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*Original article* ■

# Reasons for Extraction Obtained by Artificial Intelligence

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**SUMMARY**

**Artificial intelligence (AI) is the subfield of computer science concerned with projection of intelligent machines, software, and algorithms. By way of computer-assisted monitoring of dental patients, the amount of raw electronic data markedly enlarges, creating the possibility of using AI in scientific analysis. In order to prevent the reasons and diminish the need for dental extraction, it is necessary to always have updated information about the reasons for extraction, so we make use of AI analysis.**

**Our aim was to assess the possible use of AI in the collection, triage, sorting, counting, and analysis of electronic data, drawing scientifically acceptable conclusions.**

**A case-control study of electronic data was done. Data preparation and counting were done using special C# codes. The analysis of impact of non-dental attributes was done using the OLAP analysis and specific detection algorithm.**

**OLAP detected the attribute of age with sensitivity of 44.0% and specificity of 100.0%, and value of attibute of age from 55 to 64. The specific algorithm gave direct reasons: caries (43.77%), periodontal diseases (37.23%), fracture (6.82%), prosthetic reasons (4.31%), impactions (3.12%), orthodontic reasons (2.73%), primary teeth (0.32%), and others (1.7%). The algorithm found that the impact of attributes of gender, age, and job was statistically significant (gender: $X^2$=7.095, df=1, p=0.0077; age: $X^2\approx$261, df=8, p<0.0001; job: $X^2\approx$46, df=7, p<0.0001).**

**Using AI, raw electronic data can be successfully collected, triaged, sorted, counted, and analyzed, and utilized AI algorithms can perform non-parametric evaluation of the possible impact of non-dental attributes, producing scientifically valid conclusions.**

*Key words*: **computerized dentistry, artificial intelligence, tooth extraction, digital dental patient record, XPA3 Prolom**

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## INTRODUCTION

Artificial intelligence (AI) is a branch of computer science, concerned with projection of intelligent machines, especially intelligent computer programs, in order to better understand and imitate human intelligence by machines, and does not have to confine itself to methods that are biologically observable (1). It is used in various fields such as medical diagnosis, exchange market, robotic guidance, legislation, various sciences, or entertainment. Although its origins can be traced further in the history (machines and drawings of Leonardo Da Vinci; ancient Greek machines, such as the Antikythera mechanism), it is usually associated with first usable computers after the Second World War, or even more commonly, with John McCarthy and 1956, who was the first to use the term in its full meaning. Roughly, AI consists of a knowledge base, search methods, problem solving system, reasoning system, systems for planning, learning (both from experience and knowledge base), genetic programming, and decision-making and conclusion-drawing process (2).

In medicine, computer systems for analysis and decision-making have been gaining importance with more and more common electronic registration of medical data, including those from general practitioner examinations, through biochemical analyses, hospitalization, electronic patient history, to post-treatment patient follow-up. The amount of raw electronic data constantly enlarges with computer-assisted monitoring of patient management, and the challenge of our times is scientific analysis of these large datasets. Important instruments of AI are so called Data Mining Tools (DMTs), algorithms and softwares used to extract information (relations, associations) from large data bases and contribute to new knowledge discovery. DMTs represent a relatively new subfield of AI, contributing significantly to the research process, with most common utilization in economy and consumer behavior prediction (3). In medicine, DMTs have been used for the projection of new methods, to support decision-making, and especially in nanotechnology (4).

The primary task of these intelligent systems in the future will be to support the process of diagnosis, since the natural course of diseases is subject to change (5). Although the approach in oral surgery is in its pioneering phase, the results of use of AI have been presented in computer-aided oral implant surgery (6), analysis of radiographs (7), and decisive advances have been made in the use of AI in making the decisions about dental extractions before orthodontic treatments (8).

On the other hand, regarding this terminal option in dental treatment, tooth extraction, there is this objective problem in oral surgery of monitoring the main reasons and influences leading to extraction, but also of follow-up of incidence of each of the causes and reasons related to the total number of extractions. In spite of the availability of relevant studies (9-37), the dynamics of these problems, extending through time, geographical and demographic traits, age, education, accompanying or primary diseases, and various other attributes, presents the challenge in view of continual control, monitoring, and adequate measures, in order for us to react appropriately, prevent the reasons, and diminish the necessity for extraction as the most radical treatment method.

The study aims to investigate a possible use of AI in the collection, triage, sorting, counting, and analysis of raw electronic information, helping us to draw scientifically valid conclusions about the reasons and influences leading to dental extraction.

## MATERIAL AND METHODS

A case-control study was done using the electronic information from digital dental records of 10.582 patients, entered in the period from January 2008 to April 2010. Using a Pentium Dual Core PC, 3 GB RAM, 250 GB HDD, ATI Radeon HD 4350 512 MB, Microsoft Windows XP SP3 (USA), a unique dataset was formed out of the bases of digital dental records from five dental clinics. All five bases were in the Microsoft Access 2003 (USA) format, created and entered using the XPA3 Prolom ver. 5.0 (Serbia) software, and data merging was done using a special programming script written by the authors of this paper, ignoring patient identification data in order to protect their privacy, and patient uniqueness at the level of merged dataset was preserved by way of creating a Secure Hash Algorithm (SHA-1) digital signature for each patient (*Figure 1*).

Storage, classification, and counting of data were performed using the software code developed in C# programming language by the authors. The algorithm for data processing, counting of extractions and their direct causes was created as follows (in pseudo-code form):

```
extractionRows = select all rows with sanation therapy "extraction" from
DataTable;
patientArray[]; //array of patients with extractions
foreach (DataRow extractionRow in extractionRows)
{
      patient = get patient of current extractionRow by unique patient
identifier;
      if(patient.patientID not present in patientArray) add patient to
patientArray;
      toothName = get name of extracted tooth from extractionRow;
      diagnoses[] = get diagnoses for toothName that prior extraction for same
patient;
      foreach(DIAGNOSE diagnose in diagnoses)
      add diagnose, patient's gender and patient's date of birth to
diagnoseRange;  //Sets diagnose to appropriate group for counting
}
//Writes information to file and inform user
writeAndInformUser_Extraction();// Extraction range
writeAndInformUser_Diagnose();//Diagnose range
writeAndInformUser Patient();//Patient range
```

In order to sort and simplify the attributes such as job, demographic data, and other compulsory information from dental records, marking by humans was done. Occupations were based on the ISCO (38) and JMHLW (39) classification, with adaptation and division into seven main groups. Place of residence and place of work were classified using the division into regions of the Republic of Serbia (40). Systemic and accompanying diseases recorded in dental records were classified using the ICD-10 (41), while warning signs were kept in their original textual format.

The analysis of possible non-dental attributes was then done in order to find out possible predispositions or risks which can directly or indirectly lead to dental extraction. This analysis and detection of non-dental influences were performed in two ways, one of them being the standard OLAP (Online Analytical Processing), and the other being the detection algorithm based on data cross -referencing and testing of the probability of association, created for this purpose by the authors:

- After adjustment of the dataset format to required processing conditions, inductive OLAP analysis was performed of the representative sample of 250 rows with Data Mining Server: „Inductive Learning by Logic Minimization" by the „Ruđer Bošković" Institute (Croatia) (42). The following parameters were used:

```
Separation mark:           - Comma (,)
Model number:              - 1
Generalization parameter:  - 1
Noise detection:           - No
```

- Individual algorithm to detect possible influence of non-dental attributes was created in C# programming language on the Microsoft. NET Framework 2.0 Service Pack 2, USA, in the following way (pseudo-code):

```
array attributeList = makeList(); //Creates list of all personal and medical
information from patient electronic dental record
foreach(Attribute attribute in attributeList)//loops through attributes for
influence assessment
{
     if(!checkForAttributeDataQuality())//checks if attribute entry data conform
the conventional statistical standards (quantity and quality)
           continue();
     array attributeSections = attribute is divided or sorted into logical units
that can be individually assessed, and their influence on extraction can be
tested. E.g., attribute of gender into male and female units; attribute of age
into: 5-14 years, 15-25…; attribute of place of work into regions, such as
Belgrade, Pancevo…; attribute of occupation into professionals, students,
workers…
 records[,,] = new array[attributeSections.Length,2]; //Tridimensional array of
records ready for attribute name to be placed, as well as the observed and
expected frequencies of nonparametric attribute analysis.
      fillAttributeNames(records, attributeSections); //Writes in the first
dimension of attribute section
     getAndFillExpectedFrequencies(records); //Writes in the third dimension the
expected frequencies related to the percentual presence of patients in the base
corresponding to attribute sections
     getAndFillObservedFrequencies(records); //Writes in the second dimension the
obtained frequencies for attributes sections
     statsResult = analzyeRecords(records);//Analyzes array values: arraystruct
      -------------------------------------------------------------------
N x  |Attributes section  | Observed frequency | Expected frequency |
      -------------------------------------------------------------------
      //Assesses the probability of association of two variables by way of X²
test formula:
```

$$\chi^2 = \Sigma \frac{(f_o - f_t)^2}{f_t}$$

```
For freedom degree records.Count-1, and obtained
value is compared to the values from the table of boundary values for the
significance cut-off of 5%
           if(statsResult.SignificantDifference)
              {
                relativeRiskInfo = getRelativeRisk(records);
                oddsRationInfo = getOddsRatio(records);
                writeAndInform(attributeSection, statsResult, relativeRiskInfo,
oddsRationInfo); //If a statistically significant association is found between
attributes section and extractions, relative risk and odds ratio are calculated,
using the first record of attribute section using the formula:
```

- Relative risk: $$RR = \frac{\frac{a}{a+b}}{\frac{c}{c+d}}$$ where a and b are observed and expected record frequencies in the records array, while c and d are observed and expected frequencies of the first record in the *record* array.

- Odds ratio: $$OR = \frac{\frac{p1}{1-p1}}{\frac{p2}{1-p2}}$$ where p1 and p2 are ratios of the observed and expected frequencies of the monitored and first record in the *record* array.

This function writes the obtained information and creates the information for the user about the finding.

```
              }
           else
                continue;
      }
}
```

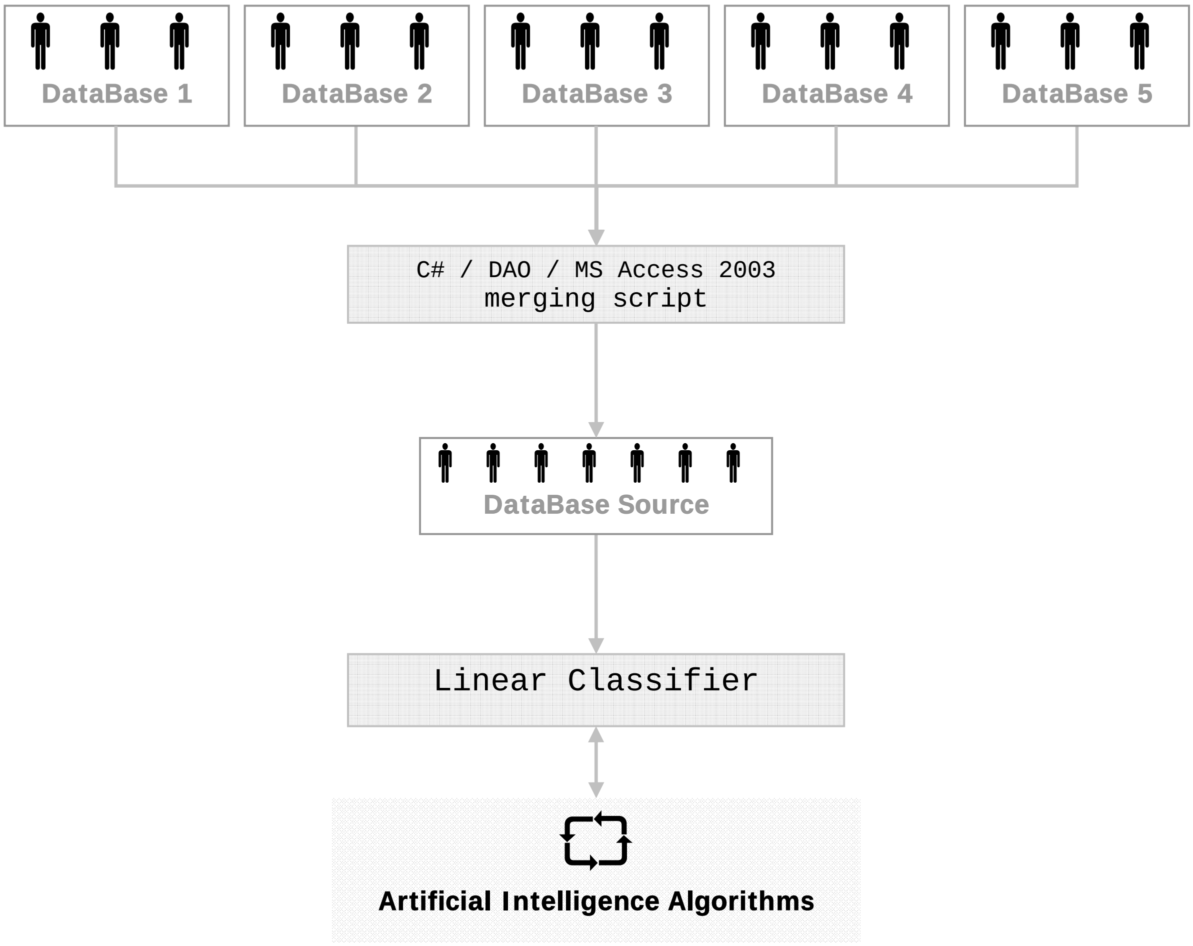


***Figure 1***. *Collection and preparation of data for computerized reasoning*

## RESULTS

Data Mining Server „Inductive Learning by Logic Minimization“ detected the attribute of age with the share of positive part, i.e. sensitivity, of 44.0%, and negative part (specificity) of 100.00%, with the condition for attribute of age value of 55-64 years. Other induction data were not obtained.

The specific algorithm produced the following results: out of the total number of patients (n=10582), 7.321 (69.2%) patients had tooth extraction, while in the remaining 3.261 (30.8%) there was no evidence of extraction treatment. Out of those with extraction, there were 3.953 (54.0%) men and 3.368 (46.0%) women (*Table 1*, *Figure 2*).

***Table 1.*** *Number of patients with extractions by the factors of age and gender, and the total number of patients in the database*

| | PATIENTS WITH EXTRACTION | | | | ALL PATIENTS | | | |
|---|---|---|---|---|---|---|---|---|
| **Age** | **Male** | **Female** | **Total** | **%** | **Male** | **Female** | **Total** | **%** |
| 5-14 | 56 | 41 | 97 | 1.32 | 356 | 338 | 694 | 6.56 |
| 15-24 | 202 | 162 | 364 | 4.97 | 503 | 469 | 972 | 9.19 |
| 25-35 | 335 | 255 | 590 | 8.05 | 724 | 673 | 1397 | 13.20 |
| 35-44 | 531 | 414 | 945 | 12.91 | 848 | 745 | 1593 | 15.05 |
| 45-54 | 762 | 698 | 1460 | 19.94 | 865 | 762 | 1627 | 15.38 |
| 55-64 | 969 | 851 | 1820 | 24.86 | 977 | 863 | 1840 | 17.38 |
| 65-74 | 725 | 651 | 1376 | 18.80 | 742 | 658 | 1400 | 13.23 |
| 75- | 262 | 189 | 451 | 6.17 | 269 | 196 | 465 | 4.40 |
| Unknown | 111 | 107 | 218 | 2.98 | 359 | 235 | 594 | 5.61 |
| **TOTAL** | 3953 | 3368 | 7321 | 100.00 | 5643 | 4939 | 10582 | 100.00 |

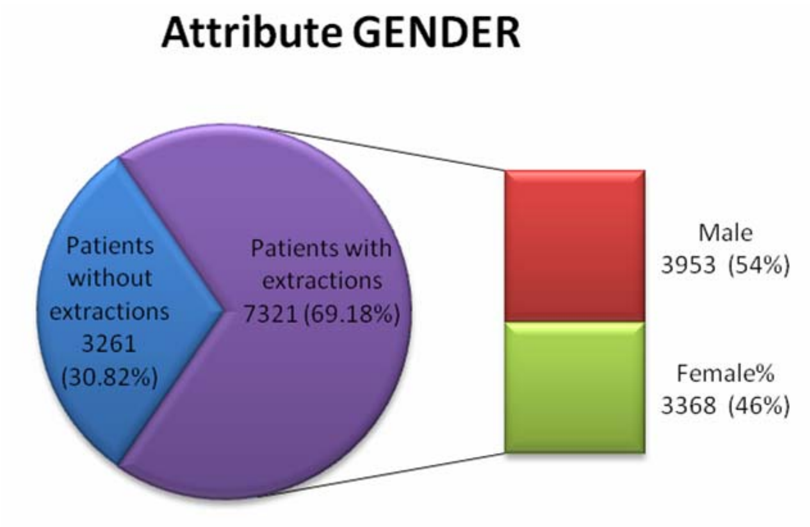


***Figure 2.*** *The attribute of gender in the group of patients with at least one extraction*

The number of performed extractions was 12.010, out of which 6.278 (52.27%) in men, and 5.732 (47.73%) in women, distributed by age groups, as shown in *Table 2* and *Figure 3*.

***Table 2***. *Number of extractions by the factors of age and gender*

| Age | Male | Female | Total | % |
|---|---|---|---|---|
| **5-14** | 60 | 55 | 115 | 0.96 |
| **15-24** | 208 | 199 | 407 | 3.39 |
| **25-35** | 386 | 338 | 724 | 6.03 |
| **35-44** | 687 | 582 | 1269 | 10.57 |
| **45-54** | 1235 | 1061 | 2296 | 19.11 |
| **55-64** | 1683 | 1561 | 3244 | 27.01 |
| **65-74** | 1568 | 1474 | 3042 | 25.33 |
| **75-** | 332 | 341 | 673 | 5.60 |
| **Unknown** | 119 | 121 | 240 | 2.00 |
| **TOTAL** | 6278 | 5732 | 12010 | 100.00 |

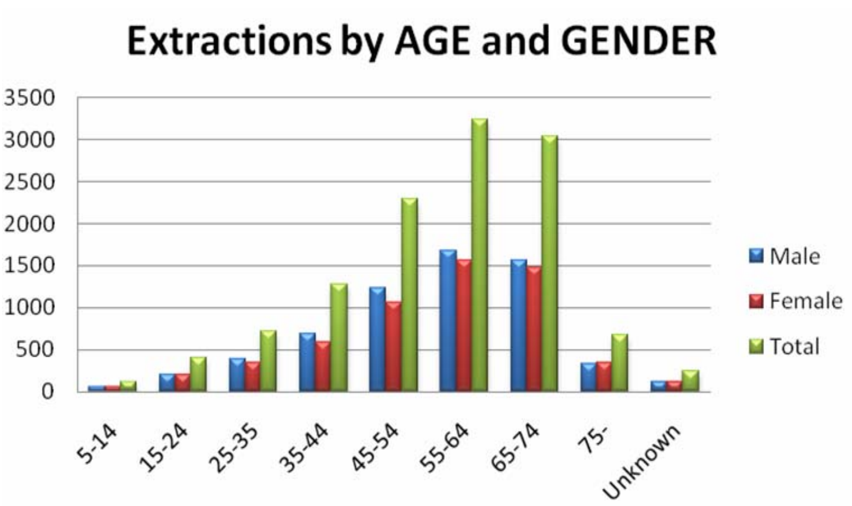


***Figure 3.*** *Number of extractions by the factor of age*

As direct reasons for extraction, the following were counted: caries in 5.257 (43.77%), periodontal diseases in 4.471 (37.23%), fracture in 819 (6.82%), prosthetic reasons in 518 (4.31%), impactions in 374 (3.12%), orthodontic reasons in 328 (2.73%), milk teeth extractions in 39 (0.32%), and other reasons in 204 (1.7%) (*Table 3*; *Figure 4*).

***Table 3.*** *Dental reasons for tooth extraction*

| Reason | Male | Female | Total | % |
|---|---|---|---|---|
| **Deciduous (replacement)** | 21 | 18 | 39 | 0.32 |
| **Orthodontics** | 169 | 159 | 328 | 2.73 |
| **Prosthetic** | 275 | 243 | 518 | 4.31 |
| **Fracture** | 426 | 393 | 819 | 6.82 |
| **Impaction** | 194 | 180 | 374 | 3.12 |
| **Caries** | 2731 | 2526 | 5257 | 43.77 |
| **Periodontal disease** | 2348 | 2123 | 4471 | 37.23 |
| **Other** | 114 | 90 | 204 | 1.7 |
| **TOTAL** | 6278 | 5732 | 12010 | 100.00 |

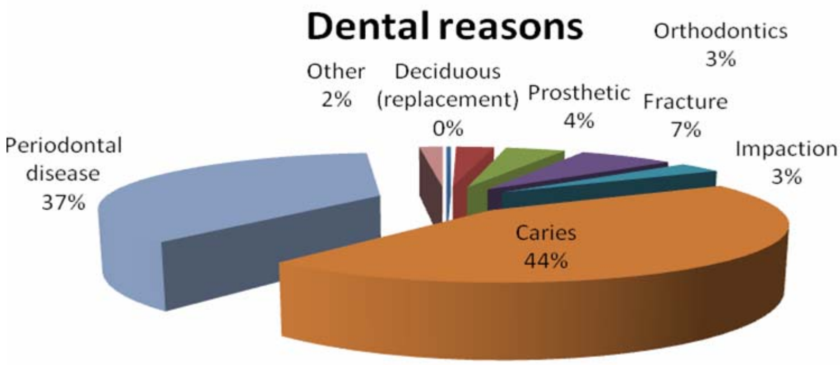


***Figure 4****. Dental reasons for tooth extraction*

The number of extractions in patients with unknown place of residence was 6.285 (52.33%), with place of residence in Belgrade 5.510 (45.88%) and in other places 215 (1.79%), while the number of extractions in patients with unknown place of work was 6.301 (52.47%), with place of work in Belgrade 5.543 (46.15%), and in other places 166 (1.38%). The number of extractions in patients with accompanying diseases recorded in their dental records was 412 (3.43%), while in 16 extractions (0.13%) there was evidence of the tests, laboratory or histopathologic findings. The number of patients by their job with at least one extraction is shown in *Table 4* and *Figure 5*, and the number of extractions by job in *Table 5* and *Figure 6*.

***Table 4.*** *Number of patients with extractions by the factors of job and age*

| Job classification | 5-14 | 15-24 | 25-35 | 35-44 | 45-55 | 55-64 | 65-74 | 75- | Unknown | Total | % |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Professionals** | 0 | 14 | 38 | 77 | 205 | 234 | 50 | 2 | 0 | 620 | 8.46 |
| **Managers** | 0 | 3 | 9 | 36 | 66 | 109 | 10 | 1 | 0 | 234 | 3.20 |
| **Office workers** | 0 | 27 | 58 | 82 | 141 | 176 | 11 | 0 | 1 | 496 | 6.78 |
| **Skilled workers** | 0 | 74 | 122 | 161 | 217 | 232 | 30 | 0 | 0 | 836 | 11.42 |
| **Salespersons** | 0 | 33 | 68 | 107 | 135 | 134 | 12 | 1 | 0 | 490 | 6.69 |
| **Scholars/ Students** | 73 | 80 | 19 | 0 | 0 | 0 | 0 | 0 | 0 | 172 | 2.35 |
| **Other** | 10 | 23 | 39 | 67 | 78 | 115 | 202 | 75 | 0 | 609 | 8.32 |
| **Unknown** | 14 | 110 | 237 | 415 | 618 | 820 | 1061 | 372 | 217 | 3864 | 52.78 |
| **TOTAL** | 97 | 364 | 590 | 945 | 1460 | 1820 | 1376 | 451 | 218 | 7321 | 100.00 |

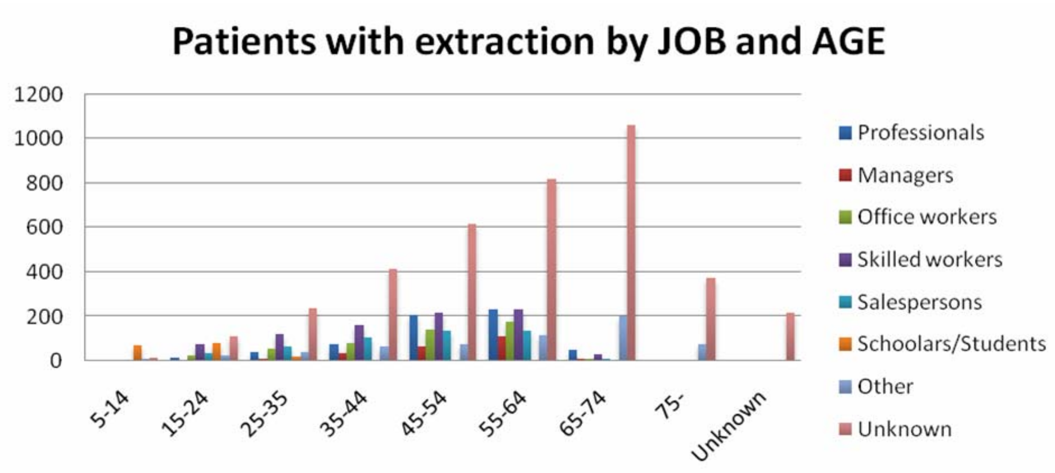


***Figure 5.*** *Patients with extraction by the factors of job and age*

***Table 5.*** *Number of extractions by the factors of job and age*

| Job classification | 5-14 | 15-24 | 25-35 | 35-44 | 45-55 | 55-64 | 65-74 | 75- | Unknown | Total | % |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Professionals** | 0 | 16 | 42 | 89 | 230 | 347 | 97 | 12 | 0 | 833 | 6.94 |
| **Managers** | 0 | 3 | 14 | 52 | 87 | 165 | 37 | 5 | 0 | 363 | 3.02 |
| **Office workers** | 0 | 31 | 73 | 121 | 223 | 406 | 21 | 0 | 5 | 880 | 7.33 |
| **Skilled workers** | 0 | 84 | 170 | 246 | 434 | 522 | 46 | 0 | 0 | 1502 | 12.51 |
| **Salespersons** | 0 | 39 | 97 | 165 | 248 | 306 | 24 | 2 | 0 | 881 | 7.34 |
| **Scholars/Students** | 86 | 90 | 22 | 0 | 0 | 0 | 0 | 0 | 0 | 198 | 1.64 |
| **Other** | 14 | 27 | 47 | 90 | 110 | 197 | 444 | 108 | 0 | 1037 | 8.63 |
| **Unknown** | 15 | 117 | 259 | 506 | 964 | 1301 | 2373 | 546 | 235 | 6316 | 52.59 |
| **TOTAL** | 115 | 407 | 724 | 1269 | 2296 | 3244 | 3042 | 673 | 240 | 12010 | 100.00 |

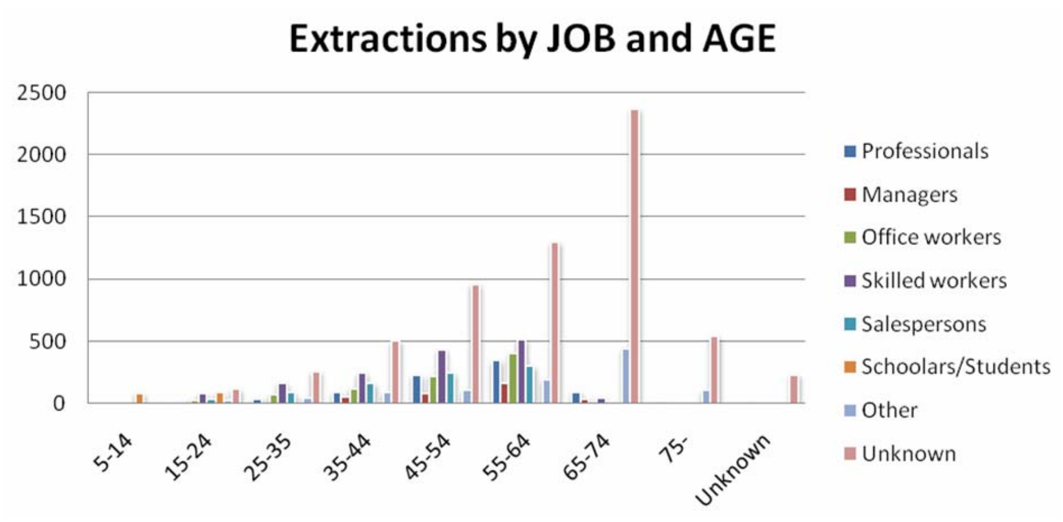


***Figure 6.*** *Extractions by the factors of job and age*

AI specific algorithm found that attributes of gender, age, and job had a statistically significant impact on the number of patients with at least one extraction, while other examined factors were skipped because of insufficient statistical sample quality (place of residence; place of work) or because of their insufficient presence in dental records (<5%) (accompanying diseases, tests, histopathologic findings, place of birth, warning signs, signs of disease). The impact of gender on the number of patients with at least one extraction was statistically significant ($X^2$=0.633, df=1 and p= 0.4263, relative risk=0.987, odds ratio=0.973) (*Table 6*), and the impact on the number of extractions was also statistically significant ($X^2$=7.095, df=1 and p= 0.0077, relative risk=1.035, odds ratio=1.072) (*Table 7*).

***Table 6.*** *Impact of the attribute of gender on the number of patients with at least one extraction*

| Gender | Observed frequencies | Expected frequencies | Proportion | Relative risk | Relative risk 95% CI | Odds ratio | Odds ratio 95% CI |
|---|---|---|---|---|---|---|---|
| **Male** | 3953 | 3904 | 1.013 | 1.000 | | 1.000 | |
| **Female** | 3368 | 3417 | 0.986 | 0.987 | 0.9551 to 1.0192 | 0.973 | 0.9122 to 1.0388 |
| **TOTAL** | 7321 | 7321 | | | | | |

$X^2$=0.633, df=1, p=0.4263

***Table 7.*** *Impact of the attribute of gender on the number of extractions*

| Gender | Observed frequencies | Expected frequencies | Proportion | Relative risk | Relative risk 95% CI | Odds ratio | Odds ratio 95% CI |
|---|---|---|---|---|---|---|---|
| **Male** | 6278 | 6485 | 0.968 | 1.000 | | 1.000 | |
| **Female** | 5732 | 5525 | 1.037 | 1.035 | 1.0093 to 1.0617 | 1.072 | 1.0187 to 1.1274 |
| **TOTAL** | 12010 | 12010 | | | | | |

$X^2$=7.095, df=1, p= 0.0077

The impact of age attribute on the number of patients with at least one extraction was statistically significant ($X^2 \approx 741$, df=8 and $p<0.0001$, relative risk and odds ratio are shown in *Table 8* and *Figure 7*), and the impact on the number of extractions was also statistically significant ($X^2 \approx 261$, df=8 and $p<0.0001$, relative risk and odds ratio are shown in *Table 9* and *Figure 8*).

***Table 8.*** *Impact of the attribute of age on the number of patients with at least one extraction*

| Age | Observed frequencies | Expected frequen-cies | Proportion | Relative risk | Relative risk 95% CI | Odds ratio | Odds ratio 95% CI |
|---|---|---|---|---|---|---|---|
| **5-14** | 97 | 480 | 0.202 | 1.000 | | 1.000 | |
| **15-24** | 364 | 673 | 0.541 | 2.088 | 1.7104 to2.5490 | 2.676 | 2.0787 to 3.4460 |
| **25-35** | 590 | 966 | 0.611 | 2.256 | 1.8609 to 2.7338 | 3.022 | 2.3750 to 3.8461 |
| **35-44** | 945 | 1102 | 0.858 | 2.746 | 2.2767 to 3.3123 | 4.244 | 3.3552 to 5.3668 |
| **45-54** | 1460 | 1126 | 1.297 | 3.358 | 2.7922 to 4.0394 | 6.416 | 5.0897 to 8.0887 |
| **55-64** | 1820 | 1272 | 1.431 | 3.501 | 2.9132 to 4.2082 | 7.080 | 5.6275 to 8.9082 |
| **65-74** | 1376 | 969 | 1.420 | 3.490 | 2.9019 to 4.1983 | 7.027 | 5.5655 to 8.8721 |
| **75-** | 451 | 322 | 1.401 | 3.471 | 2.8671 to 4.2011 | 6.931 | 5.3394 to 8.9968 |
| **Unknown** | 218 | 411 | 0.530 | 2.062 | 1.6697 to 2.5456 | 2.625 | 1.9975 to 3.4489 |
| **TOTAL** | 7321 | 7321 | | | | | |

$X^2 \approx 741$, df=8, $p<0.0001$

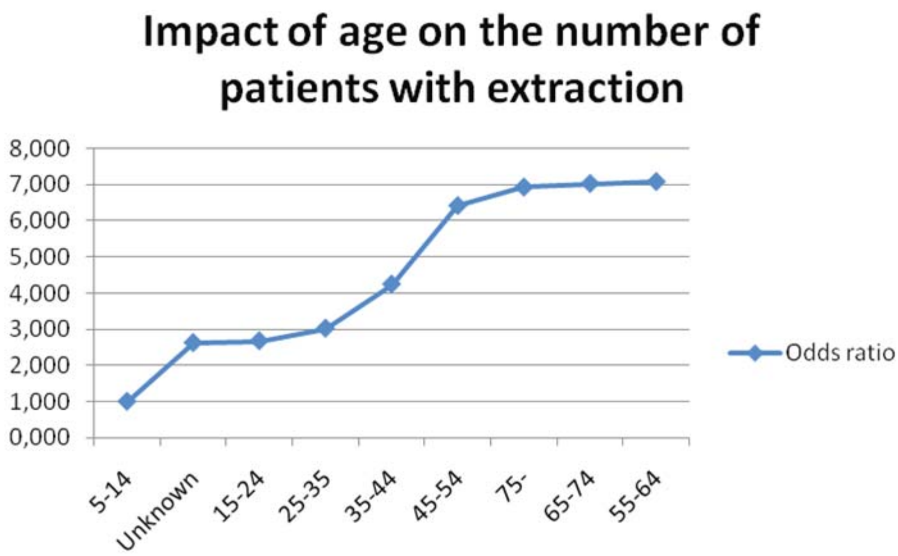


***Figure 7.*** *Impact of the attribute of age on the number of patients with at least one extraction (odds ratio)*

***Table 9.*** Impact of the attribute of age on the number of extractions

| Age | Observed frequencies | Expected frequen-cies | Proportion | Relative risk | Relative risk 95% CI | Odds ratio | Odds ratio 95% CI |
|---|---|---|---|---|---|---|---|
| 5-14 | 115 | 159 | 0.723 | 1.000 | | 1.000 | |
| 15-24 | 407 | 597 | 0.682 | 0.966 | 0.8246 to 1.1313 | 0.943 | 0.7188 to 1.2360 |
| 25-35 | 724 | 967 | 0.749 | 1.020 | 0.8783 to 1.1849 | 1.035 | 0.7993 to 1.3406 |
| 35-44 | 1269 | 1550 | 0.819 | 1.073 | 0.9277 to 1.2400 | 1.132 | 0.8806 to 1.4551 |
| 45-54 | 2296 | 2395 | 0.959 | 1.166 | 1.0115 to 1.3444 | 1.326 | 1.0357 to 1.6963 |
| 55-64 | 3244 | 2986 | 1.086 | 1.241 | 1.0772 to 1.4289 | 1.502 | 1.1756 to 1.9191 |
| 65-74 | 3042 | 2258 | 1.347 | 1.368 | 1.1875 to 1.5748 | 1.863 | 1.4564 to 2.3822 |
| 75- | 673 | 741 | 0.908 | 1.134 | 0.9765 to 1.3170 | 1.256 | 0.9666 to 1.6313 |
| **Unknown** | 240 | 357 | 0.672 | 0.958 | 0.8080 to 1.1355 | 0.930 | 0.6952 to 1.2427 |
| **TOTAL** | 12010 | 12010 | | | | | |

$X^2 \approx 261$, df=8, p<0.0001

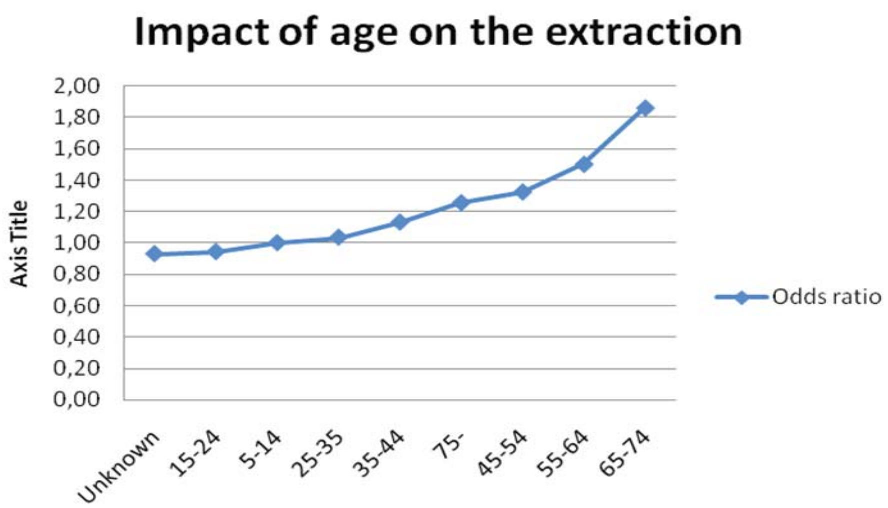


***Figure 8.*** *Impact of the attribute of age on the number of extractions (odds ratio)*

The impact of the attribute of job on the number of patients with at least one extraction was statistically significant ($X^2 \approx 293$, for df=7 and p<0.0001, relative risk and odds ratio are shown in *Table 10* and *Figure 9*), and the impact on the number of extractions was also statistically significant ($X^2 \approx 46$, for df=7 and p<0.0001, relative risk and odds ratio are shown in *Table 11* and *Figure 10*).

***Table 10.*** *Impact of the attribute of job on the number of patients with at least one extraction*

| Job classification | Observed frequen-cies | Expected frequen-cies | Propor-tion | Relative risk | Relative risk 95% CI | Odds ratio | Odds ratio 95% CI |
|---|---|---|---|---|---|---|---|
| Professionals | 620 | 676 | 0.917 | 1.000 | | 1.000 | |
| Managers | 234 | 220 | 1.064 | 1.077 | 0.9693 to 1.1976 | 1.160 | 0.9364 to 1.4363 |
| Office workers | 496 | 480 | 1.033 | 1.062 | 0.9768 to 1.1553 | 1.127 | 0.9541 to 1.3304 |
| Skilled workers | 836 | 747 | 1.119 | 1.104 | 1.0257 to 1.1881 | 1.220 | 1.0534 to 1.4135 |
| Salespersons | 490 | 458 | 1.070 | 1.080 | 0.9936 to 1.1749 | 1.167 | 0.9865 to 1.3794 |
| School./Suden. | 172 | 637 | 0.270 | 0.444 | 0.3847 to 0.5134 | 0.294 | 0.2409 to 0.3598 |
| Other | 609 | 530 | 1.149 | 1.118 | 1.0332 to 1.2090 | 1.253 | 1.0682 to 1.4695 |
| Unknown | 3864 | 3573 | 1.081 | 1.086 | 1.0219 to 1.1543 | 1.179 | 1.0478 to 1.3269 |
| **TOTAL** | 7321 | 7321 | | | | | |

$X^2 \approx 293$, df=7, p<0.0001

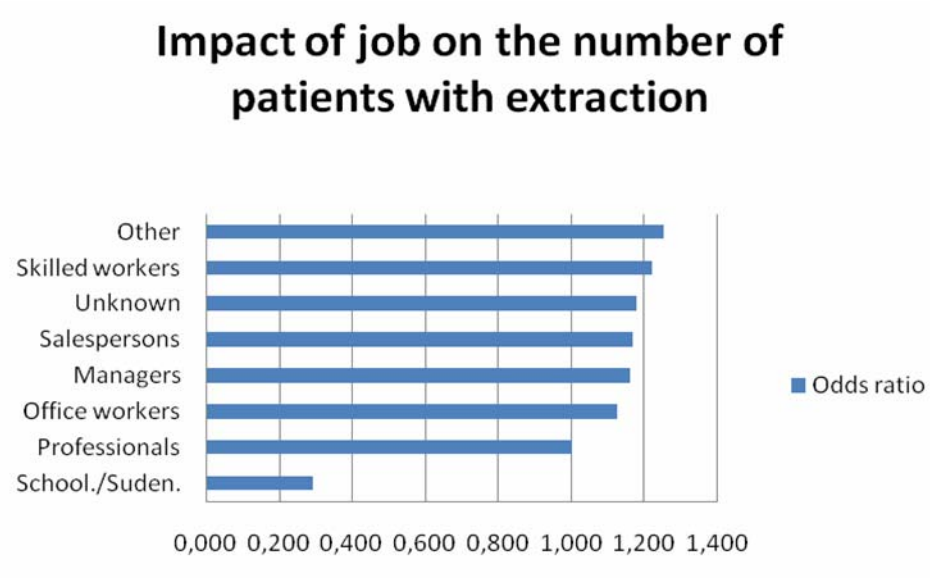


***Figure 9.*** *Impact of the attribute of job on the number of patients with at least one extraction (odds ratio)*

***Table 11.*** *Impact of the attribute of job on the number of extractions*

| Job classification | Observed frequencies | Expected frequencies | Proportion | Relative risk | Relative risk 95% CI | Odds ratio | Odds ratio 95% CI |
|---|---|---|---|---|---|---|---|
| **Professionals** | 833 | 1017 | 0.819 | 1.000 | | 1.000 | |
| **Managers** | 363 | 384 | 0.945 | 1.079 | 0.9870 to1.1800 | 1.154 | 0.9735 to 1.3683 |
| **Office workers** | 880 | 814 | 1.081 | 1.154 | 1.0778 to 1.2350 | 1.320 | 1.1564 to 1.5064 |
| **Skilled workers** | 1502 | 1372 | 1.095 | 1.161 | 1.0917 to 1.2340 | 1.337 | 1.1887 to 1.5028 |
| **Salespersons** | 881 | 803 | 1.097 | 1.162 | 1.0856 to 1.2435 | 1.340 | 1.1734 to 1.5291 |
| **Scholars/ Students** | 198 | 282 | 0.702 | 0.916 | 0.8141 to 1.0309 | 0.857 | 0.6994 to 1.0507 |
| **Other** | 1037 | 999 | 1.038 | 1.131 | 1.0589 to 1.2083 | 1.267 | 1.1170 to 1.4379 |
| **Unknown** | 6316 | 6339 | 0.996 | 1.108 | 1.0509 to 1.1691 | 1.217 | 1.1029 to 1.3417 |
| **TOTAL** | 12010 | 12010 | | | | | |

$X^2 \approx 46$, df=7, p<0.0001

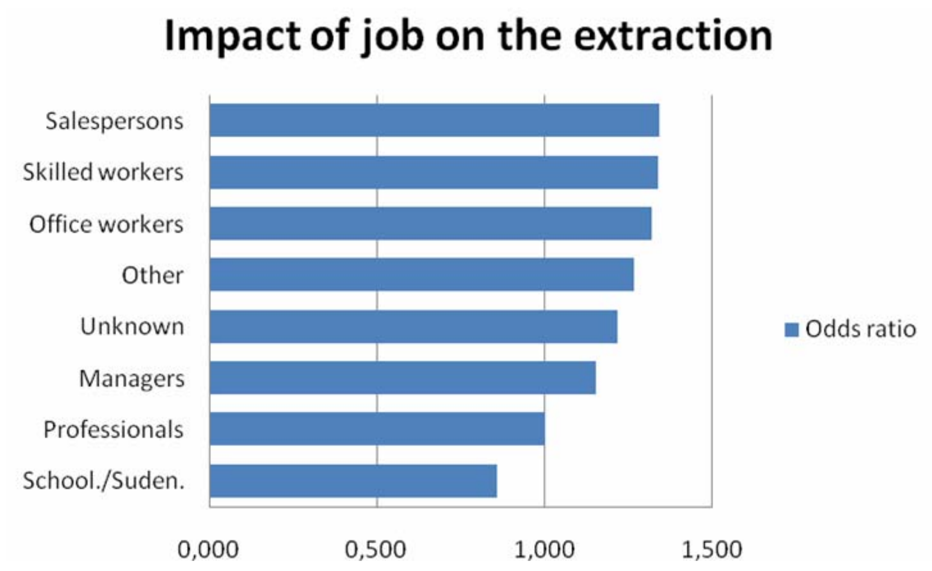


***Figure 10.*** *Impact of the attribute of job on the number of extractions (odds ratio)*

## DISCUSSION

Any scientific research, surveillance, and collection of information, in addition to their being characteristic of human beings, have been more and more associated with machines, i.e.machine intelligence. Although artificial intelligence cannot be compared with human intelligence in the domain of independent achievement, it can contribute significantly to science thanks to its speed and ability to process large amounts of data.

The results of this study demonstrate that AI algorithms are able to successfully sort, count, and help triage the patients with extractions and extractions themselves, and identify and measure the impacts of certain medical-demographic characteristics of patients on the presence of extractions.

OLAP analysis by the „Inductive Learning by Logic Minimization" server is of a general type, focused on the discovery of key attribute and its section, i.e. the pattern of the base of interest to researchers. Due to these inherent properties, this Data Mining Server is unable to perform more specific sorting, selection, and counting of dental causes of extraction, or to analyze in detail the relationship of all attributes with the issue of extraction.

On the other hand, the specific algorithm was created for the purpose of this study and it was able to render much more information and produce new knowledge. However, AI, being an important tool in scientific research, is not able to do the job independently and without instruction - it will not sit in a data base and monitor and analyze the situation, detect interesting patterns, and automatically inform by e-mail the investigator about the discovery (43). The human precondition has led AI towards the research goal, adjusted to the relation format of the tables in the dataset designed for XPA3 Prolom 5.0 software.

The obtained AI results demonstrate the extraction distibution by the factors of age and gender (*Table 2*) and agree with the results of classical human studies. *Charen et al*. (10) found an increased number of extractions in men (51.1%) versus that in women (48.9%) and similar distribution by the factor of age. *Aida et al.* (11) found similar extraction distribution by the factors of age and gender: (age: 5-14 (0.6%), 15-24 (5.6%), 25-34 (10.4%), 35-44 (8.4%), 45-54 (16.0%), 55-64 (25.7%), 65-74 (22.6%), 75- (10.8%); gender: male (50.58%), female (49.42%)). *Da'ameh* (12) found a decreased number of extractions in women (41.8%) and increased in men (58.2%) and an increased number of extractions in the period from 31 to 50 years of age. *Hull et al*. (13) found a slightly increased percentage of extractions in women (50.64%) compared to men (49.36%), with age distribution similar to our study, being the highest in the period 51-60 years of age (21.08%). Similar to our study, *Al-Shammari et al.* (14) found an increased percentage of male patients (53.5%) compared to female ones (46.5%), but a lower number of extractions in men (49.8%) compared to women (50.2%), with a maximum of 22.7% in the period 31-40 years of age.

The reasons representing direct dental causes of tooth extraction (*Table 3*) are similar to previously performed human studies, identifying two principal causes of tooth extraction: caries (43.77%) and periodontal diseases (37.23%), making up 4/5 of all extractions. *Anand et al.* (15) in a recent study came up with similar results, the main reasons being caries and its consequences (44.6%), periodontal diseases (33.2%), orthodontic reasons (11.1%) (a significant deviation from our results - 2.73%), then extraction consequences (2.5%), prosthetic reasons (2.5%), and other causes (6%). *Al-Shammari* (14) identified caries (43.7%) and periodontal diseases (37.4%) as principal reasons for tooth extraction, while the remaining ≈20% were distributed similar to our research. The results of *Johansen et al*. (9), *Charen et al*. (10), *Curilović et al*. (16), *Niessen et al*. (17), *Corbet et al*. (18), *Hull et al*. (13), *Richards et al*. (19), *Lesolang et al*. (20), *Aida et al*. (11), *Da'ameh* (12), *Ctrnactova et al*. (21), were in agreement with our AI results, identifying caries as the principal and periodontal diseases as the second by importance cause of tooth extraction. *Stabholz et al*. (22) found periodontal diseases to be the principal cause of tooth extraction (65%), with caries as the second cause by frequency (30%), but they targeted a group of geriatric patients.

The distribution of observed extractions by the factor of patient job (*Tables 4* and *5*) is in general agreement with the study by *Morita et al*. (44), where drivers (2.10), workers (1.31), and salesmen (1.32) had higher odds ratio of dental extraction compared to professionals. Our study is also in agreement with the research of *Neto et al*. (45), who found a higher number of extractions in socioeconomically endangered patients. *Kabat* (23) found more dental extractions in patients of poor economic status.

In the domain of discovery of new relationships and knowledge, OLAP „Inductive Learning by Logic Minimization" induction algorithm identified age as a key attribute for tooth extraction, and its portion, i.e. the value of 55-64 years of age, as the factor associated with highest risk for this dentistry procedure. Our specific author algorithm identified three attributes, gender, age, and job, as most important factors of influence on extractions. The sections of these attributes were sorted according to the relative risk and odds ratio, representing both positive and negative influence on extractions (*Tables 6* and *11*). Male gender, 45-75 years of age, and occupations such as worker and salesman, were associated with increased probability of extraction. We should bear in mind that other investigated attributes were not completly negative (i.e. they have an impact of their own), since a possible flaw of this study could be the inappropriately kept and updated patient information of either personal or more general anamnestic nature obtained from dental care institutions. These information were appropriate and sufficient for proper keeping of dental patient records in dental care institutions, but for an advanced AI analysis anamnestic data should have been more precise and extensive, including primary diseases, ongoing and previous diseases, and other relevant quantitative and qualitative demographic information; only then, AI studies could be expected to render at present yet unknown causal relations.

The reasons for dental extraction have been monitored for decades (9-37), and each of the pertinent studies requires lots of resources (time, financial support, research efforts). Making use of AI, in a short period of time (a week), we were able to get an insight into the reasons for dental extractions and potential influences on the incidence of extractions. However, AI is still far away from the level of independent reasoning - a human hand is still necessary to lead it towards the desired goal.

## CONCLUSION

The use of AI enables us to collect, triage, sort, count, and analyze successfully raw electronic data, and applied AI algorithms are able to perform nonparametric assessment of possible influences of non-dental attributes, enabling us to draw scientifically valid conclusions. However, AI cannot independently devise and execute a research without assistance of human intelligence.

The God Almighty created man and endowed the human race with full intelligence; whether humans are able to endow their machines with similar intelligence or it is God's exclusive prerogative, remains to be seen through the achieved results.

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# RAZLOZI ZA EKSTRAKCIJU ZUBA DOBIJENI PUTEM VEŠTAČKE INTELIGENCIJE

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**Sažetak**

**Veštačka inteligencija (AI) je nauka koja se bavi projektovanjem inteligentnih mašina, softvera i algoritama. Kompjuterskim praćenjem stomatoloških bolesnika, broj sirovih elektronskih podataka postaje veliki i otvara mogućnost naučne analize AI-om. Kako bi bili u mogućnosti da predupredimo razloge i smanjimo neophodnost za ekstrakcijom, neophodno je stalno imati sveže informacije o razlozima i uticajima na ekstrakcije, te koristimo AI analizu.**

**Cilj rada bio je ispitati mogućnosti primene veštačke inteligencije u sakupljanju, trijaži, sortiranju, brojanju i analizi elektronskih informacija i donošenju naučno-prihvatljivog zaključka.**

**Urađena je case-control studija nad elektronskim podacima. Priprema i brojanje podataka izvršeni su posebnim C# kodovima. Analiza uticaja vandentalnih atributa je sprovedena: OLAP analizom i specifičnim algoritmom za otkrivanje.**

**OLAP je detektovao atribut uzrast sa senzitivnošću 44.0% i specifičnošću 100.0%, i vrednost atributa uzrasta od 55 do 64 godine. Specifični algoritam dao je direktne razloge: karijes 43.77%, periodontalna oboljenja 37.23%, fraktura 6.82%, protetski razlozi 4.31%, impakcije 3.12%, ortodonski razlozi 2.73%, mlečni zubi 0.32% i ostalo 1.7%. Algoritam je našao da atributi: pol, uzrast i zanimanje imaju statistički značajan uticaj (pol: $X^2=7.095$, df=1, p=0.0077, uzrast: $X^2\approx261$, df=8, p<0.0001, zanimanje: $X^2\approx46$, df=7, p<0.0001).**

**Primenom veštačke inteligencije mogu se uspešno sakupljati, trijažirati, sortirati, brojati i analizirati sirovi elektronski podaci, a primenjeni AI algoritmi su u stanju da izvrše neparametrijska ispitivanja mogućih uticaja vandentalnih atributa i donesu o tome naučno-prihvatljiv zaključak.**

***Ključne reči***: **kompjuterizovana stomatologija, veštačka inteligencija, ekstrakcija zuba, elektronski stomatološki karton, XPA3 Prolom**