I. Introduction

Genes regulate the development of teeth and their surrounding oral structures, and more than 200 genes are involved in tooth development [1,2]. The embryonic development of the head and neck is controlled by a complex network of genes and protein regulators [3]. Alterations of these genetic regulators lead to congenital disorders of teeth and developmental anomalies [4]. With advances in gene sequencing technology, knowledge and genetic data are rapidly expanding. Primary databases such as GenBank have been developed to store large datasets, including sequences, interactions, and structural data from all organisms [5]. Meanwhile, second-
ary databases such as PROSITE are generated by deriving information from primary databases to meet specific research needs [6]. Currently, there are no secondary databases that compile dental-specific genomic datasets.

Students studying dentistry at the University of Alberta learn about the genetics of tooth and facial development, contributions of genes in oral health, hereditary tooth disorders, and genetic regulation of developmental anomalies. However, they are not introduced to expanding sources of genetic data and biological databases. Genetics and its newly emerging branches will dictate the future of medicine and dentistry. Bioinformatics, a division of genetics, is concerned with annotating and analyzing genetic data using computer tools. Precision dentistry aims to integrate knowledge obtained from gene analysis to provide oral health care tailored to match individual genetic profiles [7]. However, current teaching methods do not expose students to cutting-edge developments in genetics and bioinformatics.

There is a growing interest in using active learning strategies to teach genetics in higher education [8]. However, at the dental school of the University of Alberta, genetics is taught traditionally from the textbook only. Students often experience high cognitive loads with the genetics content as they navigate the complexities of gene regulation in the absence of active learning approaches. Science education through lectures alone is less effective [9] and a leading cause of students losing interest in science at the undergraduate level [10]. Many educational institutions worldwide are supplementing or replacing lectures with active-learning activities in their classrooms [11,12]. Active learning is supported by constructivist learning theory, according to which learning is a process of “making meaning,” which occurs more proficiently when learners build their understanding [13,14]. This learning approach allows students to achieve deep levels of understanding and enables them to analyze, evaluate, and synthesize ideas [15].

Teaching genetics in the dentistry program is hindered by a two-sided problem: the absence of a dental-specific genomic database and the lack of active learning strategies. In this context, we aimed to develop a dental-specific secondary database that can serve as a dental-focused genetic knowledge base and an active learning tool for teaching genetics in the dentistry program. Teaching with a database will educate students about the growing field of genetics and bioinformatics and reduce the cognitive load of memorizing complex gene regulations in tooth and oral development. In this manuscript, we report the development of a prototype (phase 1) of a secondary database called “Genetics for Dentistry.”

II. Methods

Our database currently includes human-specific genomic and proteomic data related to two cellular processes: amelogenesis (enamel formation) and dentinogenesis (dentin formation). Our endeavors to perform systematic data collection and database development are described below.

1. Data Collection and Curation

The first step was identifying the list of human genes involved in enamel and dentin formation from the genomic database of the National Library of Medicine [5]. Information related to each gene and encoded protein, chromosome location, mutations, and disease data were collected from literature and database searches. The primary sources used for data collection are listed in Table 1 [5,16-21]. The extracted data were archived in a spreadsheet. Duplicates were removed. The authors SG and NS were involved in data collection, and NS and AC checked the data for accuracy.

2. Data Validation and Database Modeling

Literature searches were conducted to validate the information included in the spreadsheet. Genes were organized according to their cellular function (dentin or enamel formation). Genes or proteins with no documented dental-or oral-specific function were removed from the list. After data collection, the spreadsheet was converted to a comma-separated values (CSV) file format.

3. Incorporation of Data in the Database

We used Ragic to create “Genetics for Dentistry.” Ragic is an online platform for database development [22]. Figure 1 represents a schematic diagram of the database development process. The color theme of the headings and background of the database were chosen for aesthetic harmony. We added options for users to search the database by cellular process (dentin formation, enamel formation), protein sequence, gene name, chromosome location, and keywords related to gene and protein function. Three-dimensional protein structure and metabolic pathway data are incorporated into the database as external tools.

4. Expansion and Application of the Database as an Active Learning Tool

In the second phase of database development, we will incorporate information from human genes involved in various stages of tooth development (bud-bell stage and tooth eruption). The database will be piloted among the students at the
University of Alberta’s School of Dentistry as an active learning tool for teaching genetics. In-class group activities and projects will be designed to use the database. Questionnaires will be distributed to discern students’ perceptions of their acquired knowledge of genetics and how the active learning tool contributed to their genetics learning. The flowchart of the research plan and progress is shown in Figure 2.

III. Results

“Genetics for Dentistry” currently archives information from 59 genes. This number represents all human genes...
Genomic and proteomic data are rapidly expanding, generating new insights in genomic medicine. A profound understanding of genetics and bioinformatics is needed to analyze the rapidly expanding datasets. Dental students at the University of Alberta study the genetics of tooth and facial development through didactic lectures only, with no active learning opportunities. We have developed a secondary database called “Genetics for Dentistry” to use as an active learning tool for teaching genetics in dentistry programs. The benefits of active learning are well-established in higher education. Freeman et al. [23] conducted a meta-analysis of 225 studies and reported that active learning improves examination performance and reduces failure rates. Students' performance on concept inventories and other assessments was also improved by active learning. Similar studies found that active learning positively impacts students’ ability to retain and understand new material [24]. Active learning strategies such as the immediate feedback assessment technique, group projects, genetic sequence analyses, and an interactive application called “Quantitative Genetics in Shiny” have been successfully applied in undergraduate genetics courses [25-27].

Adams et al. [26] implemented and evaluated the analysis of actual genetic data to enhance students’ understanding of pharmacogenomics. In an evaluation of this active learning approach, 60% of the students reported a better understanding of pharmacogenomics because of the opportunity to analyze data. Similar to Adams et al. [26], we aim to introduce “Genetics for Dentistry” as an active learning tool for dentistry students. Group projects will be designed to lead the students to analyze and annotate dental-specific genomic and proteomic data from the database. Active interactions with the actual genomic data will stimulate deep learning and enhance students’ understanding of the complex genomic regulation of tooth and oral development. Traditional genetics teaching expects students to remember genomic information that is rapidly expanding and not easily retained. Learning to analyze data from a dental-specific database, in contrast, will improve their understanding and be a lifelong skill that they can use to analyze and annotate complex genomic data. Activities involving the database will supplement the genetics lectures.

Active learning strategies are not free of limitations. Developing an interactive learning environment can be time-consuming, and not all students in a large class may meaningfully participate [28]. Despite these limitations, we hope that active interactions with tooth-related genetic data will improve students’ understanding of complex genetic regulation and pique interest in precision dentistry and bioinformatics.

Figure 2. Flowchart representing the overall research plan. This manuscript describes the initial stage of database development (phase 1) (highlighted in red).

listed in GenBank (until January 2022) as being involved in amelogenesis (enamel formation) and dentinogenesis (dentin formation). Users can search the database by cellular process (dentin formation or enamel formation), chromosome location, and other keywords related to protein and gene function. We have enabled multiple filter options, allowing users to refine their searches. A user, for example, can search the database for genes involved in a specific function and located in a specific chromosomal site. Once a gene is selected, the user can access its gene sequence, gene ID, alternative gene symbols, chromosome and cytogenic location, and description of its function in tooth development (Figure 3C). As proteomic data, users can access the protein encoded by a given gene, learn about the role of the protein in tooth development, obtain the protein sequence, read about mutations identified in the gene, and consult the supporting literature (Figure 3). “Genetics for Dentistry” also enables users to directly analyze the 3D protein structure and cellular pathways from the AlphaFold, WikiPathways, and Reactome pathway knowledge bases (Figure 3D). Ragic offers options to publish the database on a website and share the database URL and data collection URL separately.

IV. Discussion

Genomic and proteomic data are rapidly expanding, generating new insights in genomic medicine. A profound understanding of genetics and bioinformatics is needed to analyze the rapidly expanding datasets. Dental students at the University of Alberta study the genetics of tooth and facial development through didactic lectures only, with no active learning opportunities. We have developed a secondary database called “Genetics for Dentistry” to use as an active learning tool for teaching genetics in dentistry programs. The benefits of active learning are well-established in higher education. Freeman et al. [23] conducted a meta-analysis of 225 studies and reported that active learning improves examination performance and reduces failure rates. Students’ performance on concept inventories and other assessments was also improved by active learning. Similar studies found that active learning positively impacts students’ ability to retain and understand new material [24]. Active learning strategies such as the immediate feedback assessment technique, group projects, genetic sequence analyses, and an interactive application called “Quantitative Genetics in Shiny” have been successfully applied in undergraduate genetics courses [25-27].

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Conflict of Interest
No potential conflict of interest relevant to this article was reported.

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