Application of Data Science to Discover the Relationship Between Dental Caries and Diabetes in Dental Records

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Abstract
Diabetes is a chronic and metabolic disease. According to the World Health Organization (WHO), 422 million adults suffer from diabetes worldwide. In fact, in 2012 diabetes caused 1.5 million deaths in the world. In Mexico, our country, diabetes is a highly relevant public health problem. For example, in 2015 there were 11 million cases of diabetes. Our contribution is to apply novel data science techniques to medical records at a dental clinic in Northeast Mexico to discover the relationship between diabetes and dental caries. Our research work follows IBM’s data science methodology. The analysis of data was carried out with machine learning. Five experiments were carried out on 193 dental records. Our findings corroborate the results found in related work.

1. Introduction
Diabetes is a chronic and metabolic disease. It is characterized by high blood sugar levels that result from the deficit of the body to produce insulin. Insulin is the hormone that regulates the body’s glucose usage. Diabetes leads to damage to the heart, blood vessels, eyes, kidneys, and nerves.

According to the World Health Organization (WHO), 422 million adults suffer from diabetes worldwide. In Mexico, our country, diabetes has been the first cause of death in women and the second in men since the year 2000.

Previous research work has shown that diabetes is closely related to dental caries since both of them share similar risk factors. For instance, diabetic patients that do not have control of them blood sugar levels have a higher risk of presenting systemic and oral complications [1]. One of these complications is dental caries. Dental caries is a multifactorial progressive process that can be developed on the tooth surface, inside the oral cavity, where the plaque allows it to grow over a period of time.

Diabetic patients are two or three times more susceptible to developing periodontal disease than healthy patients [2]. Moreover, diabetes is the first cause of premature tooth loss, interrupting the physiological function of mastication, and leading to a softer diet with a higher level of sugar that can cause dysglycemia [3].

Our contribution is to apply novel data science techniques to medical records to discover the relationship between diabetes and dental caries. Data science consists of analyzing data, structured and unstructured, to get knowledge [4]. Although the relationship between diabetes and dental caries has been found in related work, previous approaches are based on field studies with a limited number of patients. This may be caused by the lack of automatized techniques to analyze data in dentistry. Our approach goes a step further with the analysis of a larger number of patients’ data by means of machine learning techniques.

Specifically, this work focuses on finding hidden patterns in 193 dental records of patients at the Dental Clinic “Luz y Vida” located at the campus of Universidad de Montemorelos, Montemorelos, N.L., Mexico. This study follows IBM’s data science methodology [5, 6]. In the experiments, the K-Means algorithm of machine learning was executed in Weka. Seven features in the clinical records were analyzed.

This paper is organized as follows. The second section presents the description of the dataset taken from de clinical records at the Dental Clinic “Luz y Vida”. The third section presents how we have applied IBM’s methodology to find hidden patterns in the dataset to discover the relationship between dental caries and diabetes. The last section presents conclusions and future work.

2. Description of the Dataset
In this research work, the data was obtained from 193 clinical
The clinical records used in this experiment belong to 193 patients located in the following cities: Montemorelos (140 patients), Monterrey (2 patients), Linares (4 patients), Solistahuacan (1 patient), Allende (9 patients), Mexico City (1 patient), Alamo (1 patient), Tampico (1 patient), Hermosillo (1 patient), Tamaulipas (1 patient), Coatzacoalcos (1 patient), Cancun (1 patient), Cd. Madero (1 patient), Tamasopo (1 patient), Altamira (1 patient), General Teran (3 patients), Anahuac (1 patient), Chihuahua (1 patient), Elkhart (1 patient), Santiago Tuxtla (1 patient), Camargo (1 patient), Cadereyta (1 patient), Chula Vista (1 patient), Mezcalapa (1 patient), Rayones (1 patient), Navojoa (1 patient), Georgia (1 patient), Riverside (1 patient), Caborca (1 patient). The location of 11 patients was not recorded in the dental records. Since this clinic has changed several times the paper forms used to record clinical records, we decided to take the sample for the experiments from the latest 193 clinical records, which use the same paper form.

3. Applying IBM's Methodology to Clinical Records

Data science requires a methodology that eases its application to industry and academia. That is why IBM offers a methodology for the application of data science [5, 6]. This methodology is organized into ten stages and structured in an iterative process [7]. In the following paragraphs, we describe the stages that were followed in this research according to IBM's data science methodology:

3.1. Understanding the problem: Dental caries related to diabetes is a hot topic in dentistry because there is not a clear and absolute position on the relationship between these two diseases. Moreover, related work tends to expose this relationship through field studies with a limited number of patients. In these studies, researchers take a sample of patients with diabetes and then look for the possible relationship between diabetes and dental caries. However, these studies do not propose the automatized analysis of dental records to facilitate the process.

For example, Seethalakshmi evaluated oral diseases that can be caused by diabetes, such as the incidence of dental caries and salivary pH in 20 patients [8]. The results showed that not only periodontal health was affected, but also salivary pH had a decrease of 6.51. Likewise, the incidence of dental caries increased significantly in comparison with the patients without diabetes.

On one hand, Novotna mentions that there is an increase in plaque levels and chronic gingivitis as much in adults as in children with type 1 diabetes [9]. On the other hand, Miranda found out that oral health in patients with type 1 diabetes in Chile is more precarious than in healthy patients [10]. However, he mentions that this problem could be caused by poor hygiene.

Singh concluded that patients with type 2 diabetes have a higher risk of developing dental caries [11]. Also, he points out that saliva flow and saliva calcium levels are significantly lower compared to healthy patients. Therefore, a reduction in the saliva components reduces the enamel's capacity to endure the remineralization and demineralization process. It creates the right environment for dental caries.

Oral bacteria are without a doubt a determinant factor in the formation of dental caries. For example, Kampoo found that the incidence of diabetic patients in Thailand is much higher compared to non-diabetics [12]. Also, the number of acidogenic bacteria in diabetic patients is much higher than in healthy patients. Therefore, the high dental caries incidence in diabetic patients in Thailand is positively related to de Streptococcus and Lactobacillus bacteria.

Sadia et al. made a study to establish if there is a relationship between diabetes mellitus and dental caries by measuring glucose levels related to dental caries in different patients [13]. These authors found that glucose levels in diabetic patients’ saliva are slightly higher than in healthy patients. Also, the levels of calcium in diabetic patients’ saliva are lower.

Jawe found out that the level of blood sugar and glycosylated hemoglobin, and the number of decayed, missing, and filled teeth (DMF) is significantly higher in type 2 diabetics than in health Patients [14]. These results were obtained by a saliva sample and a DMF test (DMFT).

Similarly, Miko mentions that the deficiency in glycemic control, as well as the early occurrence of diabetes, can increase the risk of dental caries [15]. This study was made with a DMFT applied to 259 teenagers with type 1 diabetes.

Stojanovic studied the condition of type 2 diabetic patients related to metabolic control [16]. The sample was composed of 47 type 2 diabetic patients randomly chosen and divided into two groups: poorly controlled diabetics and controlled patients. He found out that patients with poor control of diabetes have a significantly higher amount of dental caries compared to those that control the disease.

Hintao found that patients with type 2 diabetes, compared to healthy patients, have a higher risk of root surface dental caries [17]. However, the prevalence and crown surface decay were not significantly different. Therefore, he concluded that type 2 diabetes is an important risk factor for root decay, but not for crown surface decay.

3.2. Analytic approach: In this stage, machine learning was used to analyze data from clinical dental records. Machine learning is a branch of artificial intelligence that consists of developing techniques that allow computers to learn by means of analyzing structured or unstructured data [18].

Weka1 was used to analyze dental records by means of machine learning. Weka is a data-mining software developed by the University of Waikato [19]. This software was programmed in Java and has powerful algorithms to extract information contained in datasets [20].
3.3. Data requirements: The clinical records at the Dental Clinic “Luz y Vida” have 60 features. In the field of machine learning, a feature is a variable that summarizes key aspects to be analyzed. In our case, the features contain data about personal information, anamnesis, and intraoral exploration (Table 1).

3.4. Data collection: The clinical records analyzed in this study were in paper. Therefore, 15 students at the School of Engineering and Technology of Universidad de Montemorelos digitalized them. These students took a period of around two months in this process.

3.5. Data understanding: In this step, we decreased the number of features to 7. These features are the ones that we considered to be associated with dental caries and diabetes according to related work (the related work described in the first step). These features are as follows: 1) endocrine problems, including diabetes, family history of diabetes, thyroid gland problems, and others; 2) teeth problems, including sensitivity and bad habits (biting nails, thumb sucking, pencil biting, etc.); 3) the number of decayed teeth; 4) the number of missing teeth; 5) the number of restored or filled teeth; 6) age; and 7) blood type.

3.6. Data preparation: In this stage, the data related to each feature in the clinical records were converted to numbers. This process was necessary because Weka requires numeric values to do the analysis. The dataset with the studied clinical records is available online2.

3.7. Modeling: Among the machine learning algorithms that Weka provides, we chose K-means to generate clusters that model the relationship between dental caries and diabetes in clinical records. K-means is an unsupervised-learning algorithm that allows grouping data in clusters by discovering their centroids [20]. In K-means, each sample inside the dataset must be included in one of the clusters [19]. We decided to use this algorithm because of the following reasons: 1) data in the clinical records were not labeled, and 2) K-means is a very popular and effective clustering algorithm [21].

3.8. Deployment: The experiments were executed with a different number of clusters (K from 4 to 7). We chose the results from the experiments with the minimum within-cluster sum of squared errors (sum of distance functions of each point in the cluster to the K center). The results were iteratively presented to the team of dentists to get their feedback and avoid results that were not congruent with their domain of knowledge.

As a way of illustration, Figure 1 shows one of the results of the experiments. First, this figure shows the number of iterations in the experiment (11 in this case) and the within-cluster sum of squared errors (21.55317619018957). This image also shows the selected features for each test (21, 30, 45, 54, 56, and 57. Table 1 shows the descriptions of each one of these features), the number of clusters (K = 6), and the number of instances or samples contained in each cluster (e.g. 28 instances in Cluster 0).

The results of the 5 experiments that were conducted on the 193 clinical records are described as follows:

- **First experiment**: The objective of this experiment was to verify that diabetic patients also present problems in their teeth. 8 clusters were analyzed in this experiment. We found out that diabetic patients tend to present teeth loss and food accumulation in some zones. The within-cluster sum of squared errors in this experiment was 2.5.

- **Second experiment**: The objective of this experiment was to analyze the number of teeth with caries in diabetic and healthy patients. We found out that diabetic patients tend to present 9 to 17 teeth with caries, whereas healthy patients tend to present between 1 and 9 teeth with care. The within-cluster sum of squared errors in this experiment was 6.8. The data was organized into 4 clusters.

![Table 1: Description of dental records](image-url)

<table>
<thead>
<tr>
<th>Patient Information</th>
<th>Anamnesis</th>
<th>Intraoral Scan (Normal or Abnormal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.</td>
<td>description</td>
<td>No.</td>
</tr>
<tr>
<td>1</td>
<td>age</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>gender</td>
<td>11</td>
</tr>
<tr>
<td>3</td>
<td>city</td>
<td>12</td>
</tr>
<tr>
<td>4</td>
<td>state</td>
<td>13</td>
</tr>
<tr>
<td>5</td>
<td>marital status</td>
<td>14</td>
</tr>
<tr>
<td>6</td>
<td>occupation</td>
<td>15</td>
</tr>
<tr>
<td>7</td>
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<td>16</td>
</tr>
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<td>8</td>
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<td>17</td>
</tr>
<tr>
<td>9</td>
<td>health status</td>
<td>18</td>
</tr>
<tr>
<td>19</td>
<td>do you get tired frequently?</td>
<td>37</td>
</tr>
<tr>
<td>20</td>
<td>skin disease</td>
<td>38</td>
</tr>
<tr>
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</tr>
<tr>
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<td>42</td>
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<tr>
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</tr>
<tr>
<td>24</td>
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<td>46</td>
</tr>
<tr>
<td>25</td>
<td>nervous system disease</td>
<td>48</td>
</tr>
<tr>
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<tr>
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<tr>
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</tr>
<tr>
<td>57</td>
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</tr>
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<td>60</td>
<td>occlusion status</td>
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</tr>
</tbody>
</table>
4. Conclusions and Future Work

This paper presented the application of data science to discover the relationship between dental caries and diabetes in dental records. Our results corroborate the relationship between diabetes and dental caries found in related work. This study opens an unexplored field in dentistry: the application of data science, based on a formal methodology and machine-learning techniques, to find hidden patterns in clinical records.

In future work, we are going to build a software tool to store and manage the clinical records of the Dental Clinic “Luz y Vida.” The objective of this project is to reduce time when capturing and analyzing patients’ data. Moreover, the features in the dataset will be extended with more features related to patients’ lifestyles (e.g. exercise and nutrition habits). Also, we are going to carry out more experiments on this clinic’s data about other diseases, which could be related to other dental pathologies.

3.9. Evaluation: The evaluation of the experiments’ results was made by a team of dentists at the Dental Clinic “Luz y Vida.” This team analyzed each one of the results obtained in the previous step. Based on the presented results, they concluded that the clinical record analysis of patients’ data through data science corroborates the existence of the relationship between dental caries and diabetes. This result supports the findings in related work in this area. For example, according to Seetha Lakshmi and Sing, patients with type 2 diabetes have a higher risk to develop dental caries [8,11]. Also, Kampoo points out that the number of acidogenic bacteria in the mouth of diabetic patients is much higher than in healthy patients [12].

3.10. Feedback: In this step, the team considered making further experiments to include a higher number of clinical records. To this end, the team concluded the need for counting on a software tool to record clinical records to avoid the time-consuming process of digitalizing records in paper forms.

References

2. Navarro Sanchez, A. B., Faria Almeida, R., & Bascones


