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ORIGINAL

How to categorize a panoramic images database for automatically detection of dental treatments

Cómo categorizar una base de datos de imágenes panorámicas para la detección automática de tratamientos dentales

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Abstract

Objectives: The objective is to provide a methodology to obtain a categorized database without segmentation by sex or age that can be used in dental object detection applications and that may help in the diagnosis and usual clinical practice.
Methods: A total of 10,677 panoramic images were analyzed by four examiners. In each tooth, the examiner indicated if the tooth exists or not and the position on FDI notation. After that, and for each tooth that exists, the examiner detailed whether or not there were the variables analyzed. Those variables were filled teeth, crown, implant, endodontic treatment, caries, and prosthetic. A descriptive study of inter-observer and intra-observer concordance-consistency was performed.
Results: The results were statistically significant. Both teams obtained for all variables an almost perfect concordance k = 0.9 except in filled teeth where the kappa was k=0.8 and caries where a moderate agreement was obtained. The intra-examiner agreement was poor in caries variable and almost perfect in the rest of variables.
Conclusions: A correctly categorized database is essential to obtain correct results in applications with artificial intelligence and neural networks. This study shows how to categorize a database of dental images for use in object detection applications in the field of dentistry.

Key words: image dataset; panoramic image; categorization; dental application.

Resumen

Objetivos: El objetivo de este estudio es proporcionar una metodología para categorizar imágenes dentales que serán usadas para detectar objetos dentales sin que exista segmentación por sexo o edad y la cual ayude en el diagnóstico y la práctica clínica.
Métodos: 10.677 imágenes panorámicas fueron examinadas por 4 examinadores. En cada diente, los examinadores indicaron la existencia de dicho diente y la posición del mismo de acuerdo a la notación FDI. Posteriormente, para cada diente existente, se detalló la existencia o no de las variables analizadas. Dichas variables son: empastes, coronas, implantes, endodoncias, caries y prótesis. Se realizó un estudio de la concordancia inter e intra examinador.
Resultados: Los resultados alcanzados son estadísticamente significativos. Ambas parejas obtuvieron una concordancia casi perfecta, k=0.9, en todas las variables excepto en los empastes, donde kappa toma un valor de k=0.8 y en las caries, donde la concordancia fue moderada. La concordancia intra-examinador fue pobre para las caries y casi perfecta para el resto de variables.
Conclusiones: Una correcta categorización es esencial para obtener buenos resultados en las aplicaciones en las que se emplean las redes neuronales y la inteligencia artificial. Este estudio muestra cómo categorizar una base de datos de imágenes panorámicas que vayan a ser empleadas para detectar objetos en el campo de la odontología.

Palabras clave: base de datos; imagen panorámica; categorización; odontología.

Background

Medical practice in general, and dentistry in particular, generates massive data from sources such as high-resolution medical imaging, biosensors with continuous output and electronic medical records[1].

We nowadays require more than ever to provide healthcare which, together with the large amount of data generated, makes the use of algorithms increasingly necessary[1]. Diagnostic mistakes and errors in treatment cause loss of resources and time both for patients and clinicians[2]. This is one of the reasons why artificial intelligence is being an increasingly used tool in the field of medicine and dentistry.

Several studies have employed different computer techniques to obtain dental information from X-ray images. Lin et al.[3] employed bitewing images to automatically classify teeth, Miki *et al*.[4] proposed a neural network to classify teeth for forensic identifications.

To reduce errors on machine predictions, artificial intelligence can be trained to recognize some patters from several data inputs[5]. The results provided by the automatic algorithms and artificial intelligence have a great dependence on the data with which they learn and are training, that is, on the input data.

On the other hand, caries is one of the most common chronic diseases in the oral field with a great impact on the patient's health[6]. Clinical examination is the main method for caries detection being radiographic examination a complementary diagnostic tool[7]. Panoramic radiographies are very common in dentistry practice to make a general diagnosis of the patient[8] but intraoral bitewings images are more effective in detecting caries lesions than dental panoramic tomographies[9]. Previous studies compared the effectiveness of panoramic and bitewing radiographs for the detection of caries but with opposed results on inter-examiner agreement[10,11].

The objective is to provide a methodology to obtain a categorized database without segmentation by sex or age that can be used in dental object detection applications and that may help in the diagnosis and usual clinical practice.

Method

Four dentists with at least three years of experience in general dentistry was divided into two groups (Team 1: E.A., MF.S. and Team 2: B.S., I.J.).

Image dataset

Panoramic images were taken from Asisa Dental S.A.U. centers in the Community of Madrid (Spain). These images were completely anonymized by CareStream® Health Spain SA (Pozuelo de Alarcón, Madrid, Spain). No additional information such as name, gender, age, or when the image was taken was used to for the database. Data collection was ethically approved (Ethics Committee of Research with Regional Medicines of the Community of Madrid (CEIm-R)) in June 15th, 2018. The requirement to obtain informed consent from patients was waived by the ethics committee.

The radiographies included in the study were those that correspond to adults older than 18 years. Images with poor definition, repeated, patients with only presence of implants, edentulous, with mixed dentition or with removable prostheses (metallic or acrylic) were excluded. Periapical radiographies were also excluded.

Data collection methodology

For each non-rejected radiograph, the variables detailed in **table I** must be evaluated:

In each tooth, the examiner indicated if the tooth exists or not and the position on FDI notation. After that, and for each tooth that exists, the examiner detailed whether or not there were the variables detailed in the previous table. A program created for this propose was employed by the examiners to collect information on each of the variables. **Figure 1** details the main page of the visualization program and **Figure 2** how the variables are selected in each tooth.

This visualization program has the possibility of increase the size of the panoramic image, but it does not allow to modify brightness or contrast.

Before beginning the evaluation, the four examiners were instructed through an informational meeting where they were administered a guide manual and use of the interface. This manual met the criteria that each evaluator should consider making the diagnosis of the radiograph in detail.

Statistical analysis

The analysis was done using Stata® version 14.2 (StataCorp LLC, Texas, USA) and results were obtained with a 95% confidence interval. The interpretation was made with the classification proposed by Landis and Koch[12]. Intra- and inter-examiner agreement was evaluated by calculating Cohen's Kappa. According to Bulman and Osborn[13], values of Cohen's Kappa below 0.40 were considered as poor agreement, between 0.41 and 0.60 as moderate agreement, between 0.61 and 0.80 as substantial agreement, and between 0.81 and 1.00 as almost perfect agreement.

To perform the intra-examiner statistics, each evaluator re-analyzed 50 images.

Table I: Variables definition.

Presence	Absence
Tooth	
There is root and crown	There is no type of crown
Filling	
There is a filling of any material in the crown of the tooth Overlays (until 2/3 of the occlusal part of the clinical crown)	There is no type of obturation or overlay in the crown
Crown	
There is a total covering of any material in the crown of the vital tooth There is a total coating of any material in the crown of the root canal There is a total coating of any material in the crown of the implant	There is no total coating of any kind in the clinical crown.
Implant	
There is a dental implant on the bone	There is no dental implant
Endodontic treatment	
Presence of radiopacity in the roots of a tooth (clinical crown + root)	There is no type of radiopacity in any of the roots of the tooth.
Prosthetic	
There is a prosthetic crown, of any material, without being supported by any tooth or implant.	There is no prosthetic crown without support.
Caries	
Radiolucency may extend to the dentinoenamel junction or outer one third of the dentin. Radiolucency extends into the middle one-third of the dentin Radiolucency extends into the inner one-third of the dentin Recurrent caries lesion: irregularly shaped radiolucency below a restoration or next to it.	No radiolucency

Figure 1: Visualization program employed to collect data by the examiners.

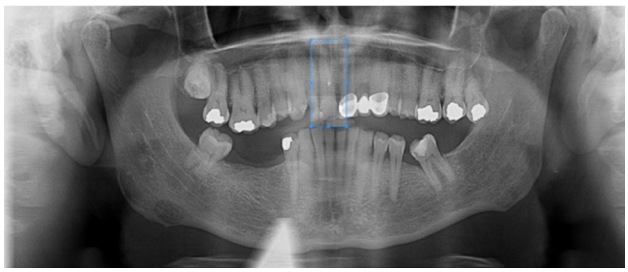
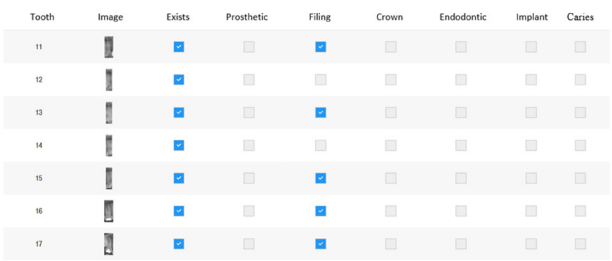


Figure 2: Detail of how variables are collected.



Results

Inter-observer agreement

The four examiners needed 30 weeks to complete the process of visualization and analysis of the images. A total of 10,684 radiographs were categorized, and after the elimination of duplicates, the final result was 10,677 panoramic radiographs.

Table II details the concordance obtained from each variable by each team with the Cohen Kappa statistic.

Table II: Concordance obtained from the total of categorized images.

	Team 1	Team 2
	kappa	kappa
Exists	0.9	0.9
Filling	0.8	0.8
Caries	0.4	0.5
Prosthetic	0.9	0.9
Crown	0.9	0.9
Endodontic	0.9	0.9
Implant	0.9	0.9

Panoramic images categorized with an ideal concordance k=1 in the variable exists were a total of 7,390. Both teams obtained for all variables an almost perfect concordance k=0.9 except in filling and caries. For filling variable, a substantial concordance k=0.8 in both teams. For the caries variable, team 1 obtained a moderate agreement k=0.4 and team 2 also a moderate agreement k=0.5.

Evaluation of sex and age of the analyzed sample

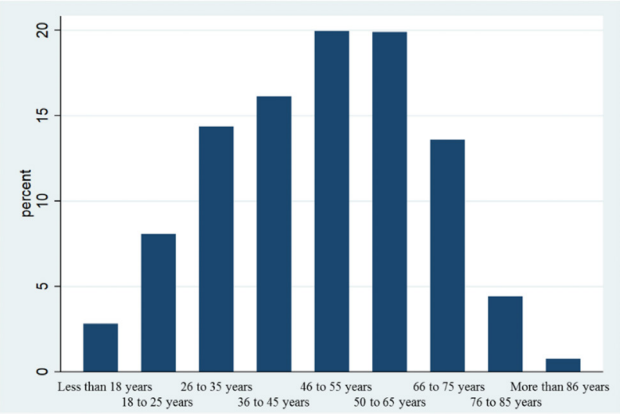
In the total of the sample analyzed (10,677 radiographs) the minimum age was 0 years and the maximum was 114. The average age was 48.93 years with a standard deviation of 17.39 years. **Table III** details the descriptive statistic of age.

Table III: Descriptive statistic of age.

Variable	N	Min	Max	p25	p50	p75	Mean
Age	10,677	0	114	35	50	62	48.92826

Figure 3 shows the distribution by age intervals.

Figure 3: Age range percentage.



Regarding the variable sex, the distribution of men represented 52.72% and women 47.28%. **Table IV** details the descriptive statistic of sex.

Table IV: Descriptive statistic of sex.

Sex	Frequency	Percentage	Cumulative
Man	5,629	52.72	52.72
Woman	5,048	47.28	100.00
Total	10,677	100.00	

Intra-observer agreement

Each examiner re-analyzed a total of 50 images. **Table V** details the intra-examiner concordance obtained from each variable with the Cohen Kappa statistic.

The results of the intra-examiner statistic for endodontic, implant, prosthetic and crown variables was an almost perfect agreement. Examiners 2 and 3 a poor agreement in caries variable while examiners 1 and 4 obtained a moderate agreement. An almost perfect agreement was obtained by all examiners in exists variable.

Table V: Intra-examiner concordance.

	Examiner 1 (E.A.)	Examiner 2 (MF.S)	Examiner 3 (B.S.)	Examiner 4 (I.J.)
	kappa	kappa	kappa	kappa
Exists	0.8194	0.8039	0.9065	0.8637
Filling	0.8553	0.6907	0.7893	0.7861
Caries	0.5176	0.3036	0.1555	0.5329
Prosthetic	0.9438	0.9467	0.9784	0.8183
Crown	0.9617	0.9602	0.9358	0.9205
Endodontic	0.9425	1	0.9876	0.9750
Implant	0.8921	1	0.9224	0.8132

Discussion

This study proposed a methodology to categorize a panoramic images database for dental object detection applications. Four examiners randomly divided into two groups analyzed 10,677 images and in each of the radiographs they selected the existence or absence of tooth and, in case of existence, if on that tooth there were filling, crown, implant, endodontic treatment, caries or prosthetic. Finally, a descriptive study of inter-observer and intra-observer concordance-consistency was performed.

One of the limitations that automatic object detection is related to the number of images used to build the algorithm. For example, Wang *et al*. employed 400 cephalometric X-ray image in different object detection algorithms[14], or Miki et al. employed fifty-two images[4]. In our study, a database of 10,677 images is prepared and categorized.

The trustworthy interpretation of dental images, such as, radiographs, can be affected by several factors like training, the experience of the observer or the quality of the image[15]. Therefore, it is important to control these potential factor sources of examiner bias. Regarding the experience of the examiner, Fortes *et al*. evaluated the possible differences when selecting an implant for dental treatment between junior and senior experienced dentists[16]. Pakbaznejad Esmaeili *et al*. compared the differences on caries detection between an expert in oral radiologists and general dentists and concluded that caries remained mainly unobserved by general dentists[9]. In our study, to avoid the possible introduction of bias in data collection, the four examiners had the same experience in general dentistry.

The main advantages of this study are, first, in the number of categorized images that could be used for the use of artificial intelligence techniques and, secondly, that the categorized database is not biased by the experience of observers.

Francio *et al*. analyzed the inter- and intra-examiner agreement to detect tooth-restoration in panoramic images. Excellent and good levels of intra-examiners agreement were obtained in detecting tooth restoration[17]. These results are in accordance with the results obtained in our study. One of the reasons for obtaining a lower concordance for the "filling" variable can be found in the noise generated in the radiographic images, which refers to an artifact that can mask a factor[17].

Interpretation of X-ray images is subjective and difficult on the occlusal surface to detect caries, therefore, to obtain lower values of kappa statistic is understandable. Thomas *et al*. compared the concordance of caries detection between bitewing and panoramic radiographies and concluded that the intra-examiner reproducibility was low[8]. Our results agree with this study. Kamburoglu *et al*. also compared proximal caries detection using intraoral bitewing, extraoral bitewing and panoramic radiography and concluded that inter-observer agreements for the panoramic images were between 0.477 and 0.740, less agreement than intraoral bitewing radiographies[18]. Our results in caries variable are closed to the range obtained in that study.

Conclusions

A correctly categorized database is essential to obtain precise results in applications with artificial intelligence. This study shows a methodology to categorize a database of dental images for use in object detection applications in the field of dentistry. As future studies are the detection of variables by artificial intelligence from the analyzed images.

Declarations

Ethics approval and consent to participate: Ethics Committee of Research with Regional Medicines of the Community of Madrid (CEIm-R)) in June 15th, 2018. The requirement to obtain informed consent from patients was waived by the ethics committee.
We confirm that all methods were carried out in accordance with relevant guidelines and regulations.

Consent for publication: "Not applicable"

Availability of data and materials: The datasets generated and/or analysed during the current study are not publicly available due they have been obtained from patients of from Asisa Dental S.A.U. centers but are available from the corresponding author on reasonable request.

Competing interests: "The authors declare that they have no competing interests"

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Authors' contributions: M.P-P, J.G.V, R.R and A.B. designed the study, C.H.M-M and C.I revised critically the content, M.P-P drafted the manuscript and all authors approved the final version.

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