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Applicability of strain measurements on a contra angle handpiece for the determination of alveolar bone quality during dental implant surgery

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ABSTRACT

Alveolar bone quality is considered to be an important prognostic factor in dental implant stability. Although numerous methods have been described, no technique allows for reliable diagnostics. The purpose of this study was to determine if strain measurements on the shaft of a contra angle handpiece during implant bed preparation could be used for the determination of bone quality. Experiments in polyurethane foam and human cadaver bone were conducted to investigate whether strain measurements could be correlated with other diagnostic parameters, such as the surgeon's tactile sensation during drilling, implant insertion torque, implant stability, elastic modulus of bone and bone quality as assessed radiographically. Tests were also performed to determine if strain measurements could be used to distinguish various types of bone. As axial feed and contact pressure during the drilling process could not be standardized under simulated clinical conditions, substantial deviations in the time needed to complete the drilling occurred. Under controlled circumstances using polyurethane foam, this problem could be addressed by a normalization procedure, but great variations occurred in human cadaver bone. As bone quality could not be reliably determined, especially when a cortical layer was present, strain measurements on a contra angle handpiece appears to be inappropriate for this purpose.

1. Introduction

The quality of alveolar bone has been shown to affect treatment planning, the surgical and loading protocol applied as well as the long term success of dental implants (Brunski, 1988; Norton and Gamble, 2001). For treatment planning purposes, preoperative assessment methods based on radiographic examinations as well as specific classification systems have been described (Vercellotti and Vercellotti, 2009). Based on the partially contradictory results presented in the literature, it appears that these techniques do have specific limitations in the field of implant dentistry.

The widely applied classification system for alveolar bone quality introduced by Lekholm and Zarb allows for a clinically relevant classification of alveolar bone in four categories ranging from solid, mainly cortical bone to soft trabecular bone providing limited primary stability for dental implants (Lekholm and Zarb, 1985). This classification system in its original form is based on the surgeon's tactile sensation during implant site preparation using varying sets of drills (Trisi and Rao, 1999; Alsaadi et al., 2007). It has been shown that with this technique differentiating between the two extreme classes described above is possible, but differentiating between the two intermediate classes as well as between neighboring classes is not possible (Trisi and Rao, 1999; Shapurian et al., 2006). Given the variability in design and surgical protocol of the different implant systems available, it appears that an objective classification cannot be established using subjective hand feelings.

Implant related measurement techniques allowing for assumptions to be made about the underlying bone quality have also been introduced. Besides implant insertion torque measurements (Friberg et al., 1999a; Beer et al., 2003; Johansson et al., 2004), evaluating the primary stability of dental implants by means of resonance frequency and damping capacity assessments are being used (Schulte et al., 1992; Tricio et al., 1995; Meredith, 1998; Nkenke et al., 2003; Turkyilmaz et al., 2006). With varying correlations of the resulting measurement values with other factors related to bone architecture and the differences in the implant systems available, it appears to be impossible to establish a valid classification system based on these approaches.

Based on the clinical observation that the pressure exerted on the contra angle handpiece during implant bed preparation depends on the drilling resistance experienced by the surgeon, it was the aim of this investigation to determine whether strain gauge measurements on the shaft of the contra angle handpiece could be used for setting up an objective classification system for alveolar bone.

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2. Materials and methods

2.1. Modification of a contra angle handpiece for strain measurements during implant bed preparation

A unidirectional strain gauge (LY11-0.6/120; 120 Ω reference resistance; Hottinger Baldwin Messtechnik GmbH, Darmstadt, Germany) was attached to a contra angle handpiece (E20RI, NSK Europe, Eschborn, Germany; gear ratio 20:1) with the sensing element being oriented in the anterior–posterior direction (Fig. 1). A measurement amplifier (Spider 8®; Hottinger Baldwin) and analyzing software (BEAM for Spider 8®; AMS Gesellschaft für Angewandte Mess-und Systemtechnik GmbH, Flöha, Germany) allowed recording of the strains occurring in the contra angle handpiece during drilling.

Testing in polyurethane foam materials

Commercially available polyurethane foam blocks (Sawbones Europe AB, Malmö, Sweden) differing in structure and density (given in pound per cubic foot; pcf) were used as bone surrogate material for preliminary testing (Gibson, 1985):

- Blocks with a solid, homogeneous structure (Solid Rigid Polyurethane Foam 10 pcf, 20 pcf, 30 pcf, 40 pcf)
- Blocks with a cellular structure (Cellular Rigid Polyurethane Foam 10 pcf, 20 pcf)
- Blocks with a simulated cortical layer (Solid Rigid Polyurethane Foam 10 pcf, 20 pcf laminated with one sheet of Solid Rigid Polyurethane Foam 40 pcf; Cellular Rigid Polyurethane Foam 10 pcf, 20 pcf laminated with one sheet of Solid Rigid Polyurethane Foam 40 pcf)

Ten sockets 3.5 mm in diameter and 11 mm in length were prepared for the placement of screw-shaped cylindrical implants with a diameter of 4.1 mm and 10 mm length (Straumann Standard Implant; Institut Straumann AG, Basel, Switzerland) in each of the materials. The implant positions were marked with a round burr and a set of twist drills 2.2 mm, 2.8 mm and 3.5 mm in diameter was used in combination with a surgical motor (KaVo INTRAsurg 1000; KaVo Dental GmbH, Biberach, Germany) to create standardized implant beds. For drilling with the 2.8 mm twist drill, the strain gauge equipped contra angle handpiece was used and the strains occurring at the contra angle handpiece during drilling were recorded (Fig. 2). Mean values for the time required to complete the 2.8 mm drilling were calculated for each material and measurements showing deviations from the mean value greater than 0.9 s were excluded from analysis. For valid measurements, strain readings over time were approximated using a polynomial of 5th degree and the integral value was taken for analysis.

Implants were installed using the surgical motor (KaVo INTRAsurg 1000) which also allowed for measuring the maximum torque needed to seat the implants. Primary implant stability was determined by means of damping capacity assessment (Periotest, Medizintechnik Gulden, Modautal, Germany) and resonance frequency measurements (Osstell mentor, Osstell AB, Gothenburg, Sweden).

Ten standardized cylinders 6 mm in diameter and 10 mm in length were harvested from each material using trephine burrs (Meisinger Bone Management, Meisinger, Neuss, Germany). The elastic moduli of the cylinders were determined by compressive testing in a universal testing machine (Inspekt mini 3kN; Hegewald & Peschke, Nossen, Germany) at a crosshead speed of 1 mm/min until 1 mm compression was reached.

2.3. Testing in human cadaver bone

Segments of embalmed human mandibles and maxillas were obtained from the Institute of Anatomy, University of Erlangen-Nuremberg and subject to cone beam computed tomography

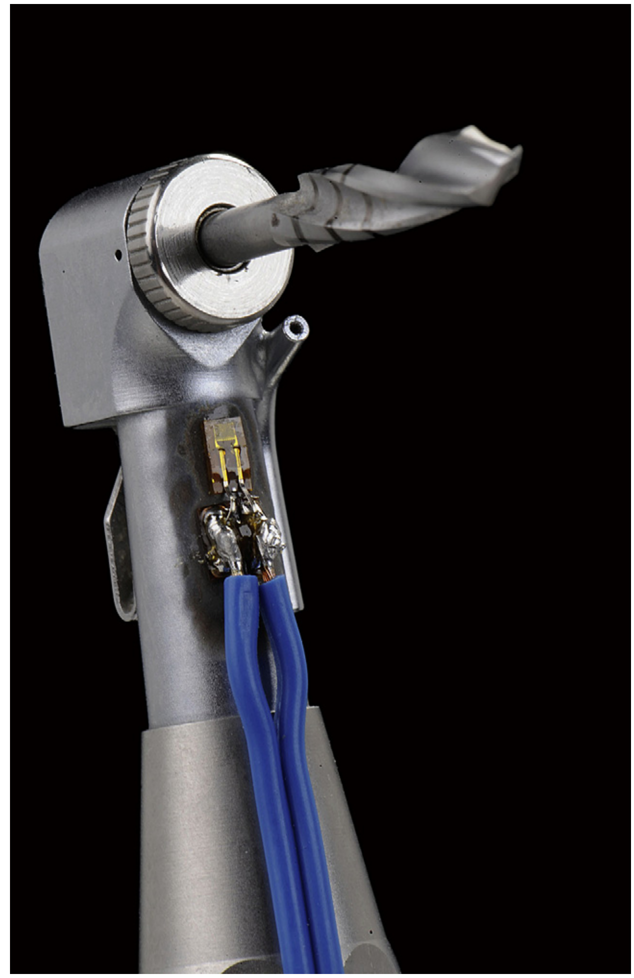

Fig. 1. Total view of the modified contra angle handpiece used for strain measurements during dental implant surgery. The strain gauge is positioned with the sensing element in the anterior–posterior direction and in conjunction with a measurement amplifier allows for strain measurements during implant bed preparation.

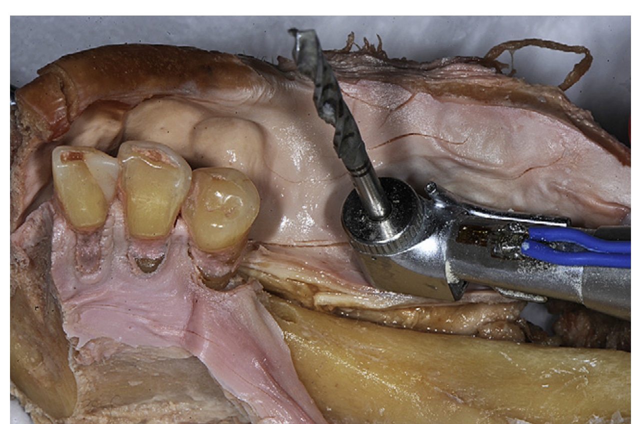

Fig. 2. Following the creation of an initial 2.2 mm osteotomy, a 2.8 mm twist drill in combination with the strain gauged contra angle handpiece was used to further prepare the implant site while the strains occurring were measured.