# Developmental Dental Anomalies: Prevalence and Association with Medical Background

BY

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## DEDICATION

This capstone is dedicated to my wonderful faculty in the Department of Pediatric Dentistry. You have each pushed me to succeed, grow, and never stop learning. It is because of you that all of our residents will become incredible practitioners able to provide the best, high-quality, evidence-based care to the patients we will be lucky to treat. I hope I can inspire future generations of children, and pediatric dentists alike, as much as you have me. Thank you for all that you do for your patients, our program, and for me.

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**RAV**

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## LIST OF ABBREVIATIONS

| | |
|---|---|
| AAPD | American Academy of Pediatric Dentistry |
| ADD/ADHD | Attention Deficit Disorder/Attention Deficit Hyperactivity Disorder |
| AI | Amelogenesis Imperfecta |
| ASA | American Society of Anesthesiologists |
| COD | College of Dentistry |
| CMC | Chronic Medical Conditions |
| DCF | Data Collection Form |
| DDA | Developmental Dental Anomalies |
| EHR | Electronic Health Record |
| PI | Principal Investigator |
| PR | Panoramic Radiographs |
| SHCN | Special Health Care Needs |
| UIC | University of Illinois at Chicago |

## SUMMARY

**Developmental dental anomalies (DDA) may occur during various stages of the dental development. Their etiology is complex and can be associated with genetic inheritance, environmental exposures, systemic health disturbances and/or a combination of factors. DDA may affect individuals worldwide and are shown to have variation in prevalence in populations from different geographic areas. A number of DDA can be identified directly from a panoramic radiograph examination, while other types require comprehensive assessment, including clinical exam and adjunct diagnostic modalities. Pediatric dentists see children from an early age and may be the first oral health care professionals to encounter DDA in patients. Moreover, pediatric dentists are the specialists that are best placed to treat children with medical conditions and typically take a lot of referrals from primary dental providers.**

**This retrospective study aimed to describe the prevalence of radiographically identifiable types of DDA, including anomalies of number, size, shape, matrix development and root malformations in a large sample of pediatric patients from a university based dental clinic and to assess for associations between presence of DDA and patient medical status. Study data was obtained from the dental electronic health record (EHR) system, implemented for use in the clinics of the Department of Pediatric Dentistry, College of Dentistry (COD), University of Illinois at Chicago (UIC). The EHR system administrator generated a list of all patients under the age of 18 years old in the department that have had a panoramic radiograph (PR) taken in the three-year period from 01/01/2016 to 12/31/2018. The principal investigator (PI) accessed the EHR from this list and reviewed the associated PR to determine patient eligibility according to inclusion and exclusion criteria. Eligible patients were enrolled as study subjects and their demographic information (including age at time of PR exposure, sex, race, ethnicity), as well as any medical conditions/systemic disturbances were collected. The American Society of Anesthesiologists (ASA) classification for physical status was used to determine the categorization of the subjects into two groups, healthy (ASA I) and those with existing systemic disturbance (ASA II and above). The participants PR were assessed for DDA and findings recorded in the study collection form. A second examiner evaluated PR determined to have DDA. Furthermore, clinical notes and additional available radiographs for those subjects were reviewed. Both study examiners had appropriate DDA training and were calibrated. Study data was numerically coded and analyzed using SPSS statistical software. A chi-square test and bivariate logistic regression was utilized (with a p-value of <0.05 used to determine statistical significance).**

## SUMMARY

**A total of 1,551 panoramic radiographs were reviewed with 95% deemed diagnostic. The study sample comprised of 1,478 subjects. The demographic characteristics of the cohort included 54% male, 58% white, 49% Hispanic, age range of 3-17 years old (median: 9), and 69% medically healthy (ASA I). DDA were identified in 25% of the patients, with 84% having only one anomaly. Nineteen different types of DDA were detected with highest prevalence within this sample of hyperdontia (8.1%), followed by hypodontia (7.9%) and microdontia (3.6%). A statistically significant relationship was found between health status of ASA II and above and presence of DDA ($p$<.001). Bivariate logistic regression showed that subjects with health status ASA II and above have 2.1 times greater odds of having DDA ($p$<.001, CI = 1.7-2.7). A statistically significant difference between the group of participants having asthma and DDA versus the group of non-asthmatics with DDA was found indicating an association between asthma and presence of DDA (p<.035).**

**There was a high prevalence of radiographically identifiable DDA in our university based pediatric dental clinic population with one of every four patients being affected. A wide range (nineteen different diagnostic entities) of DDA types were found in the study population with anomalies in number being the most common. Special attention must be paid to pediatric patients presenting with dental anomalies, as diagnosis and treatment planning, particularly in those with medical conditions is critical for the long-term multidisciplinary approach to care required by these populations.**

# *I. INTRODUCTION*

## *I.1. Background*

### *I.1.1 Dental Anomalies Overview*

Dental development is an incredibly complex process that is regulated by a series of molecular and cellular interactions. Disruptions and alterations during the phases of initiation, morphogenesis, and histodifferentiation can lead to occurrence of developmental dental anomalies (DDA). The DDA types present in wide variety and can be classified into several categories such as anomalies in number, size, shape, root formation, and matrix deposition and mineralization.[1,2] The DDA etiology is multifactorial and includes hereditary, environmental factors or combinations of both. DDA can present in isolation, as well as in association with additional anomalies or syndromes.[3,4] As some DDA appear in coincidence with systemic and genetic disorders, their management often requires a multidisciplinary team approach.[1] Moreover, dental defects and anomalies can impact the psychosocial functioning of the affected individuals and can have profound negative impacts on their quality of life.[5] Therefore, appropriate knowledge and understanding of DDA are essential to providing quality comprehensive dental care.

The prevalence of DDA in different populations is variable. Past body of research reported a wide range of prevalence (from 4.7% to 74.8%) of specific DDA types in various patient cohorts. [3,6–11] These studies have been conducted in diverse

ethnic and patient groups and have adopted different designs.[2,8] Many of the studies look at specific subsets of populations. Based on medical history, for example, there are prevalence studies evaluating DDA specifically in pediatric patients with familial adenomatous polyposis and those with neuropsychomotor disorders.[12,13] In addition, there are medical conditions and systemic disturbances known to affect the development of dental hard tissues, such as cystic fibrosis.[14] However, it is important to note that DDA can occur in any individual or group worldwide.

DDA may manifest clinically in early childhood and can present as diagnostic and management challenges to pediatric dental professionals. Anomalies can cause esthetic concerns, require endodontic therapy, tooth extraction, orthodontic management of malocclusion, and prosthodontic solutions.[4] Appropriate knowledge and understanding in this area is of paramount importance for successful therapeutic outcomes.

### *I.1.2 Radiographically Identifiable Developmental Dental Anomalies*

#### *I.1.2.1 Anomalies of Number*

Hyperdontia and hypodontia are anomalies of tooth number and a consequence of the action of various etiological factors during the stages of initiation and proliferation of tooth development.[1]

Hyperdontia is diagnosed when there is more than the normal number of teeth in the dental arches. It can occur in both the primary and the permanent dentitions, with the permanent dentition typically more frequently affected (1-

3.5%). In the primary dentition the reported prevalence is 0.3-0.6%. These teeth can resemble the shape of the normal dentition or can be irregularly shaped and sized. Furthermore, in the permanent dentition, it is reported males are twice as affected as females. The location of supernumerary teeth can be in the midline, beyond the molars, or in the molar area.[15] While in healthy individuals supernumerary teeth are uncommon finding, medical conditions with strong association to hyperdontia are: cleidocranial dysplasia, Gardner syndrome and cleft lip and palate.[15]

Hypodontia is the congenital absence (agenesis) of teeth. It can be found in both the primary and permanent dentitions, with the permanent dentition more frequently affected (3-7.5%) and more often seen in females than males.[15] The agenesis of 6 or more teeth is usually termed oligodontia without the count of the third molars. Anodontia refers to the complete developmental absence of teeth.[16] The most commonly missing teeth after the third molars are the mandibular second premolars and the maxillary lateral incisors.[15] Tooth agenesis is usually due to direct effect of physical obstruction of the dental lamina, lack of sufficient space for the tooth development or failure in the initiation of the underlying mesenchyme.[16] Hypodontia is often associated with Ectodermal Dysplasia and cleft lip and palate.[2,15]

The anomalies of number can be diagnosed both through clinical and radiographic examination, as suspicion for the presence or absence of teeth is often confirmed via radiographs.[15]

A compound odontoma is also considered a developmental anomaly of number, defined as "an abnormal mass of calcified tissue."[17] A compound odontoma is identified radiographically as the tissue present resemble teeth-like structures. Their etiology is not well understood and since many are asymptomatic, similar to hyperdontia, they are often first identified as an incidental finding on radiographic exam.[17]

#### *I.1.2.2 Anomalies of Size and Shape*

Anomalies in the size of the tooth include microdontia and macrodontia. Both generalized microdontia and generalized macrodontia are very rare. Typically, only a single or a small number of teeth are affected in the dentition.[15]

Microdontia is defined as a condition in which a tooth has a reduced size compared to the average norm. Most commonly affected teeth are maxillary lateral incisors and third molars. The overall prevalence range in the permanent dentition is reported from 1.5% to 2.5%.[15] Microdontia has been described in association with some syndromes, including Down Syndrome and Ectodermal Dysplasia.

Macrodontia refers to a condition in which the size of a tooth is greater than the average norm. It can develop as an isolated anomaly or can be associated with syndromes and/or systemic disorders such as pituitary gigantism, congenital hemifacial hypertrophy, and craniofacial dysostosis. True macrodontia is rare and it is reported with prevalence of 1.1% in the permanent dentition. In localized macrodontia, the most commonly affected teeth are maxillary central incisors and second premolars.[15]

"Double teeth" refer to the subgroups of teeth that clinically appear to have a larger clinical crown due to either gemination or fusion. Gemination is when a single tooth bud results in a split "double" crown, whereas fusion is defined as two separate tooth buds coming together to form one clinically apparent tooth. It can be challenging to distinguish between fusion and gemination clinically, so their frequency is reported together as 0.1-0.2% in the permanent dentition and 0.5-1.6% in the primary dentition.[15]

Anomalies in the shape and morphology of the tooth include dens invaginatus and dens evaginatus. Other crown malformations can also occur in development, including mulberry molars and shovel shaped incisors. Dens invaginatus occurs when the inner enamel epithelium invaginates within the tooth during development and produces the radiographic and clinical appearance of dens in dente (i.e. a tooth inside a tooth).[8] The maxillary lateral incisors are most frequently affected. The frequency is reportedly 1-5% in the permanent dentition.[15] Dens evaginatus is an anomaly where there is an enamel tubercle extension coming from the occlusal surface of the affected tooth. It may or may not contain pulp tissue. The frequency reported in permanent teeth is 1-4%.[15]

#### *I.1.2.3 Anomalies of Enamel and Dentin Structure*

There are a variety of DDA presenting with altered enamel and dentin structure. Amelogenesis imperfecta, dentinogenesis imperfecta, and dentin dysplasia are a few that are radiographically identifiable. Additionally, Turner's teeth and other generalized enamel defects can often be identified radiographically.

Amelogenesis Imperfecta (AI) is a diagnostic entity referring to conditions of abnormal enamel formation. There are multiple subtypes based on the Witkop classification including the hypoplastic, hypomaturation, hypocalcified, and hypomaturation-hypoplastic with taurodontism types. The molecular basis of the anomaly is complex and the mode of inheritance is not uniform.[18] The prevalence of AI is stated to be around 1:4,000-8,000, with the hypoplastic subtype making up the majority of cases. [15] Since AI presents with a generalized defect of the enamel structure which can be qualitative, quantitative or both, a radiographic comparison of the radio-opacity of the affected enamel to bone or dentine may assist the clinician in recognizing radiographically this aberration. However, some forms of AI may only be diagnosed after thorough comprehensive patient evaluation.

The genetic counterpart to AI in enamel is Dentinogenesis imperfecta in dentin. It is characterized by a defect in collagen and is associated with a clinical appearance of amber-grey to purple-blue translucent teeth and usual pulpal obliteration. This disorder can occur on it's own (Type II) at a frequency of 1:8,000 or can occur simultaneously with osteogenesis imperfecta (Type I) at a frequency of 1:2,500-5,000. Lastly, dentin dysplasia is a disorder effecting the root formation and pulp of the teeth. Often, these teeth appear rootless in radiographs. It is incredibly rare, with a reported frequency of 1:100,000 cases. In these three enamel and dentin disorders, both the primary and permanent dentitions are affected.[15]

### *I.1.2.4 Anomalies of Root Structure*

There are certain root anomalies listed above that are associated with other tooth dysplasias such as dentin dysplasia. Other disorders of root structure include short root anomaly, dilacerations, molar root incisor malformation (MRIM) and taurodontism. In addition, generalized pulp stones are an anomalous finding of the pulp chamber. Short root anomaly is generally an incidental finding during radiographic assessment where the roots appear short and the crowns of affected teeth appear normal. It is more often found in females and has an overall prevalence of 0.6-2.4%.[19] Dilaceration is defined as a sharp bend in the root or crown axis, as opposed to an abnormal, physiologic curve in a root. There is a wide range in prevalence (0.42-98%) reported due to confusion regarding its definition.[19] It is often unclear how roots in posterior teeth are affected, whereas it is generally found secondary to trauma in anterior teeth. MRIM is a newly identified anomaly in which permanent first molars are always affected and distinguished by short, tapered roots and slit shaped pulp chambers. In most cases, primary second molars and permanent maxillary central incisors are also affected, identified by a cervical notching.[19] The etiology of MRIM is not known, however, the literature has reported an association with health challenges during the neonatal period of life.[20] Taurodontism describes teeth, most often molars, with elongated pulp chambers with short roots due to an apically located furcation, which is identifiable on a radiograph. This anomaly is likely due to an error in the invagination of Hertwig's epithelial root sheath. Taurodontism frequency has been reported in 6-10% of permanent dentitions and can be found sporadically or associated with conditions

such as ectodermal dysplasia, Klinefelter syndrome, trichodento-osseous syndrome, and Down Syndrome.[15,21]

#### *I.1.2.5 Anomalies of Position*

Transposition is one type of anomaly of position. It is often viewed as a severe form of ectopic eruption. It is defined as the change in position of two permanent teeth, which are adjacent to one another in the same quadrant of the dental arch.[22] It can be complete where the entire tooth is affected or incomplete, where the root stays in a normal position and only the crowns are transposed. Most often found in women, the majority of cases are also unilateral and located in the maxilla. The most often affected teeth are the canines, transposed with either the first premolar or the lateral incisor. The prevalence has been reported as 0.2%-0.38% in the literature.[22]

### *I.1.3 Panoramic Radiographs*

Panoramic radiographs (PR) are a part of the routine clinical and radiographic exam of dental patients having been utilized in practice since the early 1900s. PR are taken extraorally and allow the clinician to observe the upper and lower jaws, temporomandibular joint, and other structures of the head and neck in one image.[23] Per the American Academy of Pediatric Dentistry (AAPD) guidelines, PR are recommend as early as after the eruption of the first permanent tooth and are prescribed based on clinical judgment and individual patients needs.[24]

PR are taken for a variety of pediatric clinical situations, including but not limited to, caries diagnosis, acute infection, dental trauma, dental anomalies,

developmental disorders, and pathological conditions.[25] Additionally, PR are used in research studies as a means to identify DDA.[3,4,8,9,13] Overall, PR are important diagnostic tools as well as a good method to quantitatively evaluate DDA.[13] Inter- and intra-examiner reliability regarding interpretation of anomaly presence on PR has not been studied extensively. However, it has been found that certain DDA, like agenesis, can be reliably assessed while others, like blunted roots, may not.[26] PR still serve as good diagnostic aids, particularly when examining younger patients and those with special health care needs (SHCN), because placing and properly positioning intraoral films can be a challenge.[13] Moreover, when indicated for a pediatric patient, panoramic imaging may have the benefit of reduced radiation dose, cost, and imaging of a larger area.[25]

### *I.1.4 American Society of Anesthesiologists Classification and Children with Special Health Care Needs/Chronic Medical Conditions*

An integral component of pediatric dentistry is treating patients with chronic medical conditions (CMC) and SHCN. Patients who are medico-compromised or have SHCN may present with unique oral health care issues, including DDA, that are best handled by well-equipped, trained pediatric dental specialists.[27] It is important for the pediatric dental practitioner to be able to qualify the health status of their patients as it may impact delivery of care. Common modalities that practitioners utilize to better, more systematically aid in the categorization and evaluation of their patients' health status include the American Society of Anesthesiologists (ASA) Classification system and the AAPD definition of SHCN.

The ASA is utilized to categorize patients by their physiological status and is a way to identify those who are medically healthy, an ASA I, versus those who are medically compromised, ASA II and above.[28] The definition of ASA I is "a patient with no systemic disease. They do not possess any organic, physiologic, biochemical or psychiatric disturbances."[29] Patients who are ASA II have mild to moderate physiologic disturbance that is controlled. ASA III patients have a difficult to control/manage systemic disturbance. Patients that are ASA IV and above have more severe, life threatening conditions and will likely not be encountered in the outpatient dental setting.[29]

As dental practitioners often communicate regarding patient care, it is important to have a shared understanding of the terms being used by each party. The AAPD provides a definition of SHCN which is inclusive of "any physical, developmental, mental, sensory, behavioral, cognitive, or emotional impairment limiting condition that requires medical management, health care intervention, and/or use of specialized services or programs."[30] As there is limited consensus in the medical literature regarding the definition of a CMC and/or chronic disease, the AAPD definition of SHCN is useful as it encompasses many patients with a wide variety of chronic conditions, allowing the dental practitioner to apply this definition broadly.[31]

# *II. LITERATURE REVIEW*

A review of the literature was conducted using the PRISMA guidelines and the PICO question "Utilizing PR as the diagnostic tool in identifying DDA, do children with SHCN/CMC have the same prevalence of DDA as their healthy counterparts?" In this review, the population is children. The intervention is PR taken of the dentition. The comparison is made according to health status and the outcome is the result of the analysis between groups for prevalence of DDA.

PubMed was utilized to obtain a search of the current literature. The key search words were "panoramic radiographs," "dental," "anomalies," "aberration," "prevalence," "developmental," "medical," "condition," "disease," "child," and "pediatric." Studies were eligible for review if they met the following inclusion criteria: publications had to be written in English, published in the past 10 years (from 2010 to 2020), had a patient population of age 21 or younger, evaluated multiple DDA, utilized panoramic radiographs to identify DDA, and were conducted in the general population.

Studies were excluded if they were expert opinions, case reports, or literature reviews. Research trials, published before 2010 were not included, as well as articles in a language other than English. Studies that used other identifiers (not PR) to assess presence of DDA were excluded. Trials that studied DDA in a population with a specific genetic syndrome or medical condition, and/or evaluated only a single type of DDA were also excluded.

The search returned 252 articles. The PI reviewed all publication titles and/or abstracts for relevance to this literature review. Only six studies fully met the inclusion and exclusion criteria and were selected for further appraisal. All six studies had a retrospective design and are summarized in Table I for reported overall prevalence of DDA and for evaluated types of DDA.

***TABLE I: SUMMARY OF REVIEWED LITERATURE***

| Study | Aims/Purpose | Results/Outcomes |
|---|---|---|
| Marsillac *et al*., 2013[32] | Evaluation of prevalence of dental anomalies of patients treated at the Pediatric Clinic of the State of University of Rio de Janeiro | • 1, 359 panoramic radiographs reviewed<br>• Children aged 5-12 years old<br>• Total prevalence of DDA 11.72%<br>• Most common DDA was hypodontia (4.63%) followed by hyperdontia (3.31%)<br>• Children with "diagnosed syndromes" were not analyzed |
| Goncalves Filho *et al.*, 2014[8] | Evaluate the prevalence of dental anomalies using panoramic radiographs in the city of Belem, Brazil | • 487 panoramic radiographs reviewed<br>• In population aged 1-12 years old, prevalence of DDA was 72.22%<br>• Most common DDA was Taurodontism (38.26%) followed by hypodontia (11.11%)<br>• Children with syndromes were not analyzed |
| Bekiroglu *et al.*, 2015[33] | Examine and determine the situation of oral lesions and dental anomalies and pathologies with panoramic radiographs | • 1,056 panoramic radiographs reviewed<br>• Children aged 4-12 included<br>• Total prevalence of DDA was 43.28%<br>• Most common DDA was mesiodens (3.5%) followed by hyperdontia |

| | | |
|---|---|---|
| | | (0.85%)<br>• No mention was made regarding exclusion of syndromic patients |
| Laganà *et al.*, 2017[9] | Analyze the prevalence and association among DDAs detectable by panoramic radiographs | • 4,706 radiographs reviewed<br>• Children aged 8-12 years old<br>• Total prevalence of DDA was 20.9%<br>• Most common DDA was displacement of maxillary canine (7.5%) followed by hypodontia (7.1%)<br>• Excluded were patients with syndromes, craniofacial malformation, and orthodontic patients |
| Dang *et al.*, 2017[34] | Determine presence of DDA through panoramic radiographs within Australian population | • 1,050 radiographs reviewed<br>• Children aged 6-18 years old<br>• Total prevalence of DDA was 5.14%<br>• Most common DDA was hypodontia (4.28%) followed by impaction (0.6%)<br>• No mention of syndrome exclusion |
| Pallikaraki *et al.*, 2019[10] | Investigate the presence and distribution of DDA in a Greek population | • All orthodontic patients<br>• 1,200 panoramic radiographs reviewed<br>• Total prevalence of DDA was 18.67%<br>• Most common DDA was hypodontia (6.9%) followed by impaction (5.7%)<br>• Excluded were patients with syndromes |

The overall DDA prevalence in these studies ranged from 5.14% to 72.22%.[8–10,32–34] Each study evaluated it's own subset of specific DDA types. For example, Dang *et al.,* (2017) looked at tooth agenesis (i.e. hypodontia), impaction, mesiodens and other supernumerary teeth; whereas, Pallikaraki *et al.,* (2019) looked at taurodontism, dilacerations, macrodontia, microdontia, ankylosis, impaction, ectopic eruption, migration, transposition, fusion, hypercementosis, hypodontia, oligodontia, and supernumerary teeth. The variation in which selected types of DDA were evaluated affected the overall prevalence percentage, making direct comparison not possible. In addition, four out of the six studies excluded patients with syndromes and the remaining two publications did not specify if the analysis included syndromic patient populations. None of these studies separated prevalence of DDA in primary and permanent dentitions. The only separation was made according to age group.

## *II.1 Gaps in the Literature*

Prior research on DDA has focused on estimation of prevalence of selected groups DDA in adult and/or children populations from various geographic regions and countries, such as Turkey, France, Iran, Brazil, and Nigeria.[4,8,11,35,36] Previous studies have also evaluated DDA presence and type in specific patient cohorts, particularly those diagnosed with syndromes and/or CMC.[12,37]

There are no available studies in the current literature evaluating prevalence of radiographically identifiable DDA in university/specialist clinic based pediatric

patient populations in the United States. In addition, there are no existing studies in the literature evaluating the relationship between the presence of DDA in medically healthy children versus children with medical conditions/systemic disruptions.

# *III. AIM AND OBJECTIVE*

## *III.1 Aim*

To describe the prevalence of radiographically identifiable types of DDA, including anomalies of number, size, shape, matrix development and root malformations in a large sample of pediatric patients from a university based dental clinic and to assess for associations between presence of DDA and patient medical status.

## *III.2 Objectives*

- To identify a study sample from a university based pediatric dental clinic that included patients under the age of 18 years who have had panoramic radiographs taken within a three-year period from 01/01/2016 until 12/31/2018.

- To describe the demographic characteristics of the study sample, including age, sex, race and ethnicity, as well as the medical status of the participants.

- To estimate the overall prevalence of DDA as well as the prevalence of different types of radiographically identifiable DDA within the study sample.

- To describe demographic and medical status characteristics of the study cohort of participants with identified DDA.
- To assess for associations between presence of DDA and medical status of the subjects.

## *IV. HYPOTHESIS OF THE STUDY*

The null hypothesis of the study is there is no statistically significant difference between the prevalence of radiographically identifiable DDA amongst medically healthy versus medically compromised patients from a three-year cohort of patients who have had a panoramic radiograph exposed at a university based pediatric dental clinic.

## *V. MATERIALS AND METHODS*

### *V.1 Ethical Approval*

The Institutional Review Board of the University of Illinois at Chicago (UIC) granted permission to conduct this study on January 28, 2019 with protocol number 2018-1564 (Appendix A). No external funding was utilized for this project.

### *V.2 Study Site*

The study was conducted at the Pediatric Dentistry Department, College of Dentistry (COD), UIC.

## *V.3 Study Design and Procedures*

This research trial utilized a retrospective clinical study design. All information pertinent to the study was obtained from the dental electronic health record (EHR) system, AxiUm, implemented for use in the clinics of the Department of Pediatric Dentistry, COD, UIC.

The EHR system administrator generated a list of all patients that have had a panoramic radiograph exposed (insurance codes D0330 and D0335 completed) in the three-year period from 01/01/2016 to 12/31/2018.

The principal investigator (PI) accessed the EHR of all patients from the provided list and reviewed the associated PR. Records were assessed for patient eligibility to be enrolled in the study according to the strict inclusion and exclusion criteria.

To be included in this retrospective study, participants had to be younger than 18 years of age (legal age of becoming an adult in the state of Illinois), had to have a PR taken at the Department of Pediatric Dentistry, COD, UIC in the three-year period from 01/01/2016 to 12/31/2018, and their PR had to be of a diagnostic value. PR were deemed non-diagnostic if the presence of a DDA could not be ruled out, or if the whole or majority of the PR was blurred/unclear.

Patients with PR taken outside of the designated three-year period were excluded from enrollment. All PR had to be taken at the Pediatric Dentistry Department, COD, UIC, which implied that these radiographs were indicated for the

requirements of a Pediatric Dentistry examination. PR taken at other Departments such as the Department of Orthodontics or Department of Maxillofacial and Oral Surgery were excluded.

All PR taken at Pediatric Dentistry Department, COD, UIC were exposed using the same equipment (Orthopantomograph OP200 D) and by a team of professionals (dental assistants, faculty members and residents) trained by the same set of standard operating procedures for taking PR implemented at the clinic.

Patients fulfilling all inclusion criteria were enrolled in the study and each subject received a study number generated by a random digit table. The study numbers were coded with the EHR numbers and the document containing the key to the code was kept in a separate encrypted file in a password-protected computer.

For each subject, the PI accessed the EHR and reviewed all available information pertinent to the study objectives. The PI used the obtained data to complete the specially designed for this trial data collection form (DCF, Figure 1). Participants' demographic information including age (at time of PR exposure), sex, race, ethnicity, as well as any medical conditions/systemic disturbances (all medical diagnoses) and medical status was populated in the DCF.

***Figure 1: Data Collection Form***

| Subject Study Number | Is PR of Diagnostic value (Y/N) | Age (at time of PR) | Sex | Race | Ethnicity | ASA | Specific Medical History | DDA Present (Y/N) | Number of DDA | Specific DDA | Chart Note Diagnosis |
|---|---|---|---|---|---|---|---|---|---|---|---|
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For the purposes of this study, the medical status of the patient was categorized based on presence or absence of medical diagnoses/ systemic disturbances disclosed in the EHR and using the American Association of Anesthesiologists (ASA) classification (Table II).

***TABLE II. AMERICAN ASSOCIATION OF ANESTHESIOLOGISTS CLASSIFICATION OF PATIENT MEDICAL STATUS***

| Physical Status (ASA) | Description |
|---|---|
| I | A normally healthy patient with no organic, physiologic, biochemical or psychiatric disturbance or disease |
| II | A patient with mild-to-moderate systemic disturbances |
| III | A patient with severe systemic disturbances |
| IV | A patient with life threatening systemic disturbances |
| V | A moribund patient who is unlikely to survive without the planned procedure |
| VI | A declared brain-dead patient whose organs are being removed for donor purposes |

By adopting the ASA classification, this study considered all normally healthy participants with no organic, physiologic, biochemical or psychiatric disturbance or disease to be of ASA I status. Participants with any kind of systemic, physiologic, biochemical or psychiatric disturbance or disease were categorized as having medical status ASA II and above.

The PI assessed all PR for presence of DDA. If a DDA was not identified from a radiograph, the PI recorded the participant's information in the DCF and moved on to the next record. However, if a single or multiple DDA were identified from a PR, the PI invited a second examiner to also review the radiograph. The PI was a resident in Pediatric Dentistry who had undergone special training in the topic of DDA. The training included a lecture course at the COD, UIC and familiarizing with a number of didactic materials, such as articles and books pertinent to the DDA subject. The second examiner was a faculty member at the COD, UIC who was a Pediatric Dentist with experience in the diagnosis and treatment of children with DDA. The examiner had undergone the same training in the topic of DDA, including the lecture course and the didactic materials. Both examiners were calibrated for the purposes of this study by completing a questionnaire in a Microsoft PowerPoint format, which aimed at identifying DDA presence from a set of 20 PR.

The second examiner assessed the records deemed with positive DDA findings by the PI. This was done first independently and then the cases were discussed between the two examiners in order to reach a definitive decision on the DDA diagnosis and resolve any disagreements. Furthermore, for the subjects having

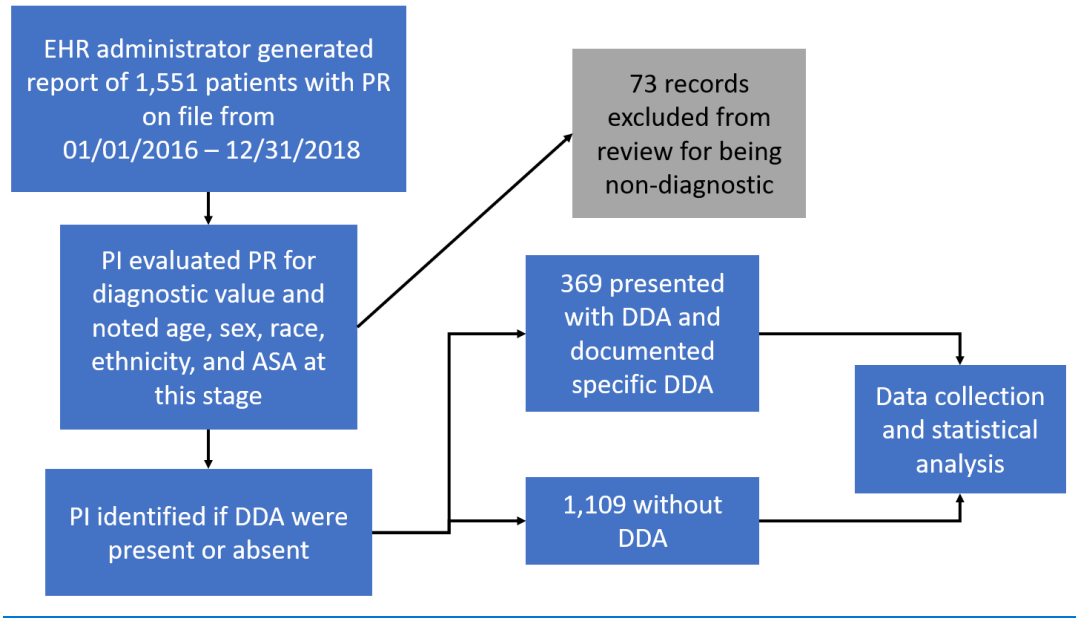
DDA, the examiners accessed all other available information from the EHR, including clinical notes and radiographs (periapical or bitewing exposures). This was completed in an aid to confirm the DDA diagnosis by all possible sources of information from the EHR.

This study aimed at identifying different types of DDA including hyperdontia, hypodontia, macrodontia, microdontia, crown malformations, fusion/gemination, taurodontism, amelogenesis imperfecta, dentinogenesis imperfecta, generalized enamel defect, Turner tooth, dens invaginatus, dens evaginatus, dentin dysplasia, dilacerations, transposition, short root anomaly, generalized pulp stones, MRIM, and odontoma. The definitions of the DDA described by Neville *et al.,* (2015) and White and Pharoah (2018) were used for the purposes of this study in order to diagnose the DDA[38,39]

All obtainable data was recorded in the DCF. If the EHR did not have well documented information with regard to the requirements of this study, such findings were marked on the form as not obtainable information and reported in the results as limitations of the retrospective design.

The Flow Chart diagram in Figure 2 illustrates the stages of the study process.

***Figure 2: Flow Chart of Study Process***




## *V.4 Intra- and Inter-examiner Reliability*

The two examiners of the study were calibrated. Intra- and inter-examiner reliability was analyzed. The PI completed twice a questionnaire aiming to assess twenty randomly selected PR for presence of DDA in an interval of one week. The PI and the second examiner separately for presence of DDA evaluated another twenty randomly selected PR and responses were compared.

## *V.5 Statistical Analysis*

All study data gathered throughout the forms was numerically converted and transferred into Microsoft® Excel 2016 (Microsoft Inc., Redmond, WA, USA). The Microsoft Excel data was then transferred and analyzed using SPSS statistical software (IBM Corporation, Armonk, NY, USA, 2019).

At the bivariate level, a chi-square test and bivariate logistic regression was utilized to compare DDA presence in ASA I versus ASA II and above. A p-value of <0.05 was used to determine statistical significance.

# *VI. RESULTS*

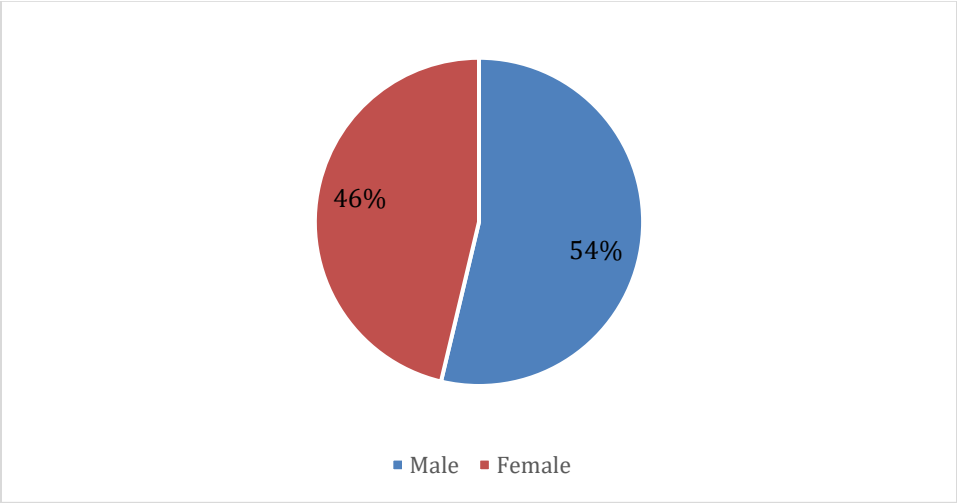
## *VI.1 Descriptive Data Analysis*

The EHR system administrator generated a list of 1,551 AxiUm patient numbers in response to the PI request to identify records of patients who have had a PR taken (D3220 code completed) at the UIC, COD, Pediatric Dentistry Department in the three year period from 01/01/2016 to 12/31/2018. The PI accessed all 1,551 patient records and associated PR were reviewed. Seventy-three patient records (4.7%) were excluded, as their PR did not meet the study's inclusion criteria. A total of 1,478 records were deemed eligible and those patients were enrolled as subjects for the study.

### *VI.1.1 Demographic Data*

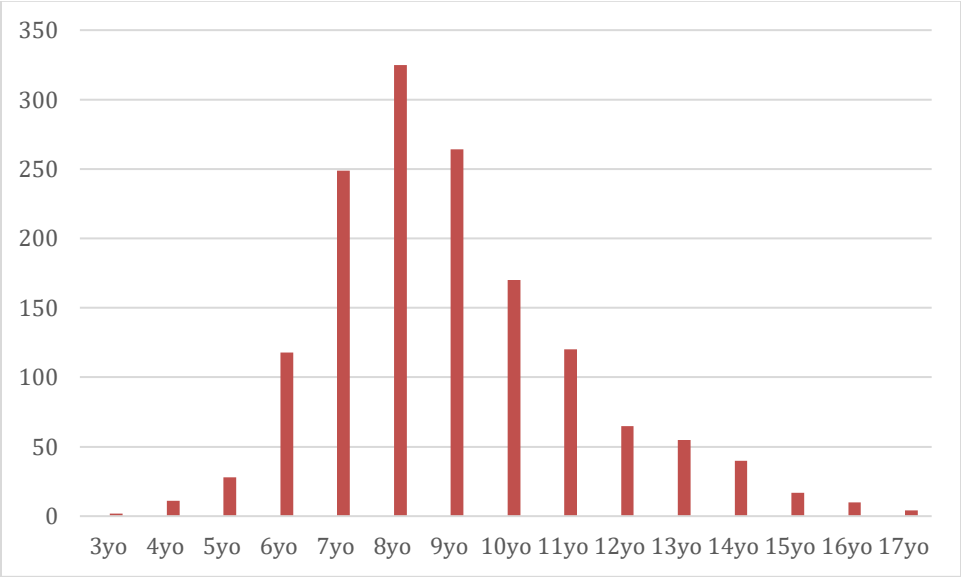
Demographic data analysis of the 1,478 subjects was completed. The sex distribution of the patient population showed a slightly higher male prevalence with 53.7% (n=794) males and 46.3% (n=684) females (Figure 3).

***Figure 3: Sex Distribution of Patient Population***



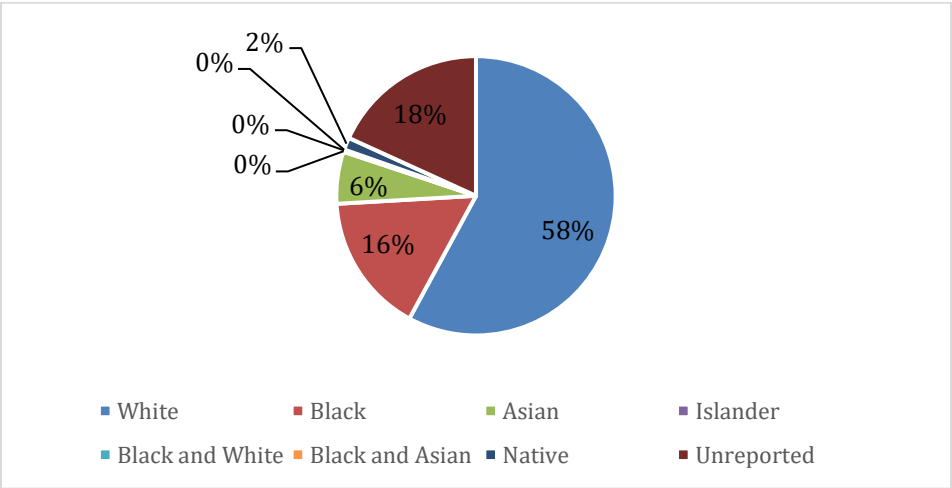

The age range of the participants was 3 to 17 years old. The mean age was 8.9 years and the median age was 9 years. The study population included 0.1% (n=2) three years old, 0.7% (n=11) four years old, 1.9% (n=28) five years old, 8% (n=118) six years old, 16.8% (n=249) seven years old, 22% (n=325) eight years old, 17.9% (n=264) nine years old, 11.5% (n=170) ten years old, 8.1% (n=120) eleven years old, 4.4% (n=65) twelve years old, 3.7% (n=55) thirteen years old, 2.7% (n=40) fourteen years old, 1.2% (n=17) fifteen years old, 0.7% (n=10) sixteen years old, and 0.3% (n=4) seventeen years old at the time the PR was taken (Figure 4).

***Figure 4: Age Distribution of Patient Population***



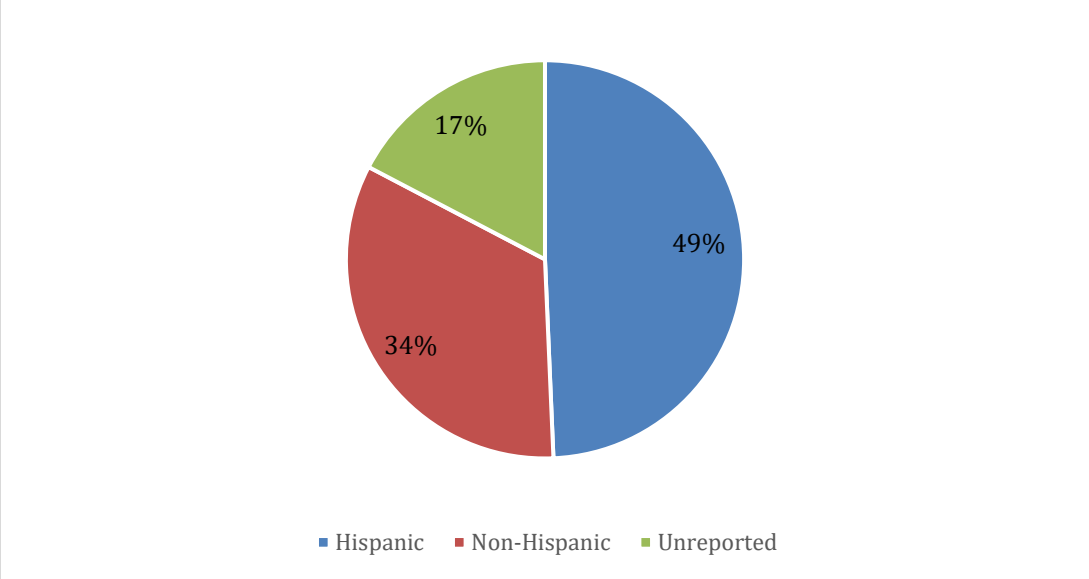

Race was reported for 81.8% (n=1,209) of the subjects and for 18.2% (n=269) of the sample the race was not recorded. The majority of participants (57.9%, n=856) self-reported White race. The rest were 16.2% (n=239) Black, 6% (n=89) Asian, 14.2% (n=21) Native, 0.1% (n=2) Islander, 0.07% (n=1) Black and White and 0.07% (n=1) Black and Asian participants (Figure 5).

***Figure 5: Racial Distribution of Patient Population***



Ethnicity was reported for 82.7% (n=1,222) of the sample. The distribution showed a higher prevalence of Hispanic patients at 49.3% (n=729) compared to 33.4% (n=493) other/non-Hispanic patients. For 17.3% (n=256) of the subjects, ethnicity was not disclosed (Figure 6).

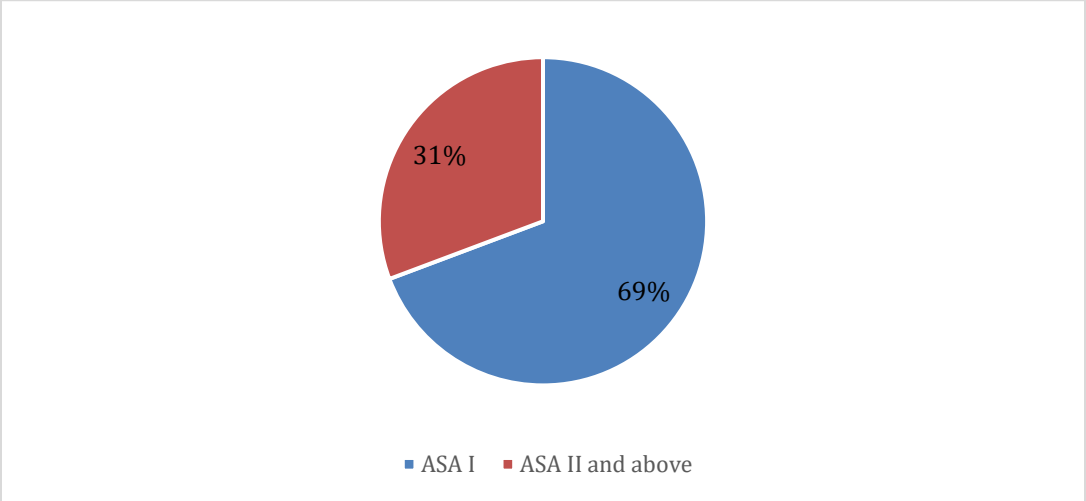
***Figure 6: Ethnic Distribution of Patient Population***




With respect to medical status, 69.3% (n=1,024) of the participants were healthy (ASA I). The remaining 30.7% (n=454) had a reported medical condition on record and were categorized as ASA II or above (Figure 7). Of those categorized as ASA II, 34.6% (n=157) were diagnosed with asthma, 14.5% (n=66) with attention deficit disorder/attention deficit hyperactivity disorder (ADD/ADHD), 13.7% (n=62) with autism, 11% (n=50) with developmental and learning delays, 11% (n=50) with cardiac conditions, 7.9% (n=36) with craniofacial syndromes including cleft lip and palate, 7.3% (n=33) with epilepsy and seizures, 5.1% (n=23) with Down

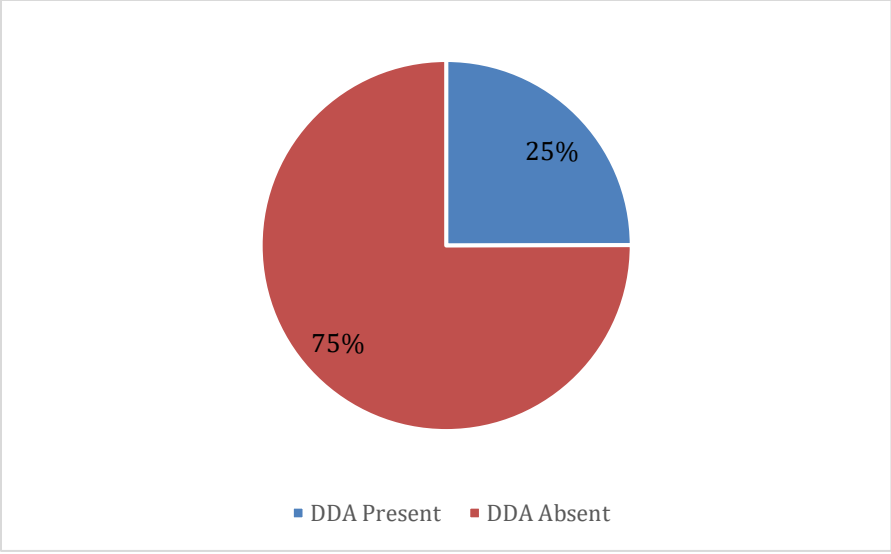
Syndrome, 2.6% (n=12) with hypothyroidism, 2.2% (n=10) with a previous history of cancer, and 1.1% (n=5) with ectodermal dysplasia.

***Figure 7: ASA Distribution in Patient Population***




For 75% (n=1,109) of the study sample, radiographically identifiable DDA were not detected. For 25% (n=369) of the participants at least one DDA was found (Figure 8).

***Figure 8: DDA Presence in Patient Population***



### *VI.1.2 Descriptive Data of the Developmental Dental Anomalies Overall*

A total of 25% (n=369) of the subjects had at least one DDA. Of those participants, 56.9% (n=210) were males and 43.1% (n=159) females. The majority of the participants with DDA (58.3%, n=215) self-reported White race, while 16.8% (n=62) reported Black race, 5.4% (n=20) Asian, and 1.6% (n=6) Native, and 17.9% (n=66) did not report a race. The ethnic distribution of those with DDA showed a higher Hispanic prevalence with 49.9% (n=184) Hispanic, 32.2% non-Hispanic (n=119), and 17.9% (n=66) without reported ethnicity. With regard to medical background, 56.6% (n=209) were healthy and classified as ASA I. The remaining 43.4% (n=160) had at least one reported medical condition placing them in the category of ASA II or higher.

The majority (84.3%; n=311) of the subjects had a single DDA, while 14.6% (n=54) had two DDA, and 1.1% (n=4) had three DDA.

### *VI.1.3 Descriptive Data of Specific Developmental Dental Anomalies*

Of all 369 subjects with DDA, 95.9% (n=354) had DDA of the permanent dentition and only 4.1% (n=15) of the cases had a DDA affecting primary teeth.

The DDA of primary teeth in this sample included 10 cases of hyperdontia and 5 cases of fusion/gemination. Table III summarizes the descriptive data of the subjects presenting with primary tooth DDA.

***TABLE III: DESCRIPTIVE DATA OF THE PRIMARY TOOTH DDA SAMPLE***

| DDA | Age range | Male | Female | Hispanic | Other | ASA 1 | ASA>1 |
|---|---|---|---|---|---|---|---|
| Hyperdontia | 4-8 | 7 (70) | 3 (30) | 7(70) | 2 (20) | 9 (90) | 1 (10) |
| Fusion/Gemination | 5-10 | 3 (60) | 2 (40) | 1 (20) | 2 (40) | 2 (40) | 3 (60) |

In comparison, Table IV summarizes the descriptive data of the sample of subjects with the same two anomalies (hyperdontia and fusion/gemination) in the permanent dentition.

***TABLE IV: DESCRIPTIVE DATA OF THE HYPERDONTIA AND FUSION/GEMINATION IN PERMANENT TEETH SAMPLE***

| DDA | Age range | Male | Female | Hispanic | Other | ASA 1 | ASA>1 |
|---|---|---|---|---|---|---|---|
| Hyperdontia | 4-16 | 81 (73.6) | 29 (26.4) | 70 (63.6) | 21 (19.1) | 86 (78.2) | 24 (21.8) |
| Fusion/Gemination | 8-12 | 3 (100) | 0 (0) | 3 (100) | 0 (0) | 2 (66.7) | 1 (33.3) |

Due to the very small sample of primary teeth, the data of these subjects is reported together with the data for DDA in permanent teeth.

For all 1,478 subjects, the most frequently identified DDA was hyperdontia with an overall prevalence of 8.1% (n=120) of which 0.7% in primary teeth and 7.4% in permanent teeth.

The majority of the subjects with hyperdontia had supernumerary teeth located in the anterior region of the dental arch (94.2%, n=113).

Hypodontia was the second most common DDA with a prevalence of 7.9% (n=117) in this study population and affected only permanent dentition. Mandibular

second premolars were the most commonly missing teeth, with a total of 76 missing second premolars in the patient sample.

Microdontia was identified only in permanent teeth and had a prevalence of 3.6% (n=53) in this cohort. The majority of the cases with microdontia presented with peg shaped lateral incisors (75.5%, n=40).

Table V summarizes the prevalence of all types of DDA identified within the study sample.

***TABLE V: PREVALENCE (% OF TOTAL) OF ALL DDA TYPES IDENTIFIED IN THE STUDY SAMPLE***

| DDA | Total Identified | Prevalence (%) |
|---|---|---|
| Hyperdontia | 120 | 8.1% |
| Hypodontia | 117 | 7.9% |
| Microdontia | 53 | 3.6% |
| Dilaceration | 24 | 1.6% |
| Dens Invaginatus | 22 | 1.5% |
| Short Root Anomaly | 17 | 1.2% |
| Taurodontism | 15 | 1.0% |
| Dens Evaginatus | 10 | 0.7% |
| Fusion/Gemination | 8 | 0.5% |
| Transposition | 7 | 0.5% |
| Odontoma | 7 | 0.5% |
| Amelogenesis Imperfecta | 6 | 0.4% |
| Molar Root Incisor Malformation | 5 | 0.3% |
| Generalized Pulp Stones | 4 | 0.3% |
| Crown Malformation | 4 | 0.3% |
| Turner Tooth | 3 | 0.2% |
| Generalized Enamel Defect | 2 | 0.1% |
| Macrodontia | 2 | 0.1% |
| Dentinogenesis Imperfecta | 1 | 0.07% |
| Dentin Dysplasia | 0 | 0% |

Table VI summarizes the sex, ethnicity, and ASA breakdown for each DDA type identified in this study sample.

***TABLE VI: NUMBER AND PERCENTAGE OF SEX, ETHNICITY, AND ASA PER DDA***

| DDA | Male | Female | Hispanic | Non-Hispanic | ASA 1 | ASA>1 |
|---|---|---|---|---|---|---|
| Hypodontia | 52 (44.4) | 65 (55.6) | 46 (39.3) | 52 (44.4) | 48 (41) | 69 (59) |
| Hyperdontia | 88 (73.3) | 32 (26.7) | 77 (64.2) | 23 (19.2) | 95 (79.2) | 25 (20.8) |
| Macrodontia | 1 (50) | 1 (50) | 1 (50) | 1 (50) | 1 (50) | 1 (50) |
| Microdontia | 31 (58.5) | 22 (41.5) | 23 (43.4) | 20 (37.7) | 18 (34) | 35 (66) |
| Fusion/ Gemination | 6 (75) | 2 (25) | 4 (50) | 2 (25) | 4 (50) | 4(50) |
| Taurodontism | 8 (53.3) | 7 (46.7) | 3 (20) | 8 (53.3) | 4 (26.7) | 11 (73.3) |
| Amelogenesis Imperfecta | 4 (66.7) | 2 (33.3) | 3 (50) | 2 (33.3) | 3 (50) | 3 (50) |
| Dentinogenesis Imperfecta | 0 | 1 (100) | 0 | 1 (100) | 0 | 1 (100) |
| Dilaceration | 13 (54.17) | 11 (45.8) | 9 (37.5) | 7 (29.2) | 12 (50) | 12 (50) |
| Transposition | 5 (71.4) | 2 (28.6) | 3 (42.9) | 3 (42.9) | 1 (14.3) | 6 (85.7) |
| Dens Invaginatus | 8 (36.4) | 14 (63.6) | 12 (54.5) | 6 (27.3) | 16 (72.7) | 6 (27.3) |
| Dens Evaginatus | 7 (70) | 3 (30) | 4 (40) | 5 (50) | 7 (70) | 3 (30) |
| Short Root Anomaly | 8 (47.1) | 9 (52.9) | 14 (82.4) | 2 (11.8) | 12 (70.6) | 5 (29.4) |
| MRIM | 3 (60) | 2 (40) | 0 | 3 (60) | 1 (20) | 4 (80) |
| Odontoma | 3 (42.9) | 4 (57.1) | 6 (85.7) | 1 (14.3) | 5 (71.4) | 2 (28.6) |
| Generalized Enamel Defect | 0 | 2 (100) | 1 (50) | 0 | 2 (100) | 0 |
| Crown Malformation | 2 (50) | 2 (50) | 2 (50) | 1 (25) | 1 (25) | 3 (75) |
| Turner Tooth | 1 (33.3) | 2 (66.7) | 0 | 2 (66.7) | 0 | 3 (100) |
| Generalized Pulp Stones | 2 (50) | 2 (50) | 2 (50) | 1 (25) | 1 (25) | 3 (75) |

Table VI identifies some outlier characteristics of note for individual DDA. Of the five cases of identified MRIM, 80% of the subjects were categorized as ASA II or above. All of the cases of Turner's tooth and dentinogenesis imperfecta are ASA II or above. In the subjects with identified Short Root Anomaly, 82.4% were documented as Hispanic and 70.6% as ASA I. Of those with Hyperdontia, the majority (73.3%)

are males, Hispanic (64.2%), and ASA I (79.2%). Similarly, the majority of the participants with identified odontoma were Hispanic (85.7%) and ASA I (71.4%).

Of the 369 subjects with DDA identified in the study, 78.9% (n=291) were, in part or whole, also documented in the patients' day notes, while for 21.1% (n=78) there was no diagnosis at all on record. Commonly undocumented radiographically identifiable DDA (where over 50% of the cases are undocumented) are dens evaginatus, dens invaginatus, taurodontism, and microdontia.

Within all medical conditions that were reported in the group of ASA II and above, most commonly subjects had asthma (13.6%; n=50), a craniofacial syndrome including cleft lip/cleft palate (6.2%; n=23), ADD/ADHD (6%; n=22), and autism (4.1%; n=15).

### *VI.2 Analysis of Association of Presence of Developmental Dental Anomalies to Health Status*

Of the 369 subjects with identified DDA, 56.6% (n=209) were classified as ASA I and 43.4% (n=160) were classified as ASA II and above.

Of the 1,109 subjects without DDA, 73.5% (n=815) were classified as ASA I and 26.5% (n=294) were classified as ASA II and above.

The group of subjects with DDA was compared to the group without DDA with respect to their ASA status of ASA I or ASA II and above (Figure 9). Statistical analysis was run using a chi-square test, and it was determined that there was a statistically significant difference between the two groups ($P$<.000) indicating an

association between health status and presence of DDA (Table VII). A bivariate logistic regression was run and it showed that the odds ratio was 2.1 (p<.000, CI=1.67-2.71). This means that patients with ASA II or above had 2.1 times greater odds of having DDA in comparison to their healthy (ASA I) counterparts.

***Figure 9: ASA Status based on DDA presence or absence***

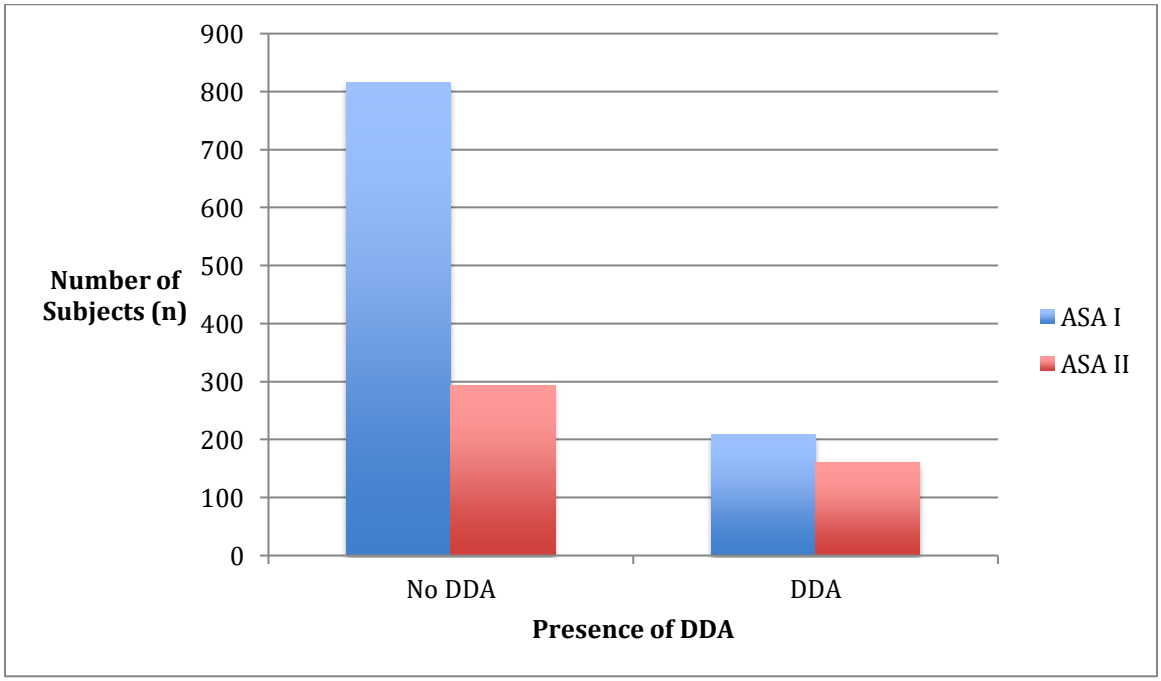



***TABLE VII: CHI-SQUARE ANALYSIS COMPARING ASA STATUS IN THOSE WITH DDA AND THOSE WITHOUT DDA***

| | |
|---|---|
| TABLE ANALYZED: Non-parametric test chi-square: | |
| P-value and statistical significance | |
| Test | Chi-square |
| Chi square, df | 36.94, 1 |
| P value | .000 |
| One or two sided | NA |
| Statistically significant (P<.05)? | Yes |

## *VI.3 Analysis of Association of Presence of Developmental Dental Anomalies to Specific Medical Condition*

Asthma was the most commonly reported CMC within this patient cohort (n=157). Of the subjects with identified DDA, 13.5% (n=50) had reported history of asthma and 86.4% (n=319) did not. Of the subjects without identified DDA, 9.6% (n=107) had a reported history of asthma and 90.4% (n=1,002) did not. The group of subjects with DDA was compared to the group without DDA with respect to their reported history of asthma (Figure 10). Statistical analysis was run using a chi-square, and it was determined that there was a statistically significant difference between the two groups ($P<.035$) indicating an association between asthma and presence of DDA (Table VIII).

***Figure 10: Asthma Status based on DDA presence or absence***

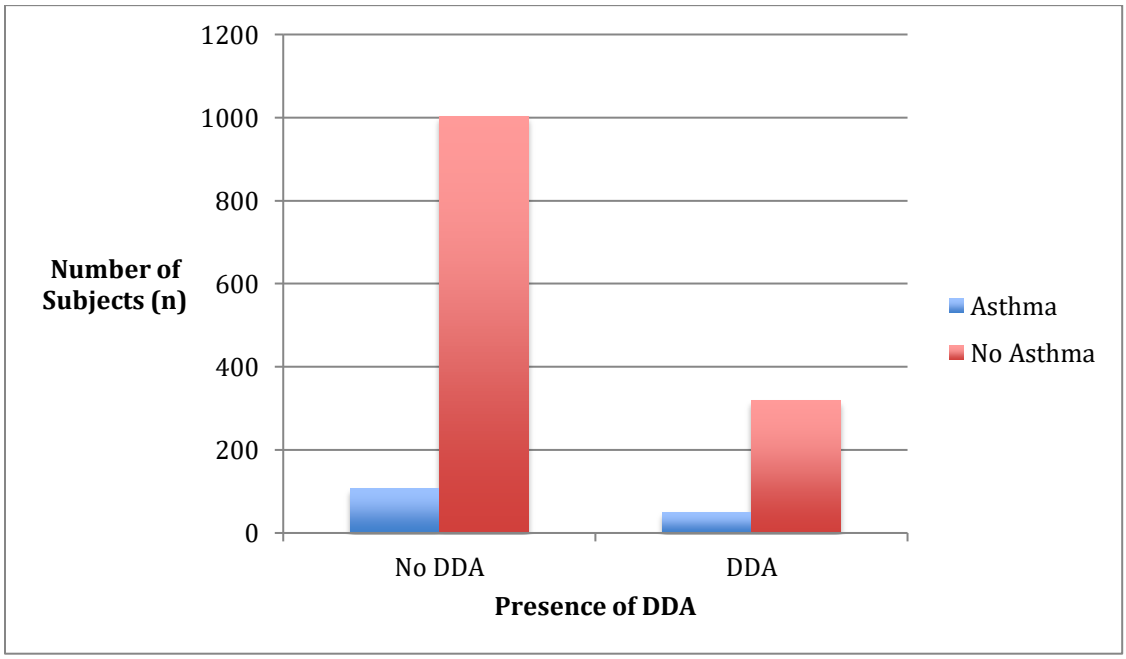


***TABLE VIII: CHI-SQUARE ANALYSIS COMPARING ASTHMA STATUS IN THOSE WITH DDA AND THOSE WITHOUT DDA***

| | |
|---|---|
| TABLE ANALYZED: Non-parametric test chi-square: | |
| P-value and statistical significance | |
| Test | Chi-square |
| Chi square, df | 4.44, 1 |
| P value | .035 |
| One or two sided | NA |
| Statistically significant (P<.05)? | Yes |

## *VI.4 Association of Medical Status to Specific Developmental Dental Anomalies*

There were a several DDA types for which the majority (>50%) of the subjects in their respective cohorts were categorized with medical status ASA II and above. Such DDA types included Dentinogenesis Imperfecta (100%), Turner's tooth (100%), transposition (85.7%), crown malformation (75%), taurodontism (73.3%), MRIM (80%), generalized pulp stones (75%), microdontia (66%), and hypodontia (59%). The subject samples of those DDA types were not large enough to be able to draw significance from statistical analysis.

## *VI.5 Intra- and Inter-examiner Reliability*

An intra-class analysis was run to assess intra-rater reliability of the PI examiner for detection of DDA on the PR. This yielded a 100% match in responses between tests for the PI.

An inter-class analysis was run to assess inter-rater reliability between the two examiners (the PI and the faculty mentor). This yielded a 95% match in response. Any discrepancy was resolved between the two raters.

# *VII. DISCUSSION*

## *VII.1 Prevalence of Developmental Dental Anomalies*

Prevalence is an important measure in epidemiology. It is defined as the proportion of a population affected by a particular condition/disease in a given location and at a certain time.[40] Knowing the proportion of affected individuals in a population is strategic to planning and allocating resources to appropriately cater for the health care needs of this population.[40] Prevalence may also be used as a measure to compare the burden of certain condition across different populations (in various locations) or over different time periods**.**

The prevalence of DDA is variable across populations and geographic regions. As the etiology of DDA is multifactorial, this variation can be considered a result of the complex contribution and interaction of genetic, epigenetic, and environmental factors.[2]

Our study sought to find the prevalence of DDA in an urban pediatric population. The prevalence of all types of DDA in our sample was 25%. This result falls within the range of 5.14% to 72.22% reported from previous research conducted in pediatric populations from other geographic locations.[8–10,32–34] Our outcome is about five times greater than the prevalence reported by Dang *et al.,*

(2017), while it is just a third of the result found by Goncalves Filho *et al.,* (2014). This large spread in prevalence range may be attributable to inherent differences of the studied populations as well as differences in sample selection and research methodology. There was also a variation between studies with respect to DDA selected for evaluation.

Dang *et al.,* (2017) looked at only four DDA types such as tooth agenesis, mesiodens, supernumerary teeth, and impacted teeth in an Australian population. Thus, the reported prevalence was relatively low (5.14%). Goncalves Filho *et al.,* (2014) evaluated a broader range of 13 different DDA including taurodontism, root dilacerations, peg shaped tooth, talon cusp, shell tooth, dens in dente, concresence, hypodontia, hyperdontia, microdontia, macrodontia, amelogenesis imperfecta, and enamel hypoplasia in a Brazilian population. Perhaps, the high prevalence of 72.22% reported by this group can be explained by the number of included diagnoses as well as by the nature of the studied DDA types. For example, the authors found that the most prevalent DDA in their sample was taurodontism. Depending on the utilized classification, milder forms of taurodontism may remain largely underreported in the literature.

A recent study evaluated fourteen DDA types. Pallikaraki *et al.,* (2019) assessed a Greek population sample and reported an overall DDA prevalence of 18.6%. This result is slightly lower, but closer to ours (25%). Pallikaraki and colleagues included anomalies of eruption, which were not examined in our research trial. Our study assessed a wider variety of DDA. We aimed to identify as

many radiographically identifiable DDA as possible and found 19 different DDA types, including diagnoses such as amelogenesis imperfecta and dentinogenesis imperfecta.

The 25% prevalence of DDA that we found in our sample is a relatively high figure. This means that one of every four patients seen in our university based pediatric dental clinic have had at least one DDA. The high prevalence can be attributed to the specifics of the studied cohort. As a secondary setting, a big part of our patient pool is comprised of referrals from primary care providers. Cases deemed complex by general dentists, such as children presenting with anomalous dental conditions and/or medical conditions/systemic disturbances, are directed for care to UIC, COD, Pediatric Dentistry department. Apart from pediatric dentists trained to manage young patients, our institutional setting offers access to further resources, such as inter and multidisciplinary teams of specialists. The sample in this study represents a typical patient cohort seen at the Pediatric Dentistry Department. All PR evaluated for the study purposes were taken at the pediatric dental clinic. Many of the subjects with DDA were managed subsequently in other departments within the COD such as the department of Orthodontics, Oral and Maxillofacial Surgery and etc.

In addition, this cohort is comprised of a sample that is represented by a low-income, as well as Hispanic, majority. It is a diverse group, with patients who have migrated from other geographic regions. People within this cohort may also have had difficulty in attaining care elsewhere, some traveling long distances within the

state or from neighboring states. The demographic of this population may be a contributing factor to the high prevalence seen in the results.

### *VII.1.1 Prevalence of Individual Types of Developmental Dental Anomalies*

The most commonly reported DDA in this study were those of number. The overall prevalence of hyperdontia was 8.1%. The prevalence of supernumerary teeth in the primary dentition was 0.7%, which corresponds well to the range reported in the literature (0.3-0.6%).[15] However, we found higher prevalence of permanent teeth hyperdontia (7.4%) than the usually cited figure (1-3.5%).[15] In comparison to other similar trials conducted in pediatric populations, the prevalence of supernumerary teeth in our study cohort was the highest.[8–10,32,33] The male to female ratio in our population was 2.75:1, which is in agreement with the literature reporting that males are frequently more affected than females.

Hypodontia was found only in the permanent dentition in our cohort with a prevalence of 7.9%. This figure matches the upper range of that reported in the literature (3-7.5%).[15] For comparison, Laganà *et al.,* (2017) showed a result of 7.1%, while Dang *et al.,* (2017) calculated 4.28% prevalence of hypodontia in their respective patient populations.[9,34] In addition, the higher female to male ratio of 1.25:1 of hypodontia that we found is similar to the previously reported ratio (1.4:1 female to male).[15]

In this study 0.5% of the subjects had a diagnosis of odontoma. This prevalence is similar to the reported 0.38% by Bekiroglu *et al.,* (2015), 0.44% by Marsillac *et al.,* (2013) and 0.6% by Laganà *et al.,* (2017).[9,32,33]

With regard to anomalies of size and shape, these were detected only in permanent teeth in our study. Microdontia was identified in 3.6% of the sample and macrodontia was found only in 0.1% of the subjects. The prevalence figure for microdontia in this population is slightly higher than the range (0.5% to 2.5%) previously reported.[8,10,15,32]

On the contrary, the prevalence rate (0.1%) of macrodontia in our study population was lower than that of other similar studies (0.58% and 0.62%).[8,10]

Gemination and fusion were found in a total of eight (0.54%) subjects with five (0.34%) cases affecting primary teeth and three (0.2%) cases in permanent teeth. This is much lower than the prevalence reported in Bekiroglu *et al.,* (2015) of 2.08% and similar to that reported of 0.33% in Pallikaraki *et al.,* (2019).[10,33]

Dens invaginatus in the studied population was found in prevalence of 1.5% in our cohort. This result falls within the accepted range reported in the literature of 1-5%.[15] Dens evaginatus was found in 0.7% prevalence of the COD, UIC population, which is slightly lower than the reported range in the literature of 1-4%.[15]

Hard tissue developmental defects of enamel and dentin are rare conditions. We identified six (0.4%) cases of Amelogenesis Imperfecta and one (0.07%) of Dentinogenesis Imperfecta. These figures correspond to the findings of other trials; for example, Amelogenesis Imperfecta had a prevalence of 0.43% in a Turkish study by AT Altug-Atac *et al.,* (2007), while Gupta et al., (2011) estimated that 0.09 % of their studied Indian cohort had Dentinogenesis Imperfecta.[11,41]

This study evaluated DDA of root structure and one diagnosis of interest was MRIM. This is a newly described anomaly and currently there are no available epidemiological studies in the literature describing its prevalence. In the cohort examined by us, the prevalence was 0.3% (n=5). MRIM is rare and this is the first research trial establishing a prevalence figure for it. Accurate knowledge for the diagnosis of this anomaly and its timely treatment is essential to ensure function and stability for the affected patients over time.

Short root anomaly was identified in 1.2% of the studied population, which falls within the reported range found in the literature of 0.6-2.4%.[19] Dilaceration was seen in 1.6% of the subjects, which is also within the reported wide prevalence range of 0.42-98%.[19] Taurodontism affected 1% of our population, which is higher than the prevalence reported in Laganà *et al.,* (2017) of 0.04% and Pallikaraki *et al.,* (2019) of 0.5%.[9,10]

As for anomalies in position, transposition was identified in 0.5% of the study population. This prevalence is higher than the reported range in the literature of 0.2-0.38%.[22] It is the exact same as the prevalence reported in Pallikaraki *et al.* (2019) and less than that reported in Laganà *et al.,* (2017) of 1.4%.[9,10]

Overall, the pediatric population at UIC COD had a sizeable representation of the entire spectrum of DDA. Anomalies of number and size (particularly microdontia) were the most common and more prevalent in comparison to other studied pediatric populations. DDA can be found on PR, sometimes incidentally, or through a thorough clinical exam, in pediatric populations. DDA of all types can have

profound effects on the dentition in the long term and require complex management. Our findings continue to underscore the importance of appropriate training for pediatric dental specialists working in large, urban clinics; they require the knowledge base to appropriately diagnose and manage DDA of all types, as they may come across these developmental aberrations in clinical practice at some point in their career.

## *VII.2 Impact of the Presence of Developmental Dental Anomalies and Association with Medical Background*

This is the first study to the best of our knowledge to evaluate associations between presence of DDA and medical status. It is known that certain types of DDA can be more common in some systemic medical conditions and syndromes. For example, hypodontia is a frequent feature in ectodermal dysplasia and enamel defects are seen more often in patients with celiac disease or vitamin D-resistant rickets.[2] Other studies in syndromic populations show an association with presence of DDA. For example, those with craniofacial syndromes, like cleft lip and palate, show a high prevalence of hypodontia and microdontia.[42] Additionally, people with Down Syndrome may be more likely to have taurodontism and hypodontia.[43]

We found that there is an association between the presence of DDA and existing systemic disturbances. Furthermore, there are approximately double the odds of having a DDA when a person has a CMC and/or SHCN. Certain DDA, like transposition, taurodontism, MRIM, and microdontia, were shown to be more

prevalent in those categorized as ASA II and above. Additionally, an association between asthma and the presence of DDA was identified. This relationship is substantiated by prior research that evaluated the association of asthma with enamel defects.[44] Although the presence of a CMC and/or SHCN does not confer causation for the presence of the DDA, this study's findings continue to support the premise of previous research findings that various systemic health conditions, including syndromes, are associated with the presence of DDA.

We rejected the null hypothesis, and concluded that there is a statistically significant association between presence of DDA and health status. Therefore, it is important for the clinician to be aware of this relationship as this can better guide the clinical exam performed and radiographic exam prescribed for each patient, with special attention paid to those belonging to a population more at risk for development/presence of DDA. It is of particular interest for pediatric dentists as DDA are often first identified within the age range of the pediatric patients presenting to them. Moreover, pediatric dentists encounter many patients with CMC and SHCN as their training and expertise is targeted to serve these patients. DDA deserve attention, generally speaking, as their treatment is often multifaceted, long term, and requires multiple specialty practitioners.

### *VII.3 Study Strengths and Limitations*

This study has several strengths. Two raters analyzed the PR with identified DDA. Both raters were calibrated and experienced with appropriate topical training. A large subject cohort was included over the course of a three-year period of time, in

an effort to be representative of typical patient flow in the UIC COD Pediatric Dentistry department. In addition, a large number of DDA were included for identification, broadening the scope of this research.

This study had limitations as well. The study population is skewed as it has a higher propensity for minorities and patients on public insurance presenting to a university based dental clinic. Moreover, the retrospective design has inherent weaknesses. There was an inability to perform clinical along with the radiographic examination of the patient cohort and there was a reliance on the patient record for information to clarify medical history along with clinical notes to clarify findings from the radiographs. Additionally, one examiner reviewed all PR and a second examiner assessed only those that were already deemed to have positive DDA findings. Naturally, the first examiner may have missed DDA, so there is a bias towards possible underreporting.

### *VII.4 Future Studies*

Future studies may continue to evaluate the relationship between specific CMC/SHCN and DDA presence. Research trials similar to our design can be conducted in other clinical settings and geographic locations worldwide to allow for comparison between populations. Furthermore, utilizing the same methodology and studying populations from the same location, but at different time points, may show changes in trends of DDA prevalence between generations.

Prospective trials evaluating dental development aberrations of children with CMC and/or SHCN could provide further insight into understanding the groups

at higher risk for DDA and for advancing best practice recommendations for practitioners treating these groups.

Our study was retrospective and used dental radiography as a tool in identifying individuals with DDA. Future studies can adopt prospective design and use both clinical and radiographic assessment in patient evaluation.

The current study generated a large data set and we utilized statistical methods that served addressing the aims and objectives of our research trial. However, this data can be further analyzed and used for different research purposes and questions.

## *VIII. CONCLUSIONS*

The following conclusions can be made based on the results of this study:

- There was a high prevalence of radiographically identifiable DDA in our university based pediatric dental clinic population with one of every four patients being affected.

- A wide range (nineteen different diagnostic entities) of DDA types were found in the study population with anomalies in number being the most common.

- There was a statistically significant association between presence of DDA and patients' medical status indicating that children with any kind of systemic, physiologic, biochemical or psychiatric disturbance or disease (categorized

as having medical status ASA II and above) had a higher (2.1 times) likelihood of having DDA.

- Asthma was the most commonly reported medical diagnosis within our patient cohort. Of the subjects with identified DDA, 13.5% had reported history of asthma. There was a statistically significant association between asthma and presence of DDA.

- As specialists, pediatric dentists may encounter many patients with DDA and/or medical problems, and should be prepared to manage appropriately the multidisciplinary care of these patients.

# *APPENDIX*

**Approval Notice**
**Initial Review (Response To Modifications)**

January 28, 2019

Rachel Vorwaller, DDS
Pediatric Dentistry
Phone: (312) 996-7532

RE: Protocol # 2018-1564
"DEVELOPMENTAL DENTAL ANOMALIES, PREVALENCE IN A UNIVERSITY BASED PATIENT COHORT AND ASSOCIATIONS WITH MEDICAL BACKGROUND"

Dear Dr. Vorwaller:

Your Initial Review (Response To Modifications) was reviewed and approved by the Expedited review process on January 28, 2019. You may now begin your research

Please note the following information about your approved research protocol:

**Protocol Approval Period:**
**Approved Subject Enrollment #:** 5000
**Additional Determinations for Research Involving Minors:** The Board determined that this research satisfies 45CFR46.404
**Performance Sites:** UIC
**Sponsor:** None
**Research Protocol(s):**

a) DEVELOPMENTAL DENTAL ANOMALIES, PREVALENCE IN A UNIVERSITY BASED PATIENT COHORT AND ASSOCIATIONS WITH MEDICAL BACKGROUND, PI: Dr. Rachel Vorwaller, Version 1, 11/28/2018

**Informed Consent(s):**

a) Waiver of informed consent granted [45 CFR 46.116(f)] applicable to all of research

**HIPAA Authorization(s):**

a) Waiver of HIPAA authorization granted [45 CFR 164.512(i)(1)(i)] applicable to all of research

Your research meets the criteria for expedited review as defined in 45 CFR 46.110(b)(1) under the following specific category:

(5) Research involving materials (data, documents, records, or specimens) that have been collected, or will be collected solely for nonresearch purposes (such as medical treatment or diagnosis).

**Please note the Review History of this submission:**

| Receipt Date | Submission Type | Review Process | Review Date | Review Action |
|---|---|---|---|---|

UNIVERSITY OF ILLINOIS AT CHICAGO
Office for the Protection of Research Subjects
(MC 672)
1737 West Polk Street
Chicago, Illinois 60612
Phone: (312) 996-1711

| | | | | |
|---|---|---|---|---|
| 12/07/2018 | Initial Review | Expedited | 12/21/2018 | Modifications Required |
| 01/08/2019 | Response To Modifications | Expedited | 01/28/2019 | Approved |

Please remember to:

→ Use your **research protocol number** (2018-1564) on any documents or correspondence with the IRB concerning your research protocol.

→ Review and comply with all requirements on the guidance,
**"UIC Investigator Responsibilities, Protection of Human Research Subjects"**
*(http://tigger.uic.edu/depts/ovcr/research/protocolreview/irb/policies/0924.pdf)*

**Please note that the UIC IRB has the prerogative and authority to ask further questions, seek additional information, require further modifications, or monitor the conduct of your research and the consent process.**

**Please be aware that if the scope of work in the grant/project changes, the protocol must be amended and approved by the UIC IRB before the initiation of the change.**

We wish you the best as you conduct your research. If you have any questions or need further help, please contact OPRS at (312) 996-1711 or me at (312) 413-3788. Please send any correspondence about this protocol to OPRS at 203 AOB, M/C 672.

Sincerely,

Rachel Olech, B.A., CIP
Assistant Director, IRB # 3
Office for the Protection of Research Subjects

Enclosure(s): None

cc: Marcio Da. Fonseca, Pediatric Dentistry, M/C 850
Evelina Kratunova,
Privacy Office, Health Information Management Department, M/C 772



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# *VITA*

**Rachel Vorwaller, DDS**

## *Education and Training*

**University of Illinois at Chicago, College of Dentistry, Department of Pediatric Dentistry,** *Chicago, IL*

- Certificate in the specialty of Pediatric Dentistry
    - Anticipated completion date: July 2020
- Master of Science in Oral Biology
    - Anticipated completion date: July 2020

**Columbia University, College of Dental Medicine,** *New York, NY*

- Doctor of Dental Surgery, May 2018

**Duke University***, Durham, NC*

- Bachelor of Arts, May 2013
    - *Cum Laude*

## *Licensure*

Licensed in Dentistry, Illinois

## *Professional Experience*

**Yummy Dental & Orthodontics for Kids, Chicago, Illinois** **April 2019-Current**

- Provide comprehensive oral health care for healthy and medically complex infants, children, and adolescents in a private practice setting

**City Year Corps** **August 2013-June 2014**

- *S*erved full time as a tutor, mentor, and role model for students in an urban school community
- Created targeted interventions for 12 off track students in the areas of attendance, behavior, and course performance in mathematics and literacy
- Coordinated afterschool programs for more than 20 students that included chorus and English as a second language

***Research Experience***

- Developmental Dental Anomalies: Prevalence and Associations with Medical Background (current)
- Analysis of Patient Communications by Columbia 4th Year Dental Students (April 2017)
- The effects of Hyaluronic Acid on the odontogenic/osteogenic differentiation of dental pulp stem cells (2012)

***Awards and Honors***

- **Omicron Kappa Upsilon National Dental Honor Society Member** (present)
- **Delta Dental Student Leadership Award** (May 2018)
- **American Academy of Implant Dentistry Award** (May 2018)
- **New York State Dental Foundation Award** (May 2017)
- **Dean's Scholar, Top 10 in the class of 2018** (May 2016)
- **Birnberg Student Research Award - First Place in Public Health** (April 2016)
- **Predoctoral Dental Student Scholarship from ADA Foundation** (March 2016)

***Professional Affiliations***

- American Academy of Pediatric Dentistry
- Illinois Society of Pediatric Dentists
- American Dental Association
- Chicago Dental Society