Can health kiosks be used to identify oral health care needs? A pilot study

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Abstract

Objective

The aim of this study was to investigate the reliability of digital imaging for detecting restorative treatment need among individuals in their 20s by comparing the outcome of digital imaging with clinical caries findings at patient level.

Material and methods

Five intraoral clinical daylight and fluorescence digital images were taken extraorally of 21 patients. A clinical examination was then performed by a trained and calibrated dentist. Additionally, the patients answered a multiple-choice questionnaire about their health habits. The images were analysed and caries findings were recorded. For statistical analysis, sensitivity and specificity were calculated. Results were shown as ROC curves and AUC values. All analyses were done using SPSS (version 24.0, Chicago, Illinois, USA).

Results

Caries lesions were most often detected in molars and least often in canines. When using the clinical status as gold standard, digital imaging gave an AUC value of 0.617, whereas the outcome by questionnaire gave an AUC value of 0.719. When using the combined outcome of digital imaging and the questionnaire, the AUC value was 0.694 with clinical validation.

Conclusions

It can be concluded that health kiosks may help to reduce the number of patients waiting for dental treatment; more specifically, the questionnaire with individual feedback may provide a new instrument for providing instructions for homecare online. However, the camera system must be developed further, and dentists and dental hygienists require training to analyse the images.

Keywords: Dental caries, daylight digital image, fluorescence digital image, questionnaire

Word count: 3172

Introduction

In 2010, untreated dental caries was the most prevalent condition in permanent teeth worldwide while dental caries in deciduous teeth was the tenth most prevalent condition [1]. There was a plateau in the prevalence of dental caries between 1990 and 2010. On a global scale, 60–90% of schoolchildren have dental caries and the majority of adults are affected by the disease [2]. The ageing of populations and the decrease in total tooth loss indicates a continuous burden of dental caries [1]. According to the Health 2011 survey, invasive dental treatment due to caries was required by approximately 20% of Finnish people aged 30 years [3]. Dental caries and periodontal diseases share common risk factors (diet, smoking) with other non-communicable or chronic diseases like atherosclerosis.

There have been a few studies showing a correlation between specific risk questionnaires and the need of restorative treatment. Questionnaires have shown good results, especially for screening large populations [4, 5]; however, the questionnaires must be specific for age and ethnic background. In addition to screening treatment need, risk questionnaire software could be beneficial for promoting individual self-care. The aim in health care is to promote health and prevent diseases. Consequently, the practice in caries treatment is to control the disease with the aim of preventing manifest caries lesions and arresting the progression of active, initial lesions [6]. Early intervention of dental caries lesions is beneficial for patients and society [7].

Health kiosks have been developed to provide patients with easy access, low cost health services and to reduce the workload in health centres [8]. Physiological parameters such as weight, height, blood pressure, LDL cholesterol and glycated haemoglobin (HbA1c) levels have been measured in health kiosks. Having the health kiosks perform routine check-ups such as these gives physicians more time with patients who have more severe care needs [8]. Bahadin et al. (2017) investigated the use of health kiosks and found that all subjects felt that the kiosk was easy to use, and 96% were positive to using the services of a kiosk instead of seeing a doctor [9]. This was especially true for subjects who visited the health kiosk twice instead of once. Using a health kiosk also reduces health care costs for the patient and society.

Today, digital imaging is easily available in general dental practice to monitor as well as detect conditions. Compared to visual examination, the sensitivity of digital photographs has been shown to be higher in detecting occlusal caries lesions, and the specificity of the two methods is nearly the same [10]. Clinical photographs could be particularly usable in areas where access to health services is difficult [11]. Digital photography could possibly be used to identify patients' cariological treatment needs; however, this is a new area and so far, literature on the topic is scarce.

The aim of this study was to investigate the reliability of imaging for detecting restorative treatment need at individual level by comparing clinical caries findings and the outcome of digital imaging and a questionnaire. The hypothesis is that patients with restorative treatment need can be reliably identified by imaging when combined with a validated, age-specific questionnaire.

Materials and Methods

This study is part of the Dentsaver project [12] aimed at developing a dental health kiosk concept. The project includes both intraoral imaging (DentoCam) and a risk questionnaire (DentoGram).

Recruitment of Study Participants

The patient sample for the study was recruited from 21-year-olds who attended Public Dental Services (PDS) clinics in Vaasa, Finland. A list of all such patients was obtained from the PDS and, in order to obtain a random sample, an invitation to take part in the study was mailed to every seventh person on the list. A total of 194 patients were thus invited to volunteer for the study. Twenty-one agreed to take part. Participation was voluntary and free of charge.

Imaging

The developed DentoCam extraoral imaging system produced intraoral clinical daylight and fluorescence images of the upper and lower dental arch and daylight photographs of the front view with the posterior teeth biting together, a total of 5 images (Figure 1). The system comprised five board level cameras ("machine vision camera") (Basler daA2500-14uc) with 6-mm focal length camera objectives (C 6 mm F1.8/ 1/2"") and flashlights (Godox VING V850II Li-ion Camera

Flash); two of the cameras were equipped with fluorescent light filters (650 nm band pass filter). The cameras and filters were protected by anti-reflection coated plastic plates which also enabled easy disinfection after each photography session. Miniature fans were used to keep the lenses dry by blowing away the moisture that forms on the plates from patients' breathing (Figure 2). The frames of the plates had mechanical guides that helped the patients to assume the correct position for photographing, together with a live video that showed the patients how well their teeth were visible. The cameras were mounted on a rotating base, and the five images were taken sequentially by rotating each camera in front of the subjects. This equipment helped to achieve the final adjustment of the cameras.

A trained person performed the imaging of the teeth with a DentoCam using an OptraGate® (Ivoclar Vivadent AG, Schaan, Principality of Liechtenstein) lip and cheek retractor to allow the best possible visibility. This person assisted the patients in putting the OptraGate® in place. After the DentoCam imaging, the subjects received feedback about the image on paper and via e-mail.

Questionnaire

The DentoGram risk questionnaire is a previously selected and tested web-based multiple-choice survey [5]. The questions cover different health habits and other information that has been noted to be associated with caries incidence in this age group. The questionnaire included the following questions: Do you think you need dental treatment? (No/Yes+); Have you had your teeth restored? (No/Yes+); Your education? (University, General upper secondary, Vocational with general upper secondary, Vocational+, Basic education+, Other+); How often do you brush your teeth? (Every day or almost every day, sometimes during the week+, never or almost never+); Do you smoke? (No, Yes+); Do you find visiting a dentist scary? (Not at all, a little+, Very much+); How long ago did you visit an oral hygienist or a dentist? (<1 year, 1–2 years, 3–4 years or more+, I don't remember+); Do you skip brushing because you feel tired or you don't feel like brushing? (Never or almost never, Every day or almost every day+, Sometimes during the week+); Did you visit the dentist last time because of toothache? (No, Yes+); How many € do you spend weekly on snacks (products like fizzy drinks and sweets)? (0–5 euros, >6 euros+) [5] (Table 1).

When the participant chose the option +, he/she scored one risk point. A sum score of all responses was calculated. After filling the questionnaire, respondents received feedback based on their individual responses and the total sum score. The feedback, which was based on the current care guidelines used in Finland [7], was categorised into four risk levels as follows: risk level 0 (0–1 risk

point), 1 (2–4 risk points), 2 (5 risk points), and risk level 3 (>5 risk points) (Table 2). The patients answered the questionnaire at the premises of the health centre using either a standard PC laptop or an iPad provided for this purpose. There was a person making sure that the respondents had no problems responding to the questionnaire

Clinical examination

A clinical oral examination was performed by a trained and calibrated dentist familiar with clinical studies on oral health (TT). The training and calibration sessions were performed beforehand to clarify the process of clinical examination. To ensure the quality of the clinical examination, interexaminer agreement (ICC 0.64, Kappa value 0.85) was calculated by having a senior researcher as the gold standard (VA). The clinical examination was carried out in a dental office of the Vaasa Health centre using the light of the unit, a fibre-optic transillumination (FOTI) device, an oral mirror and a probe to examine the tooth surfaces visual-tactilely. The dentist investigated the teeth for initial and manifest caries lesions using the ICDAS criteria [13]. The findings were recorded per surface as inactive initial/active initial/dentinal caries/caries extending to pulp.

Bitewing radiographs were taken of each patient when clinically indicated, e.g. if at least one clinically detected caries lesion penetrated into dentine or in patients with high caries risk [7]. Clinical findings were recorded in the Effica patient file system (Tieto, Oulu, Finland). In the analyses, information from the bitewing radiographs was included in clinical status.

Analysing the images

All DentoCam images were analysed by a trained dentist (AK) who registered findings per tooth. Caries lesions in the images were classified as follows: active or inactive enamel caries lesion, dentine caries lesion, deep dentine caries lesion. In addition, the dentist marked all tooth colour fillings and missing teeth. In the next stage, a second-year dental student (LP) recorded all the other teeth: healthy or not visible if the tooth was totally or partly missing in the image. The dental student also recorded amalgam fillings as well as remaining orthodontic retention wires.

Analysis was performed by using AnnotEye® software developed in 2016 by Dr Petr Martynov (OPEM) for annotating eye fundus images. The software allows labelling the image as a whole, and additionally, marking an unlimited number of individual findings on the image. Labels for both the image and single findings are selectable from editable predefined lists. The label lists were edited for the project as follows: the list of findings contained findings similar to those recorded in the oral

health examination while the image label list comprised treatment need that could be concluded from the image. Additionally, it is possible to select an attribute to each finding; here, tooth numbers were used as attributes.

Statistics

To evaluate the reliability of the annotator, a trained dentist (AK) reannotated 13 Dentocam images, after which annotations were compared to clinical caries status findings registered by a trained dentist (TT) and Cohen's kappa value was calculated. Validity was evaluated at individual level.

For analyses, clinical and image data were combined in an electronic database. The findings of the clinical examination and DentoCam images were presented as frequencies and proportions. For the analyses, teeth were categorised as incisors/canines/premolars/molars, and analyses were conducted for teeth and tooth groups. In addition, for analyses, decayed teeth (DT) were categorised into four groups as follows: DT=0, DT=1, DT=2 and DT >2. The association between clinical findings, imaging and questionnaire was analysed as sensitivity and specificity and using clinical examination as gold standard and restorative treatment need (DT>0) as cut-off point. ROC/AUC curves were subsequently produced. AUC combines sensitive and specificity measures and is a good measure of the trustworthiness of a diagnostic test's ability to categorise healthy or sick individuals. The higher the AUC, the more precise the measure.

All analyses were conducted using SPSS (version 24.0, Chicago, Illinois, USA).

Ethics issues

The Regional Ethics Committee of the Northern Ostrobothnia Hospital District issued a positive statement on this study on 6 August 2018. The city of Vaasa granted permission for the validation of the Dentsaver project in the city of Vaasa primary health care on 5 October 2018. Participants signed an Informed Consent before the Dentsaver examination. Each subject received their personal five-letter identifier when they answered the DentoGram survey. The identifier followed the same subject throughout the project. For the analyses, the IDs were excluded. The register of this study was protected with a password and only the researchers in this project had access to it.

Results

The average time to take five pictures of a patient by the DentoCam imaging system was 6 min 11 s. In addition, answering the questionnaire took on average 1 min 16 s.

The response rate of the study was 9.2%. Table 3 presents the frequency of dentine caries lesions detected clinically in each tooth group. Clinically, most caries lesions were discovered on molars while seven patients had at least one dentine caries finding. The lowest number of caries lesions was found in canines where only one patient had caries. The mean DT value among the 21-year-olds was 1.7; one third (33%) of the patients had at least two dentine caries findings. All patients with caries lesions had multiple lesions. The highest number of dentine caries lesions in a single patient was nine. The Cohen's kappa between Dentocam images and clinical status at individual level was 0.32.

When comparing imaging and clinical status, the AUC value was 0.617 whereas when the questionnaire and clinical status were compared, the AUC value was 0.719. When the combined results of imaging and the questionnaire were compared to clinical status the AUC value was 0.694 (Figure 3).

Discussion

The main finding of this study was that digital clinical photographs are inferior compared to a risk questionnaire when used for identifying individuals with caries treatment needs and with clinical examination as the gold standard.

Combining the outcome of digital imaging and the questionnaire improved the sensitivity in detecting restorative treatment need compared to imaging alone.

It has previously been shown that neither clinical examination nor photography can detect interproximal or precavitated carious lesions. In both situations, a radiograph is needed to find caries lesions [14]. With clinical imaging, it is difficult to detect small carious lesions or differentiate artefact spots from real lesions, and often, only the occlusal surface is visible in the photograph. If the quality of the photographs is poor, it degrades the quality of diagnosis [15]. These findings are in line with the present study.

Photographs are rarely used for diagnosis in dentistry even though the use of digital images has increased in recent years. In a systemic review article, it was discovered that photographs have at least equal diagnostic accuracy for occlusal caries and reliability compared to traditional visual examination [15]; for instance, digital imaging allows a reduction in monitoring initial lesions. In this study, both daylight and fluorescence photographs were taken. Fluorescence images were taken but not used in the analyses. Annotation was conducted in chronological order in pairs where normal images came first and fluorescence images second. Therefore, the fluorescence images did

not bring any additional diagnostic value when analysing the images since the daylight photographs were much easier to access. However, fluorescence images can increase the diagnostic value of individual photographs.

According to Cohen's kappa, the reliability between Dentocam pictures and clinical status was only at moderate level. To achieve better reliability, the quality of the images should be greatly improved. In this study, only 1, 2, and 4 tooth surfaces could be used as comparable surfaces between clinical status and Dentocam photographs. If better and more accurate photographs of the dental arch and dentition cannot be obtained, assessment of the need for restorative treatment at individual level will not yet be possible by using AI. In addition, AI would require a huge number of patients agreeing to both clinical examination and digital imaging.

Because of saliva in tooth fissures, framing of the picture or exposure error, it was not possible to analyse all teeth in every picture. To get a reliable overall picture of the whole dentition, it would be ideal if these sources of error could be eliminated. Drying the surfaces of the teeth could increase the diagnostic value of the images as well as enable faster diagnosing. The drying could be done by using absorbent paper or by blowing air on the occlusal surfaces of the teeth. It is also important to keep the imaging simple. If the imaging is complex and the health kiosk difficult to use, patients might not be interested in using them. In the present study, it took more than six minutes to take five pictures. The next step in developing dental heath kiosks would be to find a balance between the quality of images and ease of use. Overall daylight images reveal lots of information about oral hygiene (dental plaque), dental calculus and erosive tooth wear, all of which tell something about individuals' health behaviour. It is well known that health behaviour is closely associated with dental caries and periodontal diseases. Other findings from the images are not investigated in the present study.

It was quite promising that a set of questions gave a moderate outcome for screening patients for restorative treatment need, better than that by digital imaging. The participants also received feedback according to their responses; how this affected their health behaviours would be an interesting topic for research. Questionnaires are easily administered online and should be considered in general dental practice for promoting homecare.

There is a need for a non-invasive diagnostic method that could be used without seeing a dentist. According to Armfield & Heaton (2013), approximately one in seven people suffer from dental anxiety [16]. Those suffering from dental anxiety often avoid going to the dentist, which can lead to

poor oral health. Several delays in seeking treatment may result in worsening problems in the dentition that require more intensive and invasive treatment. This health kiosk concept could lower the threshold to seek treatment, especially for patients who are afraid to go to the dentist and do not have regular recall appointments. Finnish public dental care has a legal obligation to treat all patients who need emergency dental care. This can lead to long waiting lists due to limited resources. In particular, the provision of dental care to adults is not sufficient, and most units recall only young patients [17]. If young patients could use the health kiosk instead of seeing a dentist, more dental resources could be targeted at adults, and more specifically, at the growing elderly population. Images taken in the health kiosk and saved in the patients' health record system offer dental professionals a possibility to follow up their caries status even without an appointment. Young people such as the study population are a good target group for treatment need screening because they have had less restorative treatment than older individuals and lesions are thus easier to find by using clinical images. Clinical images also offer patients information about their overall oral health status which might motivate them to take care of their own oral health.

Artificial intelligence is constantly evolving [18]. In the future, it is possible that the images and development of caries could be analysed by a computer programme instead of a dentist. This is the first study developing the dental health kiosk concept, a small step towards utilising artificial intelligence in dental care.

The number of subjects was quite small, which is why this study is considered a pilot study. The participation rate was also low; however, this should not have any effect on the results due to the nature of the study. A larger group of subjects would be needed so that the results could be generalised, specifically if AI or machine learning were to improve.

It can be concluded that digital imaging is a less accurate method for caries diagnostics than age-specific risk questionnaire. Further research is needed to develop the camera systems.

Disclosure of interest

The authors report no conflict of interest

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Table 1. The ten questions included in the questionnaire.

1. Do you think you need dental treatment?
   a. No
   b. Yes (+)
2. Have you had your teeth restored?
   a. No
   b. Yes (+)
3. Your education?
   a. University
   b. General upper secondary
   c. Vocational with upper secondary
   d. Vocational (+)
   e. Basic education (+)
   f. Other (+)
4. How often do you brush your teeth?
   a. Every day or almost every day
   b. Sometimes during the week (+)
   c. Never or almost never (+)
5. Do you smoke?
   a. No
   b. Yes (+)
6. Do you find visiting a dentist scary?
   a. Not at all
   b. A little (+)
   c. Very much (+)
7. How long ago did you visit oral hygienist or a dentist?
   a. < 1 year
   b. 1-2 years
   c. 3-4 years or more (+)
   d. I don´t remember (+)
8. Do you skip brushing because you feel tired or you don´t feel like brushing?
   a. Never or almost never
   b. Every day or almost every day (+)
   c. Sometimes during the week (+)
9. Did you visit the dentist last time because of toothache?
   a. No
   b. Yes (+)
10. How many € do you spend weekly on snacks (products like fizzy drinks and sweets?
   a. 0-5 euros
   b. > 6 euros (+)

Table 2. The patients' feedback according to their risk points.

Patient's risk level	**The feedback**
Risk level 0 (0-1 risk point) 19%, n=4	*Great! There is probably no restorative treatment need in your dentition. Based on your answers, your health habits also favour the health of your teeth and gums. However, regular tooth examinations are important so a dentist´s examination within two years is worthwhile.*
Risk level 1 (2-4 risk points) 52%, n=11	*It is possible that you have a restorative treatment need in your dentition. If there is more than a year since your previous visit to dental care, a dentist's examination within six months is worthwhile.*
Risk level 2 (5 risk points) 19%, n=4	*It´s probable that you have a need of restorative treatment in your dentition. A dentist´s examination within six months is worthwhile.*
Risk level 3 (> 5 risk points) 10%, n=2	*It´s extremely probable that you have a need of restorative treatment. A dentist's examination as soon as possible is worthwhile.*

Table 3. Distribution of patients based on dentine caries. The table shows the number of patients out of the total 21 who had any number of dental caries lesions (0–4) in each of the tooth groups.

	Molars	Premolars	Canines	Incisors
DT	**n (patient)**			
0	14	16	20	19
1	2	2	0	0
2	2	1	1	1
3	2	1	0	1
4	1	1	0	0
Total	21	21	21	21

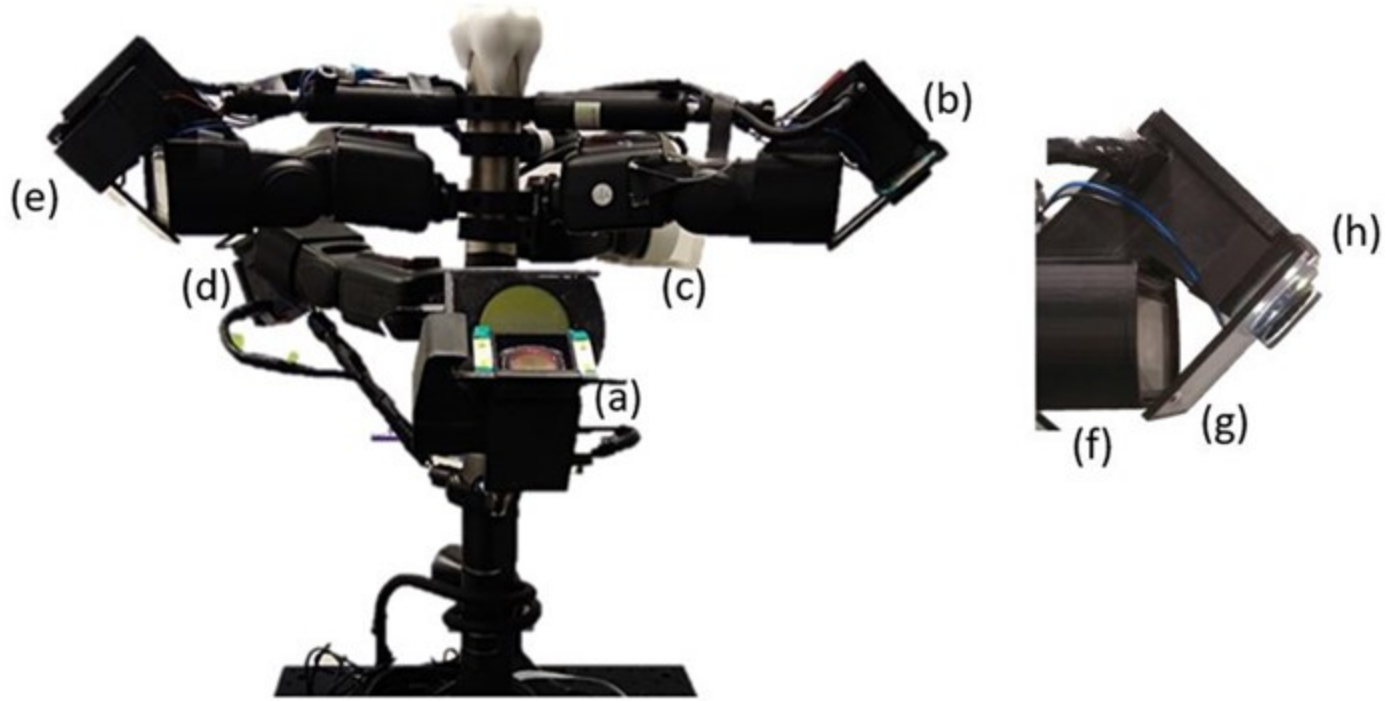
Figure legends

Figure 1. Clinical photographs: a) upper dental arch b) lower dental arch c) fluorescent upper dental arch d) fluorescent lower dental arch e) front view

Figure 2. Camera system consists of five cameras: a) upper arch camera, b) lower arch camera, c) frontal teeth camera, d) fluorescent upper arch camera, e) fluorescent lower arch camera; the figure on the right shows the parts; f) flash, g) protective plate and h) mechanical positioning guide and fan. From left to right: photographing of upper dental arch, lower dental arch and from the front view. These photographs are demo images taken in the laboratory. The chin rest that was used in the actual imaging is missing.

Figure 3. The ROC curve: clinical status about the need of restorative treatment to the Dentsaver (both DentoCam and DentoGram) results.


a)
b)
c)
d)
e)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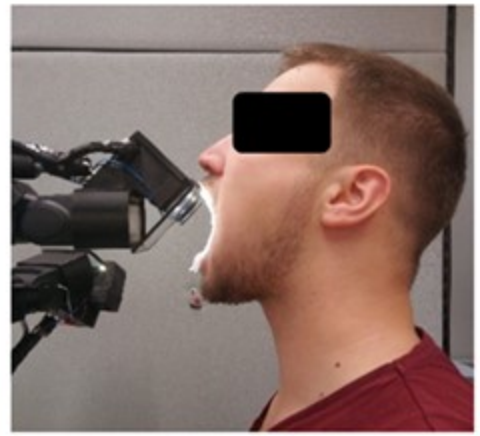

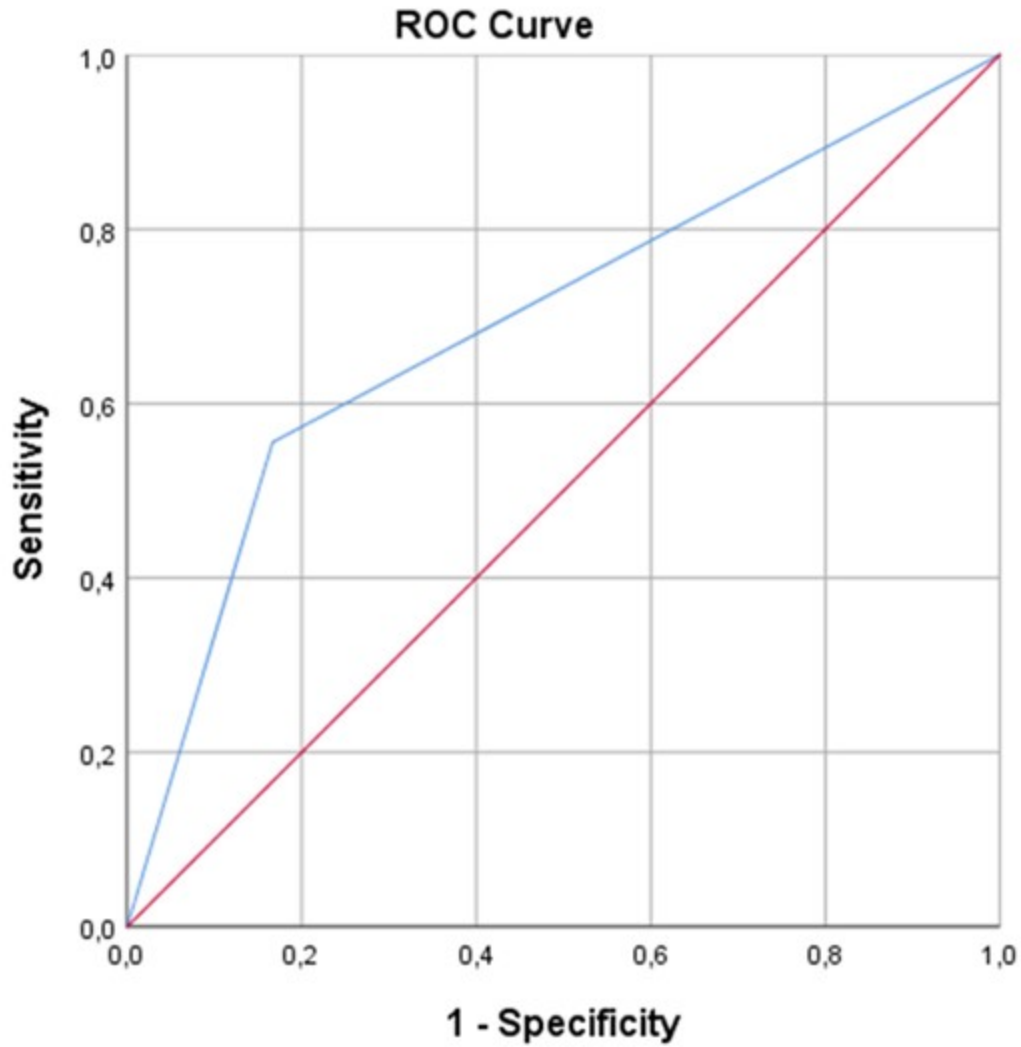

Diagonal segments are produced by ties.