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Research Paper
Dental Implants

Torque-fitting and resonance frequency analyses of implants in conventional sockets versus controlled bone defects *in vitro*

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Abstract. The primary stability of implants should be high on insertion into fresh extraction sockets. Torque-fitting and resonance frequency analyses (RFA) are used to assess primary implant anchorage and stability. The torque-fitting and RFA of implants placed in conventional surgical sockets and sockets with controlled coronal bone defects was compared. The possible relation between torque-fitting and RFA was explored. Ø 3.3 mm × 12 mm implants were placed in 16 sockets finalized with Ø 2.8 mm surgical pilot drills in the right iliac crests of two fresh cadavers (control). In the test group, implants were placed into sockets prepared by Ø 2.8 mm drill followed by Ø 4.2 mm twist drills to a depth of 6 mm to create circumferential controlled coronal bone defects (50% bone loss). Primary implant stability was assessed using insertion torque values (ITV) followed by RFA. Mean ITV and RFA measurements for test groups (7.83 ± 0.91 N cm and 40.88 ± 3.57) were significantly lower than controls (14.80 ± 1 N cm and 66.31 ± 0.9) ($P < 0.05$). Reductions of ITV and RFA measurements in relation to bone defect were 47% and 38%. The existence of controlled bone defects eliminating contact coronally leads to decrease in torque-fitting and primary stability of implants. No relationship was observed between torque-fitting and RFA.

Keywords: resonance frequency analysis; insertion torque; implant; iliac crest; bone defect.

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The shift from conventional-loading to immediate function has recently expanded to immediate/early-loading of implants in fresh extraction sockets[4,12,15]. The late approach is a treatment challenge, but it involves many advantages, such as better determination of implant position, less bone resorption, and improved quality of life because of reduced treatment time[7]. Unlike implants placed in conventional sockets with defined geometry, a three-dimensional bone defect is always left around an implant in a fresh extraction socket, which undergoes a cascade of biological events leading to distance and contact osteogenesis[6,7,13]. From a biomechanical aspect, the primary anchorage and intraosseous micromotion of implants seem to have a crucial role in achieving successful osseointegration, particularly for the immediate/early-loading protocol. An immediately loaded implant placed in a fresh extraction socket is a more demanding case and therefore, the implant should have primary stability, intraosseous torque-fitting, and micromovement values approaching those of an immediately loaded implant in a conventional surgically prepared bone socket[2,21].

The torque-fitting and primary stability of implants is influenced by several factors such as implant design[2,8,18,19], implant diameter and length[14], diameter of surgical socket[20], and available bone support[3,5,17]. The method of stability and anchorage measurement also influences the data obtained[2]. There is growing evidence that resonance frequency analysis (RFA) data from immediately placed implants in extraction sockets could be misleading in terms of predicting primary anchorage. Although the displacement of the cantilever beam of the transducer is less than 1 μm, the implant stability quotient (ISQ) may present false-positive results depending on the way the implant is installed and the bone support achieved (i.e. a regular-diameter implant having cortical bone support may lead to higher ISQ values than a wider implant lacking contact at the marginal bone region)[2,11]. Therefore, FRA measurements need to be supported by another means of quantifying anchorage, especially for immediate implants in extraction sockets, although its detection of implant stability during osseous healing is valid[16]. Unlike other mechanical assessments such as pull-out and push-out tests, the removal torque (torsion) test has been proposed to provide the most reliable data about the mechanical strength (bond) of the bone–implant interface[8]. The opposite approach (the insertion torque test), provides pure information on the intraosseous torque-fitting of implants and seems be the most appropriate way to determine primary anchorage of an implant[2,11]. Overall, RFA in combination with insertion torque values could give the clinician a better understanding of the primary anchorage of immediately placed implants in extraction sockets.

RFA on implants at the time of insertion into extraction sockets and at the abutment connection stage show that implant stability significantly increases following bone formation in the bone defect[5]. The impact of bone defect geometry and depth on the primary stability of implants has not been well-documented. It is essential to gain better insight into how the existence of bone defects influences primary stability and intraosseous anchorage of immediately placed implants. This study aimed to compare the insertion torque (torque-fitting) and ISQ values of implants in conventional surgical sockets with those in sockets with controlled bone defects. It was also hypothesized that there would not be a positive relationship between torque-fitting and RFA techniques so the level of agreement between these two techniques was also explored.

Materials and methods

Human cadavers

The experiments were undertaken in the bilateral iliac crests of two fresh-frozen human cadavers (two men aged 66 and 74 years), who had bequeathed their bodies for medical-scientific research purposes. There was no detailed systemic history for the cadavers, but the reasons for death were a traffic accident for one subject and a heart attack for the other. The cadavers were frozen at $-21 \pm 5\,^{\circ}C$ within 24 h following death. Prior to experiments, the fresh-frozen cadavers were thawed in room temperature for 48 h to achieve life-like biomechanical properties of bone tissue[2,11].

Test groups and surgical procedures

Implant placement location was determined as the entire crest 11 cm posterior from the anterior superior of the spina iliac spine. The rationale for selecting the iliac crest as the test site was to undertake the experiments in an anatomical region composed of both rich trabecular and 1–1.5 mm thick cortical bone (i.e. the fibula or the radius is basically composed of thick cortical bone, which would solely support the implant and therefore increase anchorage of the implant in bone)[17]. For test sites having thick cortical bone, the possible effect of trabecular bone cannot be included in the measurements.

Upon reflection of full-thickness flaps, Ø 3.3 mm × 12 mm Straumann Dental implants (Straumann Institute, Basel, Switzerland) were consecutively placed with 5 mm interimplant distance according to defined surgical principles[9]. In the control group, 16 sockets finalized with Ø 2.8 mm surgical pilot drills under copious saline irrigation in the right iliac crests of the cadavers received the implants. This resulted in full bone support for the implants in the control group. In the test group, 16 sockets were first prepared by up to Ø 2.8 mm surgical pilot drills to a depth of 12 mm to achieve optimum bone support at the 6-mm apical part of the implants. Then, 6-mm deep controlled bone defects were created in the coronal part of the sockets using a Ø 4.2 mm twist drill (Fig. 1). The implants in the test sites had 6 mm contact with trabecular bone at the 6–12 mm apical part of the implants and no circumferential contact for the first 6 mm contacting cortical and trabecular bone.

Insertion torque measurements and RFA

During placement of the implants in both groups, the final insertion torque value (ITV) was measured by a custom-made manual torque device. The technical details of the torque device and calibration experiments are explained elsewhere[10]. The custom-made torque device was connected to the ratchet adapter (046.462; Straumann Institute, Basel, Switzerland), which was mounted on the premounted transfer part of the implant. The ITV measurements were performed during implant placement into the final position by an approximately half-turn of the strain-gauged torque device in a clockwise direction (Fig. 2). The strain-gauge signals during torque-fitting were delivered to a data acquisition system (ESAM Traveller 1, Vishay Micromeasurements Group, Raleigh NC, USA) and were displayed as torque units (N cm) in a computer by a special software (ESAM; ESA Messtechnik GmbH, Olching, Germany) at a sample rate of 10,000 Hz. On removal of the premounted transfer part from each implant, RFA was undertaken using the

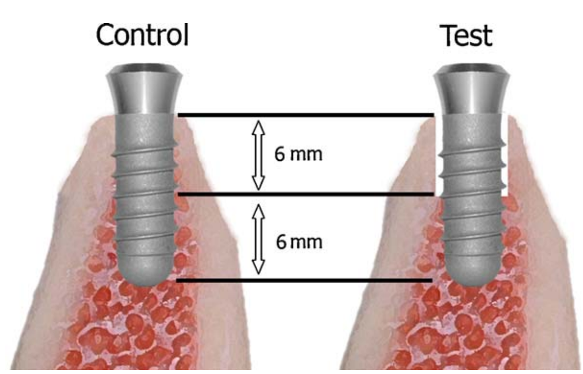

Fig. 1. Control and test implants in their sockets. Note that there is a 6-mm deep coronal defect around test implants (right).