RADIOLOGY & PHOTOGRAMMETRY

Photogrammetric Principles as Applyed in the Periapical Intra-oral Radiology: an evaluation of the accuracy and method reproducibility

Fotogrametria e Radiologia- Princípios fotogramétricos quando aplicados a radiologia periapical intra-oral: uma avaliação da acurácia e reprodudicidade do método

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ABSTRACT

The objective of this study was to evaluate the accuracy and reproducibility of photogrammetric principles and techniques over periapical radiographic images. Twelve stereoscopic radiographic pairs were obtained by means of an Auxiliary Aiming Device (AAD) fixed to a human jaw. The best angle of convergence to allow stereoscopy was verified to be 20°. The radiograph images were digitalized on a photogrammetric scanner and the data transferred to a computer memory. For each pair of images, ten readings of the coordinates of a same point were recorded. The precision obtained for the measurements of X, Y, Z coordinates were respectively 3 μm, 3 μm and 18 μm. The reproducibility of the experiment was possible due to the high rigidity and stability of the device created to hold the X-ray instrument in the right position. The method shows to be high accurate for radio-diagnosis in three-dimensional periapical radiographic images.

UNITERMS: diagnosis in radiology for X-rays stereoscopic vision

INTRODUCTION

Photogrammetry is defined as the art, science and technology to obtain reliable information of objects through the registration, measurement and interpretation of stereoscopic images[1]. To apply the principles of Photogrammetry over a particular kind of image it is necessary either that the image shows the same geometry as a photographic image or to be possible change the given geometry into that of Photogrammetry. The former statement was the used in this research, were the images result from the exposure of special film by convergent beams of X-Rays. Once such transformation is performed, all the tools of Photogrammetry are available.

The binocular or natural stereoscopic vision is one of the basic physical principles of optics for the depth perception. Three dimensions perception is possible due to the disparity among the images formed on the retinas of the right and left eyes due to the distance between the centers of perspectives called inter-pupil distance. These different images are processed and converted by the brain as to depth information. Therefore, the stereoscopic images are called to be homologous because are images of the same object but taken from different perspective centers.

The measurement of the three-dimensional images is executed with a system of coordinates arranged in the three-dimensional space on axes X, Y and Z. Each point in the three-dimensional space has its position defined by three coordinates on the given reference frame. Therefore this system allows every point in the space to be positioned through its coordinates.

In a stereoscopic model, the measurements are coordinates of selected points in the surface of the object model. Therefore to obtain the distance between a pair of points, for example, it is sufficient to compute the required distance as a function of the coordinates of the given points.

The computer screen show points arranged on a matrix form where each one can be designate by its line and column.

The technique showed in this paper aims to provide the radio-diagnosis with accurate measurement of coordinates of points defining the object model. By repeating measurements along the time it becomes possible to detect and compute motions and deformations.

The objective of this study is to evaluate the accuracy and the capability of the method to repeat measurements with images taken along the time.

MATERIALS AND METHODS

Obtaining Stereoscopic Images Through Radiographs

3D AUXILIARY AIMING DEVICE (AAD)

To obtain stereoscopic images through radiographs it is necessary to build an Auxiliary Aiming Device - the FHBG (film holder and beam guide) in order to guarantee the correct position of the radiographic film and the orientation of the X-Ray beam. For the experiments described here, this device was built in acrylic material by one of the authors, Miss Helena Keil. It consists of a support for the radiographic film, an occluding guide and an arm. The arm has a fixed length of 40cm. In its free extremity, there is a guiding ring where the long cylinder of the X-ray equipment is connected, maintaining the x-ray beam directed to the film support on the fixed extremity. This arm allows the adjustment of horizontal angles of the central ray of the X-Ray bean. The angles for the stereoscopy were fixed in ten degrees to the right and ten degrees to the left with respect to the perpendicular taken from the film holder plane, resulting in a convergent angle of 20°.

Four fiducial marks were inserted in the film holder of the FHBG device. These marks are bulkheads situated in the surface of the support of the film to be recorded by the exposition to X-ray (Fig.1). Those marks materialize system of fiducial coordinates and must be calibrated in order to correct film shrinkage.

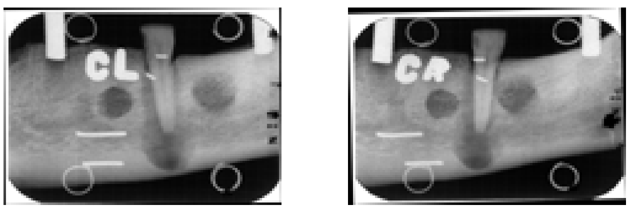
THE OBJECT FOR STEREOMETRIC ANALYSIS

The object used for these experiments was an edentate human jaw. It was submitted to the implantation of an inferior incisor and to the confection of two sockets at the level of first pre-molar and the molar in the left side of the body of the jaw. To support the FHBG device and allow later reproduction of its position, two screws were inserted in the occlusive surface of the alveolar edge.

X-RAY EQUIPMENT

The X-ray equipment used for the radiographic expositions was a Siemens (Heliodent 60B, 60 kVp, 10 mA). This equipment has a long spacer cylinder 16 cm long and coated with 1 mm of lead blade. The film used was the Kodak^{TM} Insight periapical dental film. The processing of the radiographs was made with revealing and fixing liquid of same brand of the film. A preliminary study to test different exposition times was carried out with the objective of reaching a satisfactory contrast such that the fiducial marks results visible under direct exam of the radiographic images (Fig.1). Therefore, the procedure was: exposition time of 0,25 seconds; manual developing of the radiographic films made under a temperature of 26 ºC, revelation time of two minutes, intermediate washing in running water by a period of 30 seconds followed by four minutes of fixing and final washing in water during ten minutes.

Fig. 1. Stereoscopic model C



To get a stereoscopic model, firstly, the radiographic film was placed in the support of the film and the arm of the FHBG device was positioned with horizontal angle to the angle of -10^0 (10^0 to the left) and the first exposure was made. This procedure allowed creation of the left eye image. The device was connected to the jaw with screws and fixed by two nuts conferring constant vertical alignment to the system. To follow, a new film was placed on the FHBG and the X-ray equipment was adjusted to the guiding ring of the FHBG for an angle of 10^0 to the right and the film was exposed to the X-ray. This way the radiographic image for the right eye was obtained. To simulate clinical situations, disband of all the set was made for the exchange of the film and concomitant repetition of the process. The qualitative evaluation of the stereoscopic models was carried out by method of indirect visualization with the aid of a table of light associated with a pocket stereoscope OPTO EB-1 AVR™.

SAMPLE AND IDENTIFICATION OF RADIOGRAPHIC IMAGES

Twelve stereoscopic models were made. Each radiographic image received two identification marks consisting of a letter and/or number to name the stereoscopic pair and a second letter to discern between right (R) or left (L) image.

OBTAINING DIGITAL RADIOGRAPHIC IMAGES

Digital images were obtained by indirect method[2] using the RM-1 Rastermaster photogrammetric scanner - a Photo-scanner property of the Photogrammetric Companies ENGEFOTO, AeroImagem and AeroSul. RM-1 Rastermaster is a precision photogrammetric scanner, with 12 micrometers of radiometric resolution and 1 micrometer of geometric resolution. This instrument makes the transformation of an analogical image into a digital one. Its accuracy is due to the linear encoders capable to measure x and y orthogonal coordinates within 1 micrometer. Twelve stereoscopic radiographic models were digitized at a time with a resolution of 2116 dpi (dot per inch- pixels representing 12 micrometers). Later each radiographic image was cut off from the main file and stored in a specific image file for each stereoscopic model. Following, each pair of images, after oriented, was stored in model files.

DIGITAL IMAGES MANIPULATION

The Adobe Photoshop software was used for radiometric treatment of the images to provide best contrast to the fiducial marks (Fig.1) and the best quality for the entire image. This radiometric treatment was carried out in the file of each stereoscopic model allowing the reading of the coordinates of the fiducial marks on the screen reference frame to provide the internal orientation of the images.

Adjustment of the system

OBJECT COORDINATE REFERENCE SYSTEM

The object coordinate system has its origin in the point of intersection of the central ray from the X-ray beam with the plan of the radiographic film. The X and Y-axis lay down on the film plane, Z-axis normal to the film plane and positive towards the source of X-ray beam. The X-axis is parallel to the direction of the two upper fiducial marks 1 and 2, positive towards the sense 1 to 2 resulting a right hand reference system.

The Z-axis goes through the perspective center (PC) and define the position of principal point (pp) of photogrammetry in its intersection with the plane defined

by the film surface where is situated the origin of the Object Coordinate System. The perspective center is also the point origin of the X-ray beam.
This stage aims to compute the perspective center coordinates $X_{0,}$ Y_0 and Z_0 for each x-ray image. This computation is necessary to provide the parameters demanded by the program GeoCompiler developed by Geokosmos, to digitally reproduce the stereoscopic model and to measure coordinates on the Object Reference System to provide stereo-compilation data to a given CAD. The GeoCompiler works on a computer system consisted of PC computer, a system of 3D-view – the NuVision, a 3D-mouse and two screens. The proprietary of this system is ENGEFOTO.

According to the figure 2:

CPL	CPR
$X0L = - F. \sin \alpha$	$X0R = F. \sin \alpha$
$Y0L = 0$	$Y0R = 0$
$Z0L = F. \cos \alpha$	$Z0R = F. \cos \alpha$

The X, Y and Z coordinates of any point of the object space are equated with the corresponding coordinates of the left image xl, yl and the right image xr, yr through the projective equations[1]. The points of the right and the left images are said to be homologous, because they are images of the same point object.

$$xl = f_x (X,Y,Z) \qquad xr = f_x (X,Y,Z)$$
$$yl = f_y (X,Y,Z) \qquad yr = f_y (X,Y,Z)$$
$$zl = f_z (X,Y,Z) \qquad zr = f_z (X,Y,Z)$$

Because the exterior orientation angles for both images are equal to zero, the projective equations are well simplified:

$$\begin{cases} xl = -fl \cdot \dfrac{X - XPL}{Z - ZPL} \\ yl = -fl \cdot \dfrac{Y - YPL}{Z - ZPL} \\ xr = -fr \cdot \dfrac{X - XPR}{Z - ZPR} \\ yr = -fr \cdot \dfrac{Y - YPR}{Z - ZPR} \end{cases}$$

Where:
{xl, yl} are points image coordinates measured on the left image
{xr, yr} are points image coordinates measured on the right image
{X, Y, Z} are points object coordinates

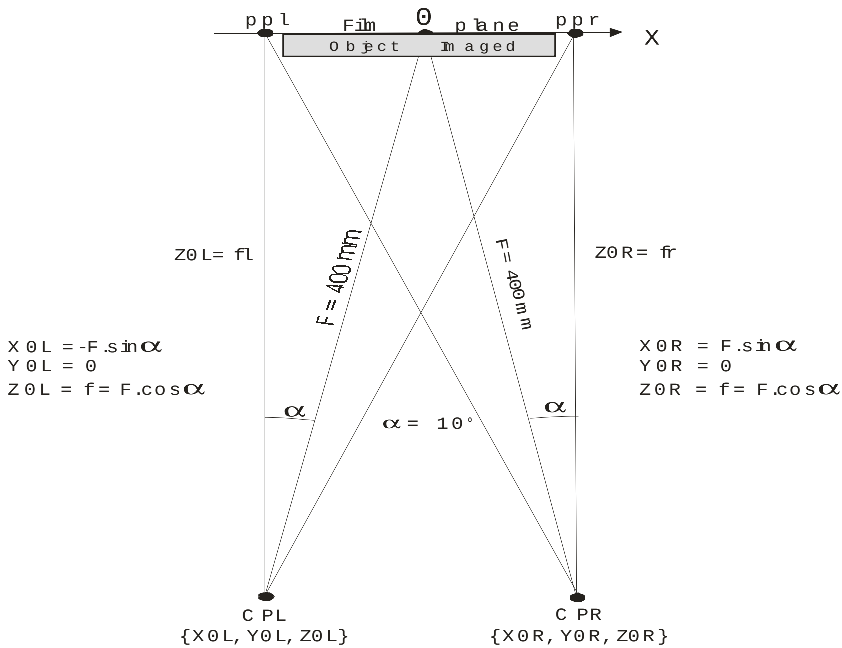
{XPL, YPL, ZPL} are the coordinates of the left perspective center
{XPR, YPR, ZPR} are the coordinates of the right perspective center

The measured quantities on the above equations are the image coordinates of the points in both left and right images. {X, Y, Z} coordinates of object points are the unknowns.

The coordinates of all these points can be measured by a Digital Stereocompiler composed by the GeoCompiler software by Geokosmos, computer hardware, and the NuVision - the device to flip the images on the screen to be seen in three dimensions, showing the pair of homologous images with orthogonal planes of polarized light. It is part of the instrument a pair of glasses with light polarizing filters with planes of polarization orthogonal to each other.

Therefore, to introduce the data in the Photogrammetric Digital Stereocompiler is necessary to have in mind that the x-rays were made from different centers of perspectives and assumed with no convergence of the synthetic "optical axis" as showed in figure 2.

Fig. 2. Geometry Created to Make 3D Radiogram to be Conform with Photogrammetric Models in a Digital Station



The origin of the system of the X, Y and Z coordinates of the object system was defined to be on the support of the radiographic film of the 3D device FHBG on the point defined by the interception of the central ray of the beam with the plane of the film. In this support, the incidence of the central beam was 7,925mm below of the point of average coordinates of the four fiducial marks. This fact happened due to the necessary geometry of the guiding ring of the arm of the 3D device in order to guarantee the corrected direction of the central beam in reference to the film.

CAMERA FILE

The camera file contains the coordinates of the four fiducial marks x_i , y_i (i=1,4) and the principal distances fl and fr (eventually, as in here, fl= fr). Therefore, each camera has its own camera file.

For the X-Ray instrument used in these experiment the X0L and X0R coordinates for each camera are:

For the left camera:

X0L = - F. sin α

X0L = - 400. sin 10º

X0L = - 69,459 mm.

For right camera:

X0R = F. sen α

X0R = 400. sen 10º

X0R= 69,459 mm;

and the principal distances (ZOL and Z0R) are computed as:

Z0L = Z0R = f = F. cos10º

Z0L = Z0R = f = 400. cos 10º

Z0L = Z0R = f = 393,923 mm.

Due to the fact that the distance from the fiducial marks to the surface of the film if different of zero, a parallax angle results displacing its images in the film. The determination of the correct projection of the images of these marks was made from the readings of the stereoscopic model that generated two camera archives. The transformation of the observed coordinates of the fiducial marks to its calibrated values was made by the very well know general form of afine transformation. This transformation was applied to all images points in order to correct film shrinkage. Now the system of measurement is systematic errors free.

DIGITAL PLOTTER

The Engefoto's Digital Plotter used for this experiment was composed by the software GeoCompiler by Geokosmos installed in a microcomputer; a video with frequency of 120 Hertz; the system NuVision for 3D image observation, consisting of a electronic board, a Kerr cell before the screen synchronized by a interchange of images each 1/120 seconds, and eye glasses of polarizing filters to visualize images in three dimensions; one second video to display the compilation, controlled by a Computer Aided Design Software (CAD) named MicroStation developed by Bentley, running on the same computer; and a three-dimensional mouse developed by Geokosmos. The workstation software (GeoCompiler) was designed and written by Dr. José Bittencourt de Andrade and Eng. Reynaldo Bittencourt Souto. The 3D mouse was designed by three persons: Professor Dr. José Bittencourt de Andrade, the mechanical engineer Reynaldo Bittencourt Souto, the technical in electronics Theodoro Paratello Jr. whom projected and constructed the electronics and by the mechanical Engineer Arie Ros whom was also its constructor.

RESTITUTION AND STEREOCOMPILATION

Restitution is defined as the reconstruction of the imaged objeto[1] from its perspectives. The result of the restitution is a stereo-model. The perspectives could be drawings, photographs, X-Ray radiographic images or any other kind of central perspective. Three-dimensional coordinates of points can be measured on a stereo-model on a workstation with software for stereo-compilation such as the GeoCompiler. These coordinates can be transformed to a map projection and transferred to a CAD for drawing purposes.

MECHANISM FOR THREE-DIMENSIONAL VISUALIZATION OF IMAGES IN THE WORKSTATION

In front of the computer screen is placed a Kerr Cell to polarize the light from the screen in a sequence of horizontal and vertical plans of polarization according to the image being stamped on the screen. Left and right images are replacing each other on a rate of 1/120 of second each. It means that each image is showed 1/120 seconds and then the other replaced it for 1/120seconds. The result is that each image is showed for a period of 1/120 second on its own polarization, let say, the left image horizontal polarization an right image vertical polarization. Looking through eyeglasses with filters for polarization, whose planes of polarization are horizontal and vertical, let say for the left eye horizontal polarization and for the right eye vertical polarization, the left eye will see only the left image and the right eye the right image. In this manner, each eye receives on its retina the same image that will be seen on natural binocular view, given the sensation of 3-D.

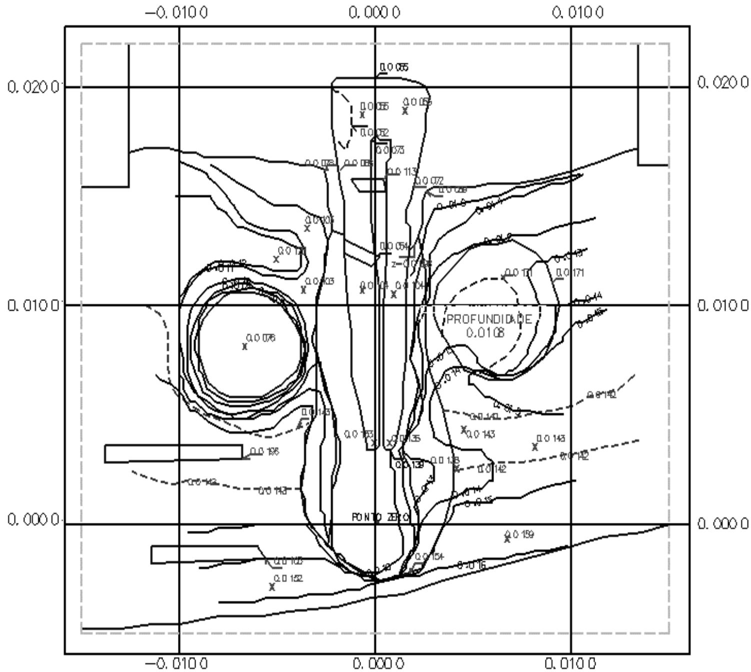
Two stereoscopic images are show on the video. The small one, on the right side shows the entire object and on the left side one image that can be amplified according to the desire of the user. About this image, with the 3-D mouse, the user may navigate through the space with a measuring mark, having the values of the space coordinates on the screen all the time. So, if one makes the measure mark to coincide with a selected point of the 3D image object, he gets the three coordinates of that point.

Any object can be mapped through its stereo-model in a workstation, representing its features in plant projected to a reference plane and curves of equal distance from the same reference plane. The result is a map of the object. (fig.3).

Then, one can define a map as a two dimensional representation of the features of a given object.

The stereo-compilation process is carried out when the user goes on the features to be compiled with the measuring mark. The 3D coordinates of the measuring mark are transformed on a map coordinate system and transferred to a CAD (Computer Aided Design) software to plot it on the screen. The figure on the screen can be plotted later in paper if desired. In the map, contour lines at a desired equidistance interval can be plotted to represent the relief. This operation requires experience, because the user must follow points of the stereoscopic surface with equal Z value. This way, a complete and accurate map of the object can be made, collecting 3-D data.

Fig. 3. Map Compiled on Digital Station from Stereo Model C



The map stereo-compiled can be edited to include more data like the values of Z for the contour-lines, to name special features, to show any other interesting parameters of a map, like title, scale, coordinates of special points and so on.

COMPUTING DISTANCES IN THE STEREO-MODEL.

The well know Pythagoras Theorem says:

$D= [(X_1-X_2)^2+(Y_1-Y_2)^2+(Z_1-Z_2)^2]^{1/2}$.

This formula allows one to compute the distance between two points, given the 3-D coordinates X_1 Y_1 Z_1 X_2 Y_2 Z_2 of the two points.

RESULTS

The standard deviation of coordinates X, Y, Z, of one isolated point as measured in one stereo-model is presented in table 1. The standard deviation of X, Y, Z, coordinates as measured in stereo-models are presented in Table 2. Then, the precision for the measurements of X, Y, Z coordinates, were respectively: 3 μm, 3 μm e 18 μm.

Table 1. Standard deviation obtained from the 10 readings of the coordinates of the same point on axes X, Y and Z are presented in this table.

	Standard deviation of the population		
		Coordinates	
Stereo model	**X** μm	**Y** μm	**Z** μm
8	2	2	25
F	2	3	17
K	2	3	14
N	4	3	30
Q	4	3	29
S	4	3	15
Y	2	4	16
Z	19	2	9
A	2	2	20
C	4	2	10
I	3	2	12
P	3	3	15

Table 2. The standard deviations of the mean coordinates as computed for each stereo-model.

		Coordinates	
	X μm	Y μm	Z μm
Standard deviation of the mean value of the coordinates of points on the stereo-model	3	3	18

The reproducibility of the experiment was obtained: for the use of the 3D auxiliary aiming device, this conferred geometric rigidity and of the three-dimensional space; for the standardization of the coordinates of the same points in all the stereoscopic models.

DISCUSSION

To fuse scientific and technologic principles of two different sciences like radiology and the photogrammetry was necessary to determine a suitable terminology and consequent definitions. Definitions were easily taken to be the same of photogrammetry. With respected to terminology, stereo-photogrammetric roentgen study, roentgen stereometric study[9,10,11] and radioestereometry study[12] were the denominations found in literature for this methodology[5,6,7,8]. Therefore, due to this disparity and tendency in searching a nomenclature to adequately characterize the methodology showed in this paper it was proposed the denomination of radiogrammetry[2,3], because it makes clear the use of photogrammetric technology and principles aiming the analysis and stereometric study of periapical intra-oral radiographic registers using a 3D Auxiliary Aiming Device.

Technical-scientific knowledge about the stereoscopic technique[12,13,14] was rescued locking for its application to radiogrammetry in periapical intra-oral radiology. The stereoscopic technique presents tremendous amount of indications [14,15,16,17], but the difficulties found for its clinical applications[13] with the necessary accuracy[15] made this method of examination to be discussed along the years. In order solve these problems and to allow the production of stereoscopic models a 3D auxiliary aiming device, named FHBG was developed to guarantee the rigidity geometric and of the three-dimensional space.

The obtained accuracy of the results shows that the process is a powerful toll to obtain reliable measurements and very promising to used on remote detection of geometric variations.The values of the coordinates are inside the expected estimated error to measurements on a bitmap. The value of this estimated error is 0,25 pixel, or 3 μm in this case (pixel size of 12 μm). The standard error for Z coordinates (18 μm) exceeded the estimated error due to absence of better geometry, but it is satisfactorily, remembering that the pixel size is 12 μm.

The computed standard deviations for each stereo-model were made aiming the analysis of the presence of systematic errors from the instruments or techniques applied. For this reason, in this study, the FHBG was used.

The standard deviations for X, Y and Z axis in the N and Q stereo-models presents discrepancies which must be further analyzed. In despite its existence, it was possible to execute metric analysis. Therefore, these stereomodels did not show parallaxes. Parallaxes (in Y direction) in stereomodels means displacement of one image with respect to it homologous. Parallaxes, among several other causes, in these experiments, can occur as consequence of the absence of film flatness due to the wrapping process and lack of relative orientation of the stereoscopic pair of images.

Problems, like the movement of the object during the radiographic exposure, are more critical in examinations that submit the patient to long time of X-ray exposure. This does not happen using rationalized times, speed films and only two exposures.

For acquisition of the stereoscopic models, the literature shows the use of 8 degrees[18] of convergence angle, 5 at 6 degrees to right and to left of the tube of the equipment of x-ray in relation to the periapical radiographic film [19,20]. For this study, the selection of an angle of 10^{o}, was made because it allowed a better stereoscopy with visualization of all the details of the object on z axes without surpassing the limited area of the periapical dental film without displacement of the object image outside the area of the film. Also there was no loss of stereoscopy in the adjacent areas to the analyzed object. An important factor to be considered in the stereoscopic radiographs is that the overlapping of anatomic structures does not interfere in the diagnosis. It really allows additional data about the relationship of structures, the determination of spatial position of the object related to a three-dimensional referential frame and the calculus of distances among structures.

It was proved in this research that Photogrammetry is a tool suuitable to be applied on radio-diagnosis and monitoring variations in position and dimensions of objects imaged with X-Ray, since the system of measurement transform the geometry of convergent radiographs into the very well know photogrammetric geometry.

The periapical dental films can be base to fix images to allow analysis of changes in morphology through accurate measurements of three-dimensional coordinates in 3D image model in a digital stereo-compiler.

Due to the use of the 3D Auxiliary Aiming Device is possible to obtain stereoscopic models in clinical practice which must be sent for specialized companies construct the stereo-models, measure coordinates of points whose distance is necessary to evaluate and perform maps. All these material constitute a strong base for analysis on the problem of teeth implantation and correlated problems.

In order to implement still more the radiogrammetry the use the CCDs (Charge Couples Device) to substitute film is very promising and must be experiment.

CONCLUSIONS

- The values of the accuracy of the radiogrammetric method on X, Y, and Z axes, are respectively: 2,690 μm, 2,637 μm and 17,501 μm.
- The reproducibility was possible due to the characteristics of the 3D Auxiliary Aiming Device, which presented geometric and three-dimensional space

rigidity, and by the standardization of the coordinates at the same points for all the stereoscopic pairs.

- The radiogrammetry revealed also to be a high accurate tool to measure structures into a three dimensional reference frame and to prepare maps with contour lines representing the three dimensional form of the imaged object. The contour lines are the geometric place of the points on the object with equal value of Z coordinate.

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REFERENCES

ANDRADE J.BITTENCOURT. Fotogrametria. 1ed. Curitiba (PR): SBEE; 1998.

KEIL, HRO. Radiogrametria. Estereometria aplicada à radiologia intra-oral periapical: avaliação da precisão e reprodutibilidade do método.{dissertation}. Ribeirão Preto (SP): USP.; 2002.

FREITAS A, ROSA, JE, SOUZA, IF. **Radiologia Odontológica**; 5 ed. São Paulo: Artes Médicas; 2000.

RUNE B, JACOBSSON S, SARNÄS K, SELVIK G. A roentgen stereophotogrammetric study of implant stability and movement of segments in the maxilla of infants with cleft lip and palate. Cleft Palate J 1979 Jul-Sep; 3(16): 267-278.

RUNE B, SARNÄS K, SELVIK G, JACOBSSON S. Movement of maxillary segments after expansion and/ or secondary bone grafting in cleft lip and palate: a roentgen stereophotogrammetric study with the aid of metallic implants. Am J Orthod 1980 Jun; 6 (77): 643-653.

LUNDH H, WESTESSON P, RUNE B, SELVIK G. Changes in mandibular positions during treatment with disk-repositioning onlays: a roentgen stereophotogrammetric study. Oral Surg Oral Med Oral Pathol 1988 Jun; 6(65): 657-62.

VALSTAR ER, VROOMAN HA, TOKSVIG-LARSEN S, RYD L, NELISSEN RGHH. Digital automated RSA compared to manually operated RSA. J Biomech 2000 Dec; 12 (33): 1593-9.

RUNE B, SARNÄS K, SELVIK G, JACOBSSON S. Posteroanterior traction in maxillonasal dysplasia (Blinder syndrome). A roentgen stereometric study with the aid of metallic implants. Am J Orthod 1982 Jan; 1 (81): 65-70.

RUNE B, SARNÄS KV, SELVIK G, JACOBSSON S. Roentgen stereometry in the study of craniofacial anomalies - the state of the art in Sweden. Br J of Orthod 1986; 3 (13): 151-7.

SARNÄS K, RUNE B, ABERG M. Facial growth in cleft palate patient treated with the Herbst appliance: a long-term profile roentgenographic and roentegen stereometric analysis of profile changes and displacement of the jaws. Cleft Palate Craniofac J 2000 Jan; 1 (37): 71-7.

BRANDSSON S, KARLSSON J, SWÄRD L, KARTUS J, ERIKSSON BI, KÄRRHOLM J. Kinematics and laxity of the knee joint after anterior cruciate ligament reconstruction. Am J of Sports Med 2002 May/Jun; 3 (30):361-367.

KELLS CE. Stereoscopic Dental Skiagraphs (Stereosgraphs). Dental Cosmos 1912; 54 (7) 745-7.

LE MASTER CA. Stereoscopic Vision Applied in the Practice of Dentistry. Dental Cosmos 1932; 74 (35): 902-5,.

WALD SS. Improved methods for dental stereoscopic radiography as an aid in accurate localization and diagnosis. Dental Cosmos 1929; 71:460-8.

HODGSON ES. Intra-oral stereoradiography. JADA 1927; 14: 2173-7.

JOHNSON LR. The stereoroentgenogram as an aid in diagnosis. JADA 1930; 2176: 2176-88.

SILVA CA. Stereoroentgenograms in dentistry. Oral Surg Oral Med Oral Pathol 1956; 9 (7): 757-64.

SILVA CA. SILVA IA. Stereoscopic roentgenography in dentistry. A direct method of examining stereoroentgenograms. Oral Surg Oral Med Oral Pathol 1961; 14 (4): 430-48.

SILVA CA, SILVA IA. Roentegenografias estereoscópicas em odontologia. Método de exame direto dos estereogenogramas. Rev Paul Cir Dent 1964; 18 (2): 41-7.

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