Application of image segmentation for implant bone level measurement in periapical standardized radiographs

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Background

The radiographic analysis is the best non-invasive method for bone level determination proximal to dental implants and is mandatory to ascertain the outcome of both routine practice and clinical trials[1-3]. However, the diagnosis of progressive bone loss or the identification of bone gain from one radiographic examination to the next may be difficult to interpret due to confounding issues such as projection errors in the alignment of successive images or the lack of examiner training and measurement calibration[4-9]. Imaging software such as ImageJ (http://rsbweb.nih.gov/ij/) or VixWin (Gendex Dental Systems, Hatfield, USA) carry out diverse measurements in radiographs[10] using a simple pixel-counter ruler to measure linear distances between two points identified by the operator, which can arise intra and inter-examiner errors. This is particularly true in conventional periapical radiographs of dental implants where projection errors lead to superimposition of structures and image distortion. The operator can be misguided in the correct identification of the first bone-to-implant contact and other landmarks. Image distortion can also induce miscalculations in the calibration procedure.

Aim

To describe a graphics user interface developed for simple bone level determination in standardized radiographs of dental implants that makes use of image segmentation methods to detect the implant edges, the crestal bone line and the first bone-implant contact. Evaluation of the reproducibility, reliability and accuracy of the segmentation method by rater agreement analysis of bone levels around Camlog® Screw-line implants.

Materials & Methods

DISIAT (Dental Image System for Implants Analysis and Tracking): The user interface was designed for importing the image files, exploring the segmentation method (image preprocessing plus deformable models application phase) and for automatized extraction of the calculated bone levels into a spreadsheet, from both single or DICOM files.

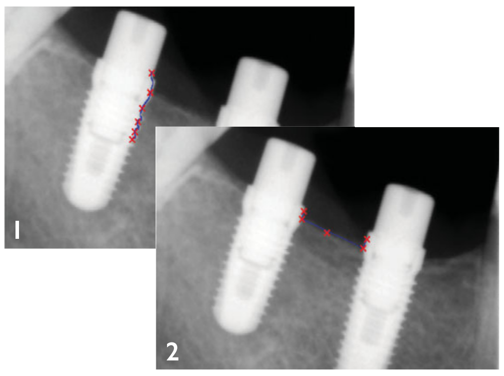
2. Definition and training of the Active Shape Models (ASM): Left and right implant profiles were built over a representative image of CAMLOG® SCREW-LINE Promote® plus implants, considering specific landmarks for each side. The bone line profile was trained simply by the selection of 5 landmarks (figures 1 and 2).

3. Implant shoulder detection: Direct visual assessment or

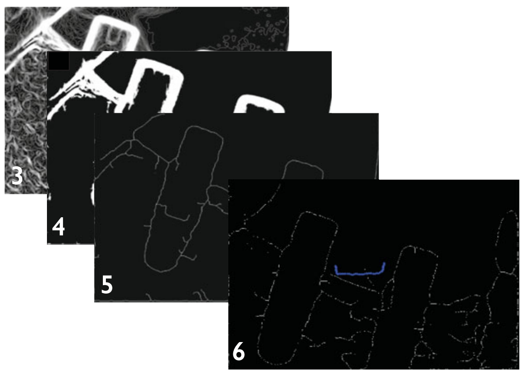
4. Measurement extraction tool: Bone line segmentation (noise suppression filters to enhance the intended structures[11] plus histogram thresholding and morphology operators (figures 3 to 5)[12]. The user interface recovers the ASM for the bone line and requests the operator to place it close to the respective site (figure 6). The good fit of the model is achieved through 125 iterations searching for the correct positioning and adaptation in the image. The final result is suitable for operator-driven changes. Implant detection occurs with binary thresholding[13] (figure 7) followed by ASM recovery for the left and right sides of the implant. The operator to places them close to the respective site in the segmented image of the implant (figure 8). The following processes run by iteration.

5. Bone level measurement: The bone level is set by the calculation of the distance between the implant shoulder and the first point of implant-to-bone contact, which undergoes an optimization process (figures 9 and 10).

Two experts from the Faculty of Medicine of the University of Coimbra trained on implant radiograph analysis executed the bone level extraction process in 60 radiographs. Data were analysed with PASW® Statistics 20.0. Bias of 0.15mm was determined as the maximum clinically acceptable difference between two radiographic measurements[8]. Significance level was set to $\alpha = 0.05$.

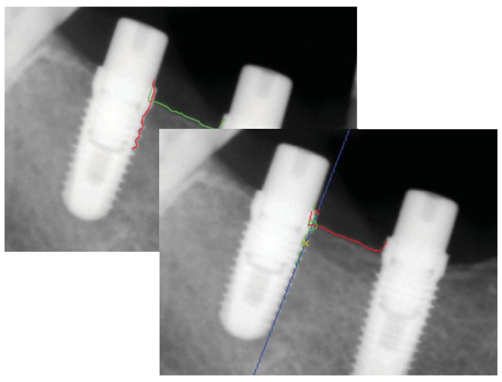


Figs. 1 and 2- Definition of the deformable models for the right side of the implant and the crestal bone line respectively. For the implant, 5 specific points of the implant geometry are selected.



Figs. 3 to 5 - Bone segmentation process with structure enhancement and application of a set of morphological operators.
Fig 6 - Aplication of the ASM for the bone line over the region of interest.

Figs. 7 and 8- Histogram binary thresholding for implant detection and application of the right side ASM close to the respective side.



Figs. 9 and 10 - Setting of the bone-implant-contact by intersection of the implant and bone ASM. Optimization and calculation of the bone level.

Results

Ninety-four measurements were obtained by the two examiners using the DISIAT user interface and considered for comparison with the manual measurements of the same images. The three measurements obtained for each image were considered repeated measures. ANOVA testing for null mean differences (α=0.05) considering the implant platform as the between-subject variable detected no differences between the three groups as $F(2, 186) = 0.16$, $p=0.852$. Pairwise comparisons were obtained with the paired samples T-test (table 1).

Reliability analysis of the measurements obtained by the three raters revealed an intraclass correlation coefficient of 0.839 [0.783-0.884, 95% CI] calculated for single measures of the three groups using the absolute agreement definition ($p<0.01$). The correlation of the measurements obtained by the two examiners using DISIAT was 0.880 [0.824-0.918, 95% CI] ($p<0.01$). Approximately 60% of the measurements obtained with the DISIAT prototype by either examiner had less than 0.15mm difference from the manual measurements and were considered perfect hits.

Table 1. t-test results for the pairwise comparisons of the three groups. Significance level α=0.05.

Pair	*Mean difference*	*SD*	*95% CI*	*Max*	*t*	*p*
Manual - DISIAT 1	-0.008	0.32	[-0.07-0.06]	1.30	-0.25	0.80
Manual – DISIAT 2	0.009	0.37	[-0.07-0.09]	1.15	0.25	0.80
DISIAT 1 – DISIAT 2	0.018	0.31	[-0.05-0.08]	1.17	0.56	0.58

Discussion & Conclusions

Up to this moment few studies focus on rater agreement, arising the problem of the trueness of the peri-implant bone levels reported[14]. Cochran et al[8] report the marginal bone level error between raters to be 0.193mm in average, whereas we found a 0.018mm difference, and 77.5% of values with less than 0.5mm difference while 90% of our measurements were within that interval. When considering 0.15mm difference for the correct value, the DISIAT chance of agreement decreases to approximately 60%, which is still close to the value reported by Lanning et al for accurate rating of bone loss by trained clinical instructors[8, 9]. Discrepancies obtained between automatized and manual measurements could be related to the manual identification of the first bone-to-implant contact, which could be underestimated[3, 15, 16]. Crestal bone line delineation could also be influenced by the densitometry calibration of the image. Brighter images have an impact on the thresholding and algorithm segmentation method, influencing the bone line positioning. It would be interesting to introduce an histogram callibration tool prior to thresholding.

Also, determining the projection planes of two consecutive radiographs would allow the corregistration of the images and higher accuracy on bone level evaluation.

Automatized image segmentation with determination of implant boundaries and crestal bone line is a promising technique for simple bone level measurement around dental implants. The proposed method has proven to be a robust tool, as no significant differences were found between the manual measurements and those produced with the prototype. The reliability analysis showed very good agreement between the measurements of different examiners and between the automatized measurements and those obtained manually.

References

1.Hanggi MP, Hanggi DC, Schoolfield JD, et al. Crestal bone changes around titanium implants. Part I: A retrospective radiographic evaluation in humans comparing two non-submerged implant designs with different machined collar lengths. J Periodontol 2005;76(5):791-802. | 2.De Smet E, Jacobs R, Gijbels F, Naert I. The accuracy and reliability of radiographic methods for the assessment of marginal bone level around oral implants. Dentomaxillofac Radiol 2002;31(3):176-81. | 3.Hermann JS, Schoolfield JD, Nummikoski PV, et al. Crestal bone changes around titanium implants: a methodologic study comparing linear radiographic with histometric measurements. Int J Oral Maxillofac Implants 2001;16(4):475-85. | 4.Benn DK. Estimating the validity of radiographic measurements of marginal bone height changes around osseointegrated implants. Implant Dent 1992;1(1):79-83. | 5.Mol A, Dunn SM. The performance of projective standardization for digital subtraction radiography. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2003;96(3):373-82. | 6.Huh KH, Lee SS, Jeon IS, et al. Quantitative analysis of errors in alveolar crest level caused by discrepant projection geometry in digital subtraction radiography: an in vivo study. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2005;100(6):750-5. | 7.Wakoh M, Harada T, Otonari T, et al. Reliability of linear distance measurement for dental implant length with standardized periapical radiographs. Bull Tokyo Dent Coll 2006;47(3):105-15. | 8.Cochran DL, Nummikoski PV, Schoolfield JD, Jones AA, Oates TW. A prospective multicenter 5-year radiographic evaluation of crestal bone levels over time in 596 dental implants placed in 192 patients. J Periodontol 2009;80(5):725-33. | 9.Lanning SK, Best AM, Temple HJ, et al. Accuracy and consistency of radiographic interpretation among clinical instructors using two viewing systems. J Dent Educ 2006;70(2):149-59. | 10.Grandi T, Garuti G, Guazzi P, Tarabini L, Forabosco A. Survival and success rates of immediately and early loaded implants: 12-month results from a multicentric randomized clinical study. J Oral Implantol 2012;38(3):239-49. | 11.Guevara M, Silva A, Oliveira H, de Lourdes Pereira M, Morgado F. Segmentation and morphometry of histological sections using deformable models: A new tool for evaluating testicular histopathology. Progress in Pattern Recognition, Speech and Image Analysis 2003:282-90. | 12.Cunha P, Guevara M, Messias A, et al. A method for segmentation of dental implants and crestal bone. International Journal of Computer Assisted Radiology and Surgery 2012:1-11. | 13.Glasbey CA. An analysis of histogram-based thresholding algorithms. CVGIP: Graphical Models and Image Processing 1993;55(6):532-37. | 14.Tonetti M, Palmer R. Clinical research in implant dentistry: study design, reporting and outcome measurements: consensus report of Working Group 2 of the VIII European Workshop on Periodontology. J Clin Periodontol 2012;39 Suppl 12:73-80. | 15.Eickholz P, Hausmann E. Accuracy of radiographic assessment of interproximal bone loss in intrabony defects using linear measurements. Eur J Oral Sci 2000;108(1):70-3. | 16.Scaf G, Sakakura CE, Kalil PF, et al. Comparison of simulated periodontal bone defect depth measured in digital radiographs in dedicated and non-dedicated software systems. Dentomaxillofac Radiol 2006;35(6):422-5.