equality. Statistical significance will be set at $p < 0.05$, with the p-value indicating whether the index differs from zero (no inequality), alongside 95% confidence intervals (95% CI).

Ethical Approval

Approval for the study was granted by the Human Research Ethics Committee of the Faculty of Medicine of the Federal University of Pelotas under protocol number 384.332. All participants provided informed consent.

Results

Of 888 participants from the first oral health subsample cohort, only 607 were followed in at least two follow-up and were included in the present study. Attrition level analysis showed no significatively losses for sex (p=0.520), race (p=0.079), and maternal schooling at birth (p=0.128) (**Table 1**). However, it was observed higher losses in the high family income group (p=0.035).Most participants were male (50.1%), White individuals (78.6%), with maternal education from 5 to 8 years of study (46.0%). The prevalence of dental pain at 24 was (n= 22.6%), 31 (n= 30.2%) and 40 years (n= 23.1%).

Table 2 presents the distribution of dental pain trajectories according to sample characteristics. Significant associations were observed for sex and race. Females were more likely to report high dental pain trajectories compared to males (51.2% vs. 43.8%, p=0.040). Regarding race, Asians (100.0%), Amerindians (70.0%) and Black individuals had the highest prevalence of high dental pain trajectories (58.1%), with significant differences across groups (p=0.030). Maternal schooling and family income at birth showed no statistically significant association with dental pain trajectories (p=0.059 and p=0.178, respectively).

Table 1. Attrition Analysis of the Birth Cohort: Comparison of Retained and Lost Participants

Co-Variables	Original Cohort (n = 5,914)	Sample (n = 606)	Not Followed (n = 5,307)	p-value*
Sex				
Male	3,037 (51.4%)	304 (50.1%)	2,733 (51.5%)	0.520
Female	2,876 (48.6%)	303 (49.9%)	2,573 (48.5%)	
Race				
White	3,238 (75.4%)	464 (78.6%)	2,774 (74.9%)	0.079
Black	673 (15.7%)	86 (14.6%)	587 (15.8%)	
Brown	235 (5.5%)	27 (4.6%)	208 (5.6%)	
Asiatic	74 (1.7%)	3 (0.5%)	71 (1.9%)	
Amerindian	76 (1.7%)	10 (1.7%)	66 (1.8%)	
Maternal schooling at birth (years)				
0 to 4	1,960 (33.2%)	188 (31.0%)	1,772 (33.4%)	0.128
5 to 8	2,454 (41.5%)	279 (46.0%)	2,175 (41.0%)	
9 to 11	654 (11.1%)	61 (10.1%)	593 (11.2%)	
12 or more	839 (14.2%)	78 (12.9%)	761 (14.4%)	
Family income at birth (quintile)				0.035
1st (lowest income)	1,183 (20.0%)	75 (15.4%)	1,108 (18.7%)	
2nd	1,178 (19.9%)	100 (20.6%)	1,078 (18.2%)	
3rd	1,180 (20.0%)	113 (23.2%)	1,067 (18.0%)	
4th	1,185 (20.0%)	111 (22.8%)	1,074 (18.1%)	
5th (highest income)	1,188 (20.1%)	86 (17.7%)	1,102 (18.6%)	

* **Chi-squared test**

Table 2. Distribution of dental pain by the sample characteristics (n=607)

Co-variables	Dental pain trajectory Low n (%)	High n (%)	p-value *
Sex			0.040
Male	171 (56.2)	133 (43.8)	
Female	148 (48.8)	155 (51.2)	
Race			0.030
White	253 (54.5)	211 (45.5)	
Black	36 (41.9)	50 (58.1)	
Brown	16 (59.3)	11 (40.7)	
Asiatic	0 (0.0)	3 (100.0)	
Amerindian	3 (30.0)	7 (70.0)	
Maternal schooling at birth (years)			0.059
0 to 4	87 (46.3)	101 (53.7)	
5 to 8	153 (54.8)	126 (45.2)	
9 to 11	29 (47.5)	32 (52.5)	
12 or more	49 (62.8)	29 (37.2)	
Family income at birth (quintile)			0.178
1st (lowest income)	43 (44.8)	53 (55.2)	
2nd	61 (48.8)	64 (51.2)	
3rd	74 (51.4)	70 (48.6)	
4th	49 (57.7)	58 (42.3)	
5th (highest income)	62 (59.0)	43 (41.0)	

* Fisher exact test

Figure 1 shows different trajectories of dental pain and how it changes according to age and dental pain report. As a result of group-based trajectory modeling analysis, the model with two trajectories had a better fit than that with the number of trajectories. The sample was separated into two trajectories one with a high prevalence of dental pain (53.5%) and another with a low prevalence (46.7%). Both trajectories were linear, but one trajectory showed the highest levels of dental pain. BIC scores for the number of groups were (1856.45) (**Table 3**).

Figure 1. Dental pain trajectories by age with 95% confidence interval

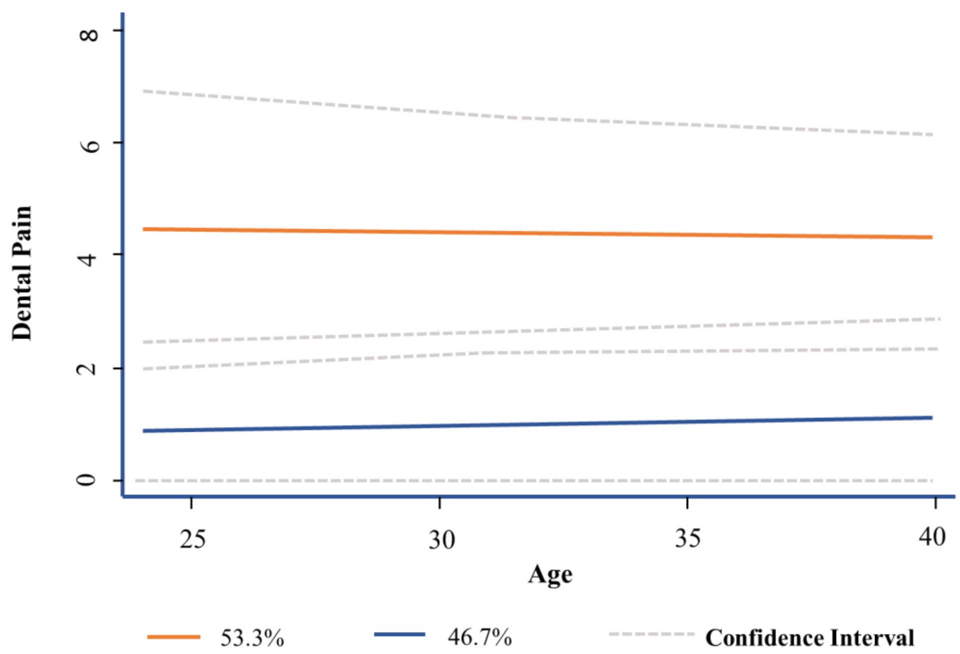


Table 3 presents the goodness-of-fit statistics and parameter estimates for dental pain trajectories in 607 individuals. It shows intercept, linear slope, and quadratic slope estimates, along with their standard errors and p-values. The table also includes AIC, BIC, and Sample Adjusted BIC values for each model, with the lowest values indicating the best-fitting model for explaining the dental pain trajectories.

Table 3. Goodness-of-fit statistics and parameter estimates for the trajectory of dental pain (n=607 individuals).

Group	Intercept	Std. Error	p-Value	Linear Slope	Std. Error	p-Value	Quadratic Slope	Std. Error	p-Value	AIC	BIC	Sample Adjusted BIC
1	0.73	0.03	<0.01	-0.01	0.08	0.87	0.00	0.04	0.93	1867.58	1875.20	1873.56
2	0.03	0.07	<0.01	-0.04	0.14	0.75	0.01	0.07	0.85	1838.65	1856.45	1852.61
	1.05	0.05	<0.01	0.00	0.11	0.96	-0.00	0.05	0.96			
3	0.37	0.11	0.01	-0.04	0.20	0.82	0.01	0.09	0.89	1842.65	1870.62	1864.58
	0.37	0.11	0.01	-0.04	0.22	0.83	0.01	0.10	0.90			
	1.05	0.05	<0.01	0.00	0.11	0.96	-0.00	0.05	0.96			
4	0.37	0.12	0.01	-0.04	0.22	0.83	0.01	0.10	0.90	1846.65	1884.79	1876.55
	0.37	0.10	0.01	-0.04	0.20	0.82	0.01	0.09	0.89			
	1.05	0.09	<0.01	0.00	0.17	0.97	-0.00	0.08	0.97			
	1.05	0.08	<0.01	0.00	0.15	0.97	-0.00	0.07	0.97			

Note: AIC = Akaike Information Criterion; BIC = Bayesian Information Criterion. * Significance $p < 0.05$

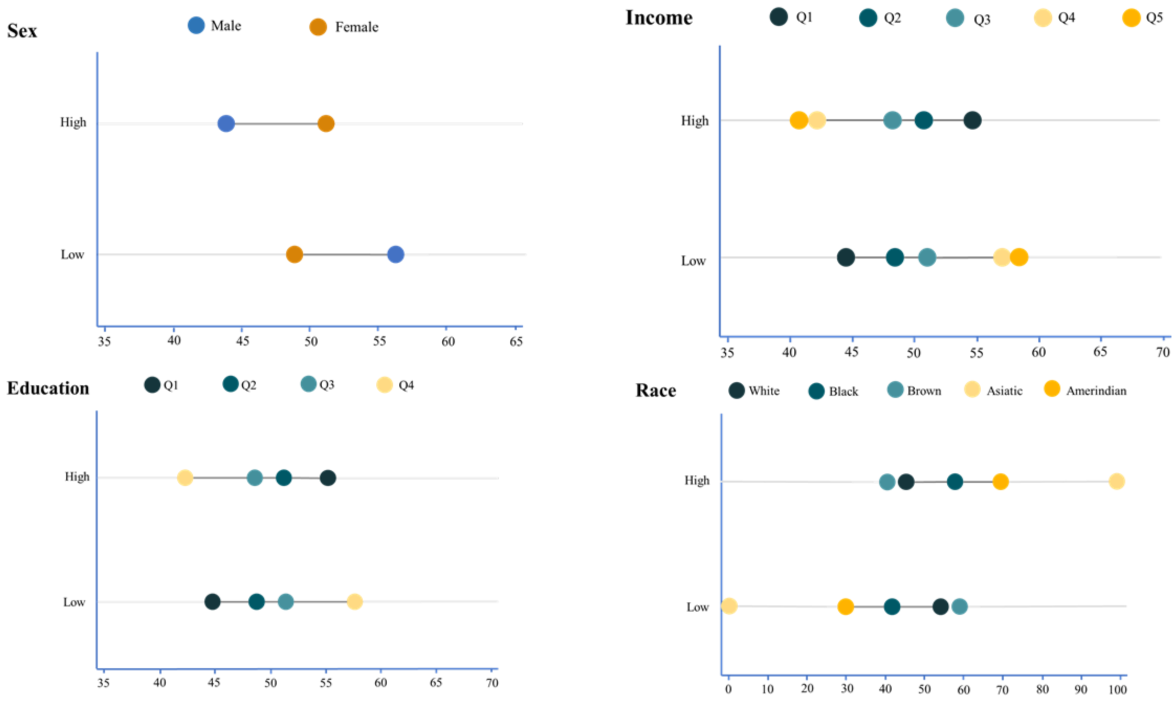
Table 4 presents the absolute and relative social inequalities in dental pain trajectories associated with family income and maternal education at birth. Both factors significantly influenced dental pain trajectories, with inequalities observed in both absolute and relative terms. Family income exhibited more pronounced inequalities, as evidenced by a SII of -0.17 (95% CI: -0.31 to -0.04; p=0.012) and a CIX of -0.06 (95% CI: -0.11 to -0.01; p=0.013). Similarly, maternal education showed significant inequalities, with an SII of -0.15 (95% CI: -0.29 to -0.01; p=0.036) and a CIX of -0.06 (95% CI: -0.10 to -0.01; p=0.024).

Table 4. Absolute and relative social inequalities in the dental pain trajectory according to the family income at birth and maternal schooling at birth, Pelotas, Brazil. (n=607)

	SII (95%IC)	**p-value**	**CIX (95%IC)**	**p-value**
Dental Trajectory				
Family income at birth (quintile)	-0.17 (-0.31 - -0.04)	0.012	-0.06 (-0.11 - -0.01)	0.013
Maternal schooling at birth	-0.15 (-0.29 - -0.01)	0.036	-0.06 (-0.10 - -0.01)	0.024

Figure 2 presents a series of equiplots depicting the trajectories of dental pain prevalence across various dimensions of social inequities: gender, income, education, and race. Women experience higher prevalence levels, particularly at the most severe levels of dental pain. A clear socioeconomic gradient is observed, with dental pain being most prevalent among individuals in the lower income quintiles (Q1 and Q2), gradually decreasing as income rises toward the higher quintiles (Q4 and Q5). Similarly, individuals with lower educational attainment (Q1 and Q2) report higher prevalence rates of dental pain, while those with higher education levels (Q3 and Q4) show significantly lower rates, reinforcing the link between education and oral health. Racial disparities are also evident, with minority groups, such as Asians, Black individuals, and Indigenous peoples, showing greater prevalence of dental pain compared to White individuals, who exhibit the lowest rates.

Figure 2. Equiplot for dental pain trajectory and different inequalities



Discussion

This study, based on a cohort design, examines how early-life factors—such as sex, income, maternal education, and race—shape dental pain trajectories over time. Its population-based approach ensures representativeness and relevance, providing a robust foundation for targeted public policies and health interventions. Longitudinal data collection over several decades enhances the study's reliability, minimizes temporal bias, and offers a comprehensive understanding of how early-life exposures influence adult health outcomes. By grouping individuals with similar trajectories, the analysis identifies high-risk and vulnerable groups, highlighting the role of social inequities in determining the likelihood of belonging to specific dental pain trajectories.

The limitations of this study include the loss of participants during follow-up, which reduced the sample size and may have impacted the representativeness of the findings, particularly in the income stratum, as this attrition was not uniform. Losses were more pronounced among individuals in the first and fifth quintiles (p = 0.035).. This pattern of attrition may introduce selection bias, potentially affecting the generalizability of the results. Specifically, the underrepresentation of higher-income participants could result in an overestimation of the prevalence of dental pain trajectories in the overall sample, as higher-income groups generally experience better oral health outcomes. Consequently, the observed associations between income and dental pain trajectories may be influenced by this bias, and the true disparities could be less pronounced than reported. Additionally, some categories of variables, such as Amerindian or Asiatic race, had very small sample sizes, leading to statistical instability and limiting the robustness of estimates for these groups. Another methodological limitation is the inconsistency in the recall periods for dental pain assessment, which were four weeks during one follow-up and six months during the subsequent two. This inconsistency introduces the risk of memory bias, as participants may struggle to accurately recall episodes of dental pain over longer periods, reducing the homogeneity of the data across follow-ups and compromising the comparability of results. Furthermore, the questions specifically addressed dental pain experienced in the past few months, restricting the study's ability to capture a comprehensive temporal trajectory of dental pain. Lastly, the subsample used in the attrition analysis revealed a statistically significant difference in family income at birth, which further limits the ability to draw robust conclusions related to this variable.

Our findings highlighted that inequities significantly influenced the different dental pain trajectories. Sex and race emerged as key determinants, demonstrating a significant impact on these trajectories. In contrast, other variables, such as maternal education (p=0.059) and family income at birth (p=0.178), did not show statistical significance. However, high dental pain trajectories were more prevalent among individuals whose mothers had lower levels of education (0 to 4 years: 53.7%) and less prevalent among those with higher maternal education (12 or more years: 37.2%). The SII (-0.15; p = 0.036) and CIX (-0.06; p = 0.024) further confirm the presence of absolute and relative inequalities, indicating a greater concentration of dental pain among individuals with lower maternal education. This underscores the importance of maternal education as a key factor in explaining dental pain inequities, suggesting a cumulative socioeconomic effect over time.

Parents with higher educational levels generally possess greater oral health knowledge, which positively influences their children's oral hygiene behaviors (74). Conversely, studies have shown that poorer health-related behaviors are more prevalent among individuals with lower levels of education and socioeconomic status (75). Research on dental pain has revealed that individuals with less than 12 years of education and who visit the dentist primarily for dental problems are 20% more likely to report dental pain. This finding highlights the association between lower educational attainment and irregular use of dental services, as well as visits motivated by dental issues rather than preventive care, contributing to the asymmetrical distribution of dental pain over time. Such patterns reflect the cumulative effects of socioeconomic disadvantages on oral health throughout life (40). These disparities are further illustrated by the strong connection between lower maternal education and higher rates of dental problems in children (76). Moreover, lower parental education is consistently associated with reduced access to preventive care and greater vulnerability to dental pain in both adolescents (77) and adults (40). This evidence underscores that limited education can restrict access to critical information and resources necessary for proper oral care, perpetuating cycles of poor oral health outcomes (78). Thus, improving maternal education emerges as a crucial intervention to reduce health disparities and enhance oral health outcomes across generations.

Individuals in the lowest income quintile exhibited a higher prevalence of high dental pain trajectories (55.2%) compared to those in the highest income quintile (41.0%). Nonetheless, this association did not reach statistical significance ($p = 0.178$), as determined by Fisher's exact test. In contrast, the SII (-0.17; $p = 0.012$) and CIX (-0.06; $p = 0.013$) confirmed that income-related inequalities are significant, with a higher prevalence and concentration of dental pain among individuals from lower-income groups. This greater burden of dental pain in lower-income individuals reflects a socioeconomic gradient, where early-life disadvantages adversely impact oral health over time. These findings underscore the need for public policies aimed at reducing income inequalities, including programs that enhance access to dental care for low-income families from early childhood. Investments in school-based dental programs and public health initiatives could mitigate the negative effects of unfavorable socioeconomic conditions, fostering greater equity in oral health.

Family income at birth is a critical factor, as it reflects the standard of living and life opportunities available to individuals and households through shared goods and services (79). The etiology of common oral conditions is strongly influenced by behavioral risk factors such as inadequate diet, tobacco use, and elevated stress levels, all of which are shaped by income disparities (80,81) Income is also a key determinant in accessing healthcare services, with higher socioeconomic conditions often associated with healthier habits, improved lifestyles, and consequently, better quality of life (82)(83). Studies have consistently demonstrated a significant association between lower incomes and an increased prevalence of dental pain (84–87). For instance, one study found that participants classified as "poor" during childhood had a 45% higher likelihood of experiencing dental pain throughout their lives, even after adjusting for factors such as parental education and oral health behaviors. Moreover, childhood poverty was linked to poorer oral health outcomes in adulthood, regardless of adult income (88). Dental pain also contributes to absenteeism from work, directly affecting family income and perpetuating socioeconomic challenges (89). Low income has been identified as a determinant of dental pain, as individuals from low-income families often seek dental care only in emergencies, leading to untreated oral conditions and a higher prevalence of dental pain (67). Based on the findings of this study, improving socioeconomic conditions during childhood has the potential to reduce the prevalence of dental pain across the lifespan and enhance oral health-related quality of life

Dental pain is a complex phenomenon and it often involves multiple interdependent factors. Various theoretical frameworks aim to elucidate these complex causal mechanisms of dental pain (11). The understanding that factors beyond individual characteristics—specifically, the social determinants of health—play a significant role in the higher prevalence of dental pain reflects patterns observed in other chronic conditions, such as hypertension and diabetes, where inequities accumulate over the life course. Therefore, exploring and understanding the inequalities and how these mechanisms operate allows for the modification of outcomes through targeted strategies (90).

Our results indicate that women exhibit a higher propensity for dental pain which suggests that biological, psychosocial, and contextual factors as key determinants of this disparity. Regarding biological factors, the association with hormonal variations remains uncertain. Some studies suggest that estrogens play a significant role in regulating pain by acting on intracellular receptors, modifying gene expression, and interacting with G-protein-coupled receptors distributed throughout the central and peripheral nervous systems, although this hypothesis lacks robust supporting evidence (91). Additionally, it has been hypothesized that gender differences in dental pain may stem from women's heightened perception of oral health, more frequent utilization of dental services, and greater likelihood of reporting pain compared to men (92). Although Social, cultural, and environmental factors are also likely to predispose women to report health problems more frequently than men, including pain. Studies have shown that contextual factors, such as living in areas with lower Human Development Index (HDI), significantly increase the likelihood of chronic pain in women. Furthermore, in cases of chronic pain, Black and Brown women are more likely to experience it compared to White women (93). Other studies investigating dental pain have also found a higher prevalence among women (6,8,10), reinforcing the role of social structures as key contributors to this association. However, this relationship remains unclear, as some studies argue that the link between gender and dental pain is not well established (94). This ambiguity is further highlighted by studies that report no difference in dental pain prevalence between males and females (95,96).

Racial inequalities in oral health refer to disparities among groups defined by ethnic-racial characteristics, with racial minorities often experiencing poorer general and oral health outcomes (97). Consistent with the findings of this study, ethnic-racial inequalities influence individuals, making these groups more likely to experience higher trajectories of dental pain. Previous research has similarly documented a higher prevalence of dental pain in racialized groups, with individuals of darker skin tones, including Black, Brown, and Indigenous populations, reporting more pain compared to White individuals (98–100). Historically, dental literature has framed race as a biological or cultural marker, overlooking structural factors such as systemic racism, including residential segregation and healthcare discrimination, which perpetuate these disparities (65). Other studies highlight that racism and social inequalities contribute to the higher prevalence of dental pain among Black and Brown adolescents, emphasizing issues like unequal access to public health programs, such as water fluoridation and oral health teams, which exacerbate ethnic-racial disparities (6). Structural racism perpetuates socioeconomic inequalities by limiting access to education, employment, and healthcare, increasing the risk of poor oral health outcomes, including untreated caries and dental pain. Both structural and interpersonal racism exacerbate these disparities through economic, social, and psychosocial barriers, disproportionately affecting marginalized racial groups. Addressing racism as a central social determinant is essential for effective public health policies (90). Including data on racism in research would enhance the understanding of these inequalities and support the development of more effective interventions.

Conclusion

This study highlighted that socioeconomic, racial and gender inequalities significantly influence dental pain trajectories over the life course, with higher prevalence among woman, racial minorities. Despite limitations, the longitudinal data underscore the need for public policies aimed at reducing inequalities and promoting oral health in disadvantaged populations.

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Final Considerations

This dissertation highlights the significant role of social, racial, and gender inequities in shaping the prevalence of dental pain over the life course. By integrating systematic reviews and longitudinal analyses, it provides a comprehensive understanding of the structural determinants underlying oral health disparities. These findings underscore the urgent need for targeted interventions and public policies that address barriers to preventive care and treatment, particularly for socioeconomically disadvantaged and racially marginalized populations.

Future research should expand longitudinal studies in diverse sociocultural contexts and strengthen intersectoral initiatives that integrate oral health into broader strategies for reducing social inequities. It is hoped that the insights provided by this work will contribute to advancing health equity and inspiring further scientific developments in the field of oral health disparities.

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