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Intraoral radiographs texture analysis for dental implant planning

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ABSTRACT

Background and Objectives: Computer vision extracts features or attributes from images improving diagnosis accuracy and aiding in clinical decisions. This study aims to investigate the feasibility of using texture analysis of periapical radiograph images as a tool for dental implant treatment planning.

Methods: Periapical radiograph images of 127 jawbone sites were obtained before and after implant placement. From the superimposition of the pre- and post-implant images, four regions of interest (ROI) were delineated on the pre-implant images for each implant site: mesial, distal and apical peri-implant areas and a central area. Each ROI was analysed using Matlab® software and seven image attributes were extracted: mean grey level (MGL), standard deviation of grey levels (SDGL), coefficient of variation (CV), entropy (*En*), contrast, correlation (*Cor*) and angular second moment (ASM). Images were grouped by bone types—Lekholm and Zarb classification (1,2,3,4). Peak insertion torque (PIT) and resonance frequency analysis (RFA) were recorded during implant placement. Differences among groups were tested for each image attribute. Agreement between measurements of the peri-implant ROIs and overall ROI (peri-implant + central area) was tested, as well as the association between primary stability measures (PIT and RFA) and texture attributes.

Results: Differences among bone type groups were found for MGL ($p = 0.035$), SDGL ($p = 0.024$), CV ($p < 0.001$) and *En* ($p < 0.001$). The apical ROI showed a significant difference from the other regions for all attributes, except *Cor*. Concordance correlation coefficients were all almost perfect ($\rho > 0.93$), except for ASM ($\rho = 0.62$). Texture attributes were significantly associated with the implant stability measures.

Conclusion: Texture analysis of periapical radiographs may be a reliable non-invasive quantitative method for the assessment of jawbone and prediction of implant stability, with potential clinical applications.

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1. Background

Computer technology is a promising way to aid the health sciences [1–3], especially in the imaging diagnosis field and medical imaging interpretation process, which have received the greatest contribution from this tool [4]. Computer-aided diagnosis (CAD) can be defined as a diagnosis made by a professional who uses the automated result of quantitative analysis of images as a "second opinion" to improve diagnostic accuracy and aid in clinical decisions [4]. Among different areas of knowledge in CAD, the computer vision is the most commonly used in different specialties of health. It automatically extracts features or attributes from the images, visible or not to the human eye: density, contrast, magnification, sharpness, uniformity, density, roughness, intensity, etc [5–7].

Within the computer vision, the texture analysis is able to describe the spatial variations in intensity of grey levels. Thus, the texture method analyses local variations in pixel values that are regularly or randomly repeated along the image. The various techniques for texture analysis are distributed in four main groups: structural analysis, statistics, fractal and anisotropy [6]. Haralick and co-workers [6] characterised texture as a two-dimensional concept. One dimension contains primitive properties of grey levels (pixels) and the other corresponds to spatial relationships among them. These authors suggested one of the most efficient methods for texture analysis, the Haralick's method, which is in the statistical group. Based on this method, fourteen texture attributes can be analysed.

Texture analysis is widely used for bone tissue evaluation in patients with osteoporosis [8–10], and the fractal analysis method has been applied to evaluate jawbone sites in dentistry. The fractal dimension analysis has been pointed as a potential method to predict bone quality at dental implant sites [11] and has been tested to analyze changes on peri-implant alveolar bone after prosthodontic loading [12–15]. However, the statistical texture method is rarely used in dentistry to assess jawbone sites.

Jawbone characteristics may influence the success of implant treatment. Pre- and trans-operative methods have been used to measure bone characteristics for dental implant planning [16–18], including the subjective classification suggested by Lekholm and Zarb. These different methods provide morphometric aspects of bone, such as cortical thickness and trabecular density, which are related to mechanical anchorage of the implant during its placement. This implant stability at placement, defined as primary implant stability, has frequently been associated with successful implant treatment outcome [19]. Measurements of some bone morphological characteristics in a quantitative/objective way could contribute to predict primary implant stability and osseointegration success, particularly prior to invasive procedures. The aim of this study was to investigate the ability of statistical texture analysis performed in periapical radiographs of jawbone sites to identify the different bone types and predict primary implant stability.

2. Methods

2.1. Sample

Periapical radiographic images were obtained from forty-eight volunteers with an indication of dental implant treatment, selected according to clinical criteria, laboratory tests and radiographic images. One hundred and twenty-seven pre- and post-implant periapical images composed the sample of this study. Post implant radiographs were taken six months after implant placement.

Periapical radiographs were performed using Heliodent Dentotime (Siemens, Benshein, Germany) with the following parameters: 70 kVp, 10 mA, aluminium filter of 2.0 mm, rectangular collimator 3 x 4 cm, focus-film distance of 21 cm, exposure time ranging between 0.25–0.4 s. E-speed dental films (Kodak Ektaspeed, Eastman Kodak Co., Rochester, NY) were used and processed automatically (Peri-Pro, Air Maintenance Techniques, USA) with a cycle of 6 minutes at 27°C.

The conventional radiographs were digitalised using a Sony Cyber-Shot DSC-W210 digital camera with 12.1 megapixel resolution and 2X optical zoom. Images were obtained with standardised criteria of lens–film distance and lightness, and saved in JPEG format, with 256 gray levels.

2.2. Subjective bone classification and implant stability measurements

The subjective bone classification, according to Lekholm and Zarb [19] criteria (bone types 1, 2, 3 and 4), was performed by the three oral surgeons who placed the implants. Each surgeon evaluated only the sites to be operated by himself, since Lekholm and Zarb classification [19] required radiographic interpretation associated with tactile perception of the surgeon during the drilling of the bone site, which does not allow simultaneous classification by more than one surgeon. The surgeons received a calibration card with schematic design and description of the bone type classification according to Lekholm and Zarb (Fig. 1), which serves as a reference (calibration) during each reading. They registered their subjective rate of each implant site in the patient's records. So, bone classification was carried out in two steps: at first, a radiographic imaging interpretation was performed based on periapical and panoramic images, under favourable light conditions, using a schematic bone type drawing [19] as a reference. During surgery, the final bone classification was established based on previous radiographic interpretation associated with the surgeon's tactile perception of bone resistance at first drilling for implant installation (Fig. 1).

Implants were installed using the two stage protocol [20,21]. Trans-operative implant stability measurements were collected: peak-insertion torque (PIT) and implant stability quotient (ISQ). PIT was recorded by the surgical micromotor display (BLM 600 Plus, Driller, Sao Paulo, SP, Brazil) at 1300 rpm for the initial drill hole. These values ranged from 15 to 55 Ncm. When final anchorage required a torque higher than 55 Ncm, this was achieved by a manual wrench (Neodent, Curitiba, Brazil).

Resonance frequency analysis (RFA) was performed immediately after implant insertion using a wireless device, the