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DENTAL IMPLANT IDENTIFICATION THROUGH RADIOGRAPHIC IMAGES
SUBTITLE: IDENTIFICATION OF DENTAL IMPLANTS BY X-RAY

IDENTIFICAÇÃO DE IMPLANTES DENTÁRIOS ATRAVÉS DE IMAGENS RADIOGRÁFICAS
IDENTIFICAÇÃO DE IMPLANTES DENTÁRIOS PELO RAIO-X

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RESUMO

A identificação de implantes dentários por cirurgiões-dentistas é uma difícil tarefa e essa pode ser realizada a partir de imagens radiográficas e também utilizando as medidas morfométricas dos implantes para complementar essa identificação. Dessa maneira, este estudo tem como principal objetivo comparar as medidas reais de implantes dentários com suas medidas radiográficas digitais para assim estabelecer suas respectivas correlações com o uso de um *software* específico. O estudo foi realizado com seis tipos de implantes de cinco fabricantes diferentes, com diâmetro da plataforma variando de 3,5 a 4,6 mm e comprimento variando de 8,5 a 14 mm, que foram medidos com um paquímetro digital. Os implantes foram radiografados com as radiografias periapicais em três angulações diferentes, zero, vinte e quarenta graus em relação ao plano do objeto. Junto a uma esfera de aço adotada como padrão de calibração radiográfica. Assim, as radiografias periapicais obtidas foram medidas por meio de um *software* específico desenvolvido. Essas medidas obtidas foram comparadas, então, com as medidas reais dos implantes dentários. Os resultados mostraram que a comparação das medidas das plataformas dos implantes com as medidas de suas imagens em diferentes angulações não resultou em diferença estatística. Com a calibração horizontal das imagens, as comparações entre as medidas dos comprimentos a 20 e 40 graus e as medidas dos implantes foram estatisticamente significativas. A comparação entre os comprimentos dos implantes e suas imagens, realizada com o sistema calibrado verticalmente, não revelou diferença estatisticamente significativa para nenhuma das três comparações angulares. O *software* apresentou medições precisas nas variações angulares em relação ao implante, comprovando que embora o paralelismo seja importante, ele não é indispensável na identificação dos implantes.

Palavras-chave: Implante dentário; Radiografia periapical; Prótese dentária

ABSTRACT

The identification of dental implants by clinicians may be achieved through morphometric measurements and may be used in the field of forensic dentistry. This study compares the real measurements and the measurement of digital radiography of dental implants to establish their respective correlations with the use of software. The study was performed with six implants from five different manufacturers. All images were obtained using dental films with different angles. Thus, the dental films were measured using a specific software developed. These measurements were then compared with the dental implant measurements. The results showed that the comparison of the measures of the platforms of the implants with the measures of their images at different angulations resulted in no statistical difference. With the horizontal calibration of the images, comparisons between the measurements of the lengths at 20 and 40 degrees and the measurements of the implants were statistically significant. The comparison between implant lengths and their images, performed with the system vertically calibrated, did not reveal a statistically significant difference for any of the three angular comparisons. The software presented accurate measurements in angular variations in relation to the implant, proving that although parallelism is important, it is not indispensable in the identification of implants.

Key-words: Dental implant; Periapical radiograph; Dental prosthesis

INTRODUCTION

Recently, rehabilitation with implants has been increasing. The different types of implants available in the current dental market have various connections and models. When the dentist starts a prosthetic rehabilitation, the identification of the implant model becomes a challenge when there is no previous documentation of these implants that were installed in the patient.[1] Furthermore, in forensic dentistry, the identification of implants through radiographs can be decisive in the recognition of victims, due to their high specificity and easy application.[2]

After clinical evaluation, periapical radiography is commonly used to examine patients with osseointegrated implants[3], due to it is a practical and low-cost method.[4,5] However, many implants have similar radiographic images, which makes their recognition difficult. Some studies were carried out to evaluate the possibility of identifying implants already installed through radiographic images. The visual comparison methodology is not standardized and is highly subjective. [2,10]

Periapical radiographs can help in identifying the different types of dental implants. However, dentists must be familiar with implants and radiographic imaging to use radiographs for implant identification. So, radiographic features vary in different implants due to differences in design, and their radiographic images are influenced by rotation in the mandible and projection factors.[11]

Variations in radiographic images of implant bodies at different horizontal rotations and vertical inclinations to the radiographic beam and film can be attributed to different implant designs. This variability means that clinicians would have to be familiar with all possible images of an implant before they could use radiographs to identify it.[3] Thus, some studies have been performed to evaluate the possibility of identifying implants through radiographs. Although a plausible question, the methodology of visual comparison is not standardized and is highly subjective. [5,12,13]

The present study aims to evaluate a simple and easy to use technique that can provide precise measurements of implants installed through radiographic images. It consists of including a radiopaque stainless-steel ball of known size on the occlusal surface of the implant or crown if it is still present and irradiates both the implant and ball.

If the image was produced digitally, then the software of the digital company can calibrate the image, but if a conventional film was used, the film could be either digitally photographed or scanned and calibrated using a software such as Photoshop.[4] Thus, radiographically determined dimensions of implants could be compared to those informed by manufacturers to confirm if implants are similar to those installed by the dentist.

The purpose of this study was to compare the measurements of dental implants with the measurements of their digitalized radiographic images, to establish a correlation, and validate a method to help in identifying implants.

SUBJECTS AND METHODS

Six implant models from five different brands were utilized, featuring platform diameters ranging from 3.5 to 4.6 mm and lengths from 8.5 to 14.0 mm (Table 1).

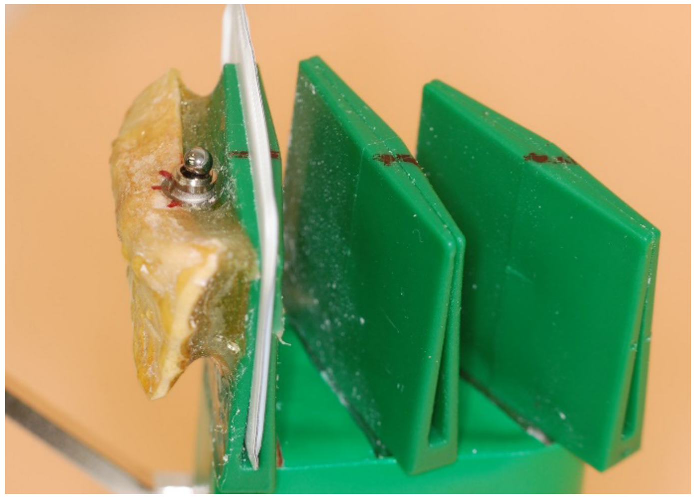
Table 1: Implants systems (n = 6)

MANUFACTURERS	Model	CONECTION	MANUFACTURERS COMPANIES
Titanium Fix	NP 310	External Hexagon	AS Technology Componentes Especiais Ltda. ME
3i	NT410	External Hexagon	Biomet 3i do Brasil Ltda
IMZ	-	External Hexagon	IMZ Implant System Inc.
Thomenn	SPI®Element	Internal Hexagon	Thommen Medical AG
Neodent	Alvim II	Cone Morse	Neodent Implante Osteointegrável Ltda
Titanium Fix	CM 411	Cone Morse	A S Technology Componentes Especiais Ltda. ME

Platforms for six implants of each model were measured six times with a digital caliper (Mitutoyo, model CD-6 '' CSX-B, serial number 500-196-20B, Mitutoyo Sul Americana Ltda.; São Paulo, SP, Brazil) with a resolution of 0.005 "/ 0.01 mm, accuracy of ± 0.001" /0.01mm and reproducibility of 0.005 "/0.01 mm. After each measurement, the caliper was reset to zero to perform a new measurement. Measurements were performed in a room with a controlled temperature of 68°F/20°C.

After measurement, implants were positioned into a socket in an apparatus specially designed to standardize the position of implants related to X-ray film. The socket was attached to an X-ray cone positioner (FPX reto model, Fabinject Indústria e Comércio Importação e Exportação Ltda.; SP, Brazil), with film inserts in three different horizontal angles: the first for the acquisition of images applying the parallelism technique, with the cone perpendicular to the implant to produce the smallest possible magnification of the image [14-17]; the second with a horizontal angulation of twenty degrees, according to Clark's modified technique [10,11]; and the third with a horizontal angulation of forty degrees in relation to the first, to simulate different positions of the implants in relation to the X-ray (Fig. 1). The distance from the implant to X-ray film was 13 cm.

Figure 1: Specific radiographic apparatus



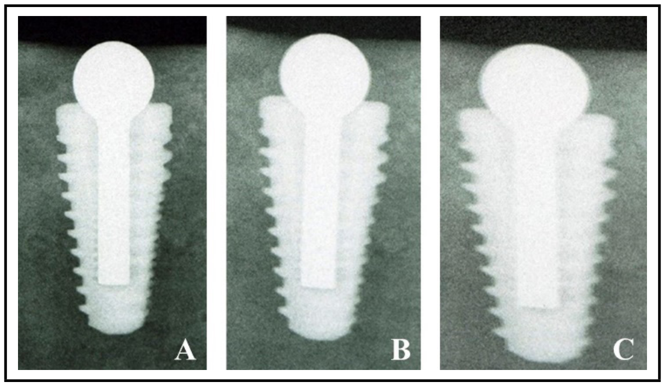
In order to reproduce actual conditions, a 5 mm thick mandibular human bone cortex blade was positioned between X-ray and implant socket. The use of human bone was approved by the Ethics Committee and Research of the University Hospital, protocol number 1853.

Before irradiation, a 3 mm stainless steel ball with a rod of 6 mm length (Só Esferas Comércio de Esferas Ltda.; São Paulo, SP, Brazil) was introduced inside screw thread of implants to be used as a reference for the calibration of the digital measures.[15,18]" (Fig. 2) Radiographic images were taken with three films positioned on different angles at the same time.

Figure 2: Calibration pattern and implant

The film used was DFL Contrast DV-54 size 0 (22 x 35 mm) (DFL Industria e Comércio SA.; Rio de Janeiro, RJ, Brazil), with exposure of 0.5 s at 70kVp, 10 mA, using a Spectro 70X X-ray generator (Dabi Atlante; Ribeirão Preto, SP, Brazil). Film processing was performed with an AT 2000 XR automatic processor (Air Techniques Inc; Hicksville, NY, USA), with a total dry run time of 8 minutes, using Kodak developer and fixative solutions (Kodak; Rochester, NY, USA). After they were processed, the radiographs were scanned with a 2900 dpi film scanner (CoolScan IV ED, Nikon; USA). Examples of radiographic images obtained at zero, twenty, and forty degrees are shown in Fig. 3.

Figure 3: (A) Alvim II – Neodent: Image with 0° of horizontal angulation; (B) image with 20° of horizontal angulation; (C) image with 40° of horizontal angulation



Initially, software was calibrated through the measure of the digitalized image of the ball in the same direction of the implant platform. Then, the implant platform's width was digitally measured to be compared with actual dimensions taken previously. Then, the implant length of two implants (3i NT410 and Titanium Fix NP 310) was measured, keeping the same horizontal calibration.

On sequence, the software was re-calibrated vertically and the same two implants were measured in the vertical direction.

RESULTS

Actual and digital measurements of implant platforms are presented in Table 2. Data were analyzed with SPSS 22 Statistic software (IBM; Armonk, NY, USA), using one-way analysis of variance (ANOVA) with the level of significance set to 0.05.

Table 2: Implant Measurements (with a digital caliper) and of respect images, with standard calibration in the horizontal direction

IMPLANTS MEASUREMENTS AND ITS IMAGES (mm)				
MANUFACTURERS/DESIGN	IMPLANT PLATAFOM	IMAGE		
		0	20	40
3i/NT410	4,04 ± 0,00	4,03 ± 0,02	4,06 ± 0,03	4,03 ± 0,01
NEODENT/Alvim II	4,30 ± 0,00	4,29 ± 0,02	4,31 ± 0,02	4,35 ± 0,01
Titanium Fix/CM411	4,77 ± 0,00	4,77 ± 0,01	4,84 ± 0,01	4,80 ± 0,02
IMZ	4,04 ± 0,01	3,99 ± 0,01	4,02 ± 0,02	4,05 ± 0,02
Titanium Fix/NP310	3,50 ± 0,00	3,50 ± 0,00	3,48 ± 0,02	3,49 ± 0,02
Thomenn/SPI®ELEMNT	4,60 ± 0,01	4,60 ± 0,01	4,63 ± 0,01	4,62 ± 0,01

The results showed that the comparison between the measurements of the implant platforms and the digital measurements of their radiographic images at zero, twenty, and forty degrees, performed with a previous horizontal calibration, did not reveal statistically significant differences ($p < 0.05$).

Comparison between the measurements of implant lengths in orthogonal radiographs and at 0° showed no statistically significant difference. Comparisons between the measurement of the lengths at 20 and 40 degrees and the measurements of the implants were statistically significant ($p = 0.015$, $p = 0.001$, respectively) (Table 3).

The comparison between the actual implant lengths and their digitalized images, performed with the system vertically calibrated, did not reveal statistically significant differences for any of the three angular comparisons ($p > 0.05$) (Table 4).

Table 3: Length measurements implant comparisons and your images with horizontal standard calibration. Images percentage variation according to the implant length.

DATE	Implant NP 310 Mm	Percentage variation	Implant NT 410 Mm	Percentage variation
Implant	10.00±0.0		10.25±0.0	
0° image	10.04±0.01	-0,40%	10.18±0.02	0,68%
20° image	9.39±0.01	6,47%	9.59±0.01	5,80%
40° image	8.22±0.01	12,46%	8.44±0.0	11,99%

N=8

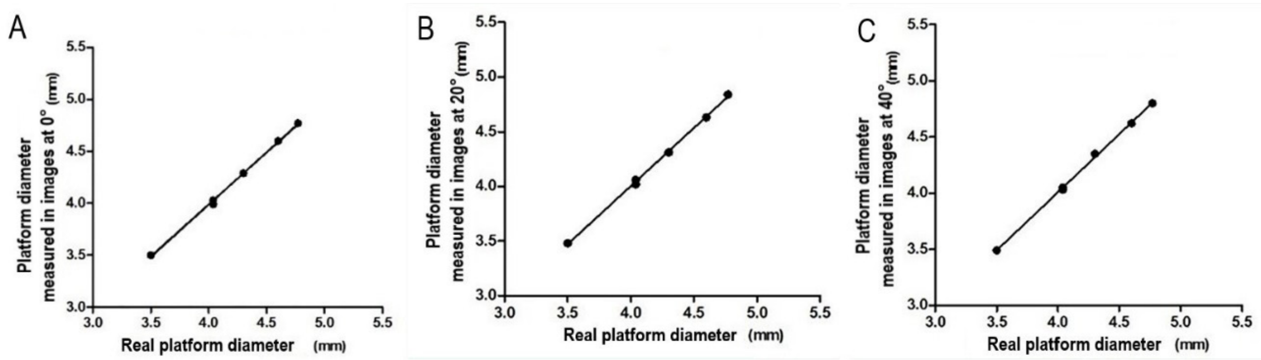
Table 4: Length measurements implant comparisons and your images with vertical standard calibration.

DATE	Implant NP 310 Mm	Implant NT 410 Mm
Implant	10.00±0.0	10.25±0.0
0° image	10.02±0.01	10.18±0.02
20° image	10.04±0.01	10.17±0.0
40° image	10.01±0.02	10.18±0.0

N=8

The correlation between the actual measurements of the implant platforms and the measurements of their X-ray images at zero, twenty, and forty degrees angles was established using GraphPad Prism version 4.00 for Windows software (GraphPad Software; San Diego, CA, USA). The Pearson Linear Correlation test revealed that the established correlation was positive and significant: Image A at 0° ($r = 0.9983$), ($p = 0.0001$); Image A at 20° ($r = 0.999$), ($p < 0.0001$); Image A at 40° ($r = 0.9987$), ($p < 0.0001$) (Fig. 4).

Figure 4: (A) Correlation between the measurements of the platforms and the measurements at 0°; (B) Correlation between the measurements of the platforms and the measurements at 20°; (C) Correlation between the measurements of the platforms and the measurements 40°.



DISCUSSION

The main objective of the present study is the acquisition of periapical radiographs, their digitization, and the use of a program dedicated to the measurement of digitized radiographic images. The apparatus used to acquire the images was based on several studies. [1,9] The bone specimen allocated under the implant site aimed to simulate a clinical situation of bone installation. [8,9]

The results of the study consist of objective data, with well-defined reproducibly parameters. Therefore, it not intends to eliminate visual comparison as a form of evaluation [7,8,19], since all the methods share a need to access a wide database with the manufacturer's information, but aims to emphasize the advantages of using measurements taken from digital images to guide practitioners in identifying implants. [4,12]

Dental radiographs are the most effective means in the daily clinic to identify different types of dental implant systems, and there is currently limited research on methods that allow easy identification of dental implants.[21] Although dental radiographs are one of the main means of identifying implant systems, it is still difficult to distinguish similar systems through radiographs. In addition, many professionals with little experience in the field have difficulty distinguishing between these different systems.[22]

However, only the experience of the evaluator and a database of images are decisive enough to successfully identify dental implants.[10] In order to arrive at a conclusion with the method of visual comparison, it might be necessary to acquire more than one radiograph at different angles and inclinations to identify an implant. On the other hand, with software that allows us to measure the characteristics of a dental implant, only an x-ray and a combinatorial analysis of the database is needed to identify the dental implant. [4,12]

In the present study the arrangement of the components of the apparatus ensured that in the orthogonal radiographic shots the central X-ray beam was perpendicular to the long axis of the implant and, therefore, to the film, generating images with the least possible distortion. [14,16,17] Radiographic shots with 20 and 40 degrees of angulation simulated limitations and variations in the acquisition techniques of the images. [1,14,15,18]

In a 1991, a study was performed in which samples were radiographed in a vertical projection at an angle of 0° and at an angle of 15° and then at -15° and at third rotation cycle (0°, 45°, and 90°) for identifying different implants in different angulations. [20]

As in the study in 2008 [5], digital radiographs were taken of Italian implants. These radiographs were taken at 0°; horizontal rotation of 30° and 60°, combined with -20°, -10°; and vertical inclination of 0°, +10° and +20° in relation to the radiographic beam and the X-ray sensor, varying the radiographs at different angles to carry out the identification of dental implants.[2]

According to different studies [4,12,17,18], as well as the results found in the present study it can be stated that the strict focus-object-film parallelism does not seem to be necessary to evaluate the characteristics of the images, not even to compare the measures of implants' platforms. This can be ascertained since there was no statistically significant difference in the comparison between the measurements of the implant platforms and their images.

It was observed in the present study that, in images obtained at 20 and 40 degrees of horizontal angulation, the measurement varied up to 12% in length. This alteration can lead to difficulties in determining actual implant length. However, there was no significant difference between 0 degree images and implants. It is also worth noting that 20 degrees is the angulation used to obtain radiographs in the Clark technique [14]. Concomitantly, it was observed that there is no standardization in the distances between focus, object, and film in the studies that adopt the parallelism technique.

Considering that implants require continuous monitoring, depending on the peri-implant tissues and prostheses [2,16], the results of the present study provide new applications for the program. In addition to the identification of implants, the Implant Meter 1.0 can be used in longitudinal studies of bone loss measurement, where the most used form of evaluation is the image subtraction technique, which requires a rigorous coincidence of the positioning of the radiographed structures, so that certain points can be superimposed and changes diagnosed in the comparison of digitized images due to differences in gray tones. [3,17]

The limitations of the present study were the possible variations in the density of the films as well the limitation of the number of implant systems that were evaluated. However, the measurements performed through software and radiography can help dentists to identify dental implants. Few studies are found using the measurement of dental implant sizes, and most studies describe only the identification of implants through periapical radiographs at different angulations. So, more studies are needed to continue developing techniques to perform the identification of dental implants.

CONCLUSION

The measurements of periapical radiographs with a pixel-based measurement software were precise enough to be performed at variations of up to 40 degrees when calibrated in the same direction as the standard, showing that parallelism is important but not indispensable when using x-ray images for the identification of implants.

Images obtained at zero, twenty, and forty degrees of angulation did not show appreciable distortion among themselves when calibrated in the same direction of the pattern. The correlation between the actual measurements of the implant's platforms and the measurements of their x-ray images at zero, twenty, and forty degrees angles was positive and significant.

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