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Efficacy of biologically guided implant site preparation to obtain adequate primary implant stability

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SUMMARY

The primary stability of dental implants is essentially influenced by the quality and quantity of hosting bone. To study the effects of adaptation of the drilling protocol to the biological quality of bone estimated by bone density and cortical/cancellous bone ratio, 8.5 mm-short implants were placed in different bone types by adapting the drilling protocol to result in a socket under-preparation by 0.2, 0.4, 0.7, 1 and 1.2 mm in bone types I, II, III, IV and V, respectively. The effect of the drilling protocol was studied on implant insertion torque and osseointegration. Additionally, we analyzed the relationship of demographic data and social habits to bone type and insertion torque. Then the correlation between insertion torque and bone quality was tested. One hundred ninety two patients (mean age: 62 ± 11 years) participated with 295 implants. The most common bone type at implant site was type III (47.1%) followed by type II (28.1%). Data analysis indicated that gender, age, and social habits had neither correlation with bone type nor with insertion torque. The insertion torque was 59.29 ± 7.27 Ncm for bone type I, 56.51 ± 1.62 Ncm for bone type II, 46.40 ± 1.60 Ncm for bone type III, 34.84 ± 2.38 Ncm for bone type IV and 5 Ncm for bone type V. Statistically significant correlation was found between bone type and insertion torque. The followed drilling protocol adapts socket under-preparation to the needs of establishing a sufficient primary stability for implant osseointegration.

1. Introduction

The success and wide acceptance of implant dentistry as the first choice in replacement of missing teeth is based on the outcome of bone and implant interaction in a process known as osseointegration (Meyer et al., 2012). This dynamic process is significantly influenced by the quality of housing bone and the primary stability of the implant.

Bone quality is a collective term referring to the mechanical properties, architecture, degree of mineralization, chemical composition and remodeling properties of bone (Shapurian et al., 2006). Several classification systems have been formulated to help the clinicians in describing the quality of bone using common terms (Lekohlm and Zarb, 1985; Misch, 1990; Trisi and Rao, 1999), although the most accepted system in the field of oral implantology is that of Lekohlm and Zarb (1985) (Bergkvist et al., 2010; Ribeiro-Rotta et al., 2012). Lekohlm and Zarb classified bone quality into four categories (Types I–IV) according to bone composition (ratio between compact bone and spongy bone) and the subjective bone resistance when drilling. The presence of compact bone and bone resistance decreases from bone type I to bone type IV. Several articles have corroborated the validity of Lekohlm and Zarb classification by analyzing its correlation with the outcomes of histomorphometric analysis, measurements of bone mineral density and variables of computed microtomography (CT) (Bergkvist et al., 2010; Pereira et al., 2013; Ribeiro-Rotta et al., 2011).

Periera et al. have found a correlation between the Lekohlm and Zarb classification and the histomorphometric parameters of bone volume, density, bone surface, thickness of the bone trabeculae, and inter-trabecular space (Pereira et al., 2013). Bergkvist et al. calculated the bone mineral density (BMD) using the Hounsfield units obtained from a CT scan and found a significant correlation between the BMD and Lekohlm and Zarb classification (Bergkvist et al., 2010). Ribeiro-Rotta et al. have also found a significant correlation with values of microtomography in relation to bone architecture, density and volume (Ribeiro-Rotta et al., 2012). Accordingly, these results support the clinical use of the Lekohlm

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and Zarb classification for the assessment of bone quality and the establishment of a specific treatment plan based on this property. The other parameter crucial to implant osseointegration is the primary stability of the implant (Lopes and König Júnior, 2002). This biometric parameter is the result of mechanical anchorage (direct contact) of the implant to the hosting bone (Sennerby and Meredith, 1998) and is quantitatively measured immediately after implant insertion. The main function of primary stability is to prevent excessive implant micro-movements in order to assure healthy bone remodeling around the implant and, thus, its osseointegration (Szmukler-Moncler et al., 1998). Several studies have indicated that the tolerated threshold of micro-movements is between 50 and 150 μm (Akagawa et al., 1986; Galindo-Moreno et al., 2012; Pilliar, 1991). Brunski et al. reported that there is a critical limit below 100 μm that is considered a functional stimulus generating no negative effect on bone regeneration around the implant (Brunski, 1999). Davies suggests that excessive implant micro-motion may interfere with the formation of the fibrin clot on the implant surface during early wound healing (Davies, 1998). Therefore, the primary stability allows bone formation around the implant increasing the bone to implant contact to provide the secondary stability of the implant. This secondary stability depends on the factors previously mentioned in addition to host factors (blood supply to the wound) and surface characteristics of the implant (Davies, 2003; Nevins et al., 2012; König Júnior et al., 1998).

Implant primary stability is the net outcome of quantity and quality of hosting bone, the design of the implant, and the surgical procedure (drilling technique) (Rabel et al., 2007). Implant macro-design is a parameter significantly influencing implant primary stability. Self-tapping implants incorporate a cutting edge in the apical part of the implant to avoid the need of using tapping procedures during socket preparation. The purpose of this design is to enhance the primary stability of the dental implant, particularly in low density bone (Marković et al., 2013; Olsson et al., 1995). Clinically, it can be measured by several methods like the insertion torque peak and the resonance frequency analysis (RFA). However, in the scientific literature, there is a discrepancy between studies on the correlation of the insertion torque and the implant stability quotient (ISQ) (Barewal et al., 2012; Friberg et al., 1999). This discrepancy is due to differences in the working principles of both techniques: the insertion torque measures the rotational stiffness of the implant-bone interface while the resonance frequency analysis evaluates the axial stiffness of this interface (Barewal et al., 2012).

After determination of the importance of implant primary stability, clinical research has been conducted to evaluate the optimal value of the insertion torque to ensure implant osseointegration. Engelke et al. have concluded that an insertion torque greater than 30 Ncm is advisable to obtain adequate primary stability and a torque value ≤11 Ncm is considered a risk factor increasing the likelihood of implant failure (Engelke et al., 2013).

The objective of this study has been to evaluate the efficiency of adaptation of the drilling protocol to the quality of bone in achieving adequate primary stability and minimizing the risk of implant failure at the early stage of osseointegration. This biologically driven drilling protocol will help to systematize the under-preparation of implant socket in a reproducible manner. Under-preparation of implant sockets would have the advantages of local optimization of bone density, increase in the insertion torque and primary stabilization of the implant, and increase the bone-to-implant contact (Friberg et al., 1999; Tabassum et al., 2011). For this purpose, the values of bone density obtained from cone-beam CT scan and bone composition (cortical and trabecular bone) have been used to assess the bone quality and determine the diameter of the last drill used before the insertion of the dental implant. The goal is to insert the implant at an insertion torque of 30 Ncm.

2. Materials and methods

In this retrospective study, patient records were reviewed to identify patients who had received dental implant therapy. The inclusion criteria were patients aged over 18 years, the insertion of 8.5 mm-long implants, implants insertion in pristine bone, the presence of information on bone type, insertion torque, and implant failure and/or prosthetic rehabilitation. Patients/implants that did not meet these criteria were excluded from the study.

Prior to surgery and in order to make a proper treatment plan, all patients had undergone a standard diagnostic protocol consisting of review of the medical and dental history, diagnostic casts, and radiographic evaluation (panoramic radiographs, when available, and cone-beam CT scan). The cone-beam CT scans were analyzed with diagnostic software (BTI Scan II, Biotechnology Institute, Vitoria, Spain) to measure both the residual bone height and the bone density at future implant sites. Bone density and the thickness of the cortical bone were the two parameters used to propose a bone type classification that would help in determining the diameter of the final drill used before implant insertion:

- Bone Type I: Bone density greater than 1000 HU and composed mostly of cortical bone. It corresponds to Lekohlm & Zarb type I bone.
- Bone Type II: Bone density of 850–1000 HU, composed of 3–4 mm-thick cortical bone surrounding a dense cancellous bone. It corresponds to Lekohlm & Zarb type II bone.
- Bone Type III: Bone density of 550 to <850 HU, composed of 2 mm-thick cortical bone surrounding a dense cancellous bone. It corresponds to Lekohlm & Zarb type III bone.
- Bone Type IV: Bone density of 400 to <500 HU, composed of 0.5–1 mm thick cortical bone surrounding cancellous bone. It corresponds to Lekohlm & Zarb type IV bone.
- Bone type V: Bone density of 100 to <400 HU, composed mostly of cancellous bone. It corresponds to Lekohlm & Zarb type IV bone.

2.1. Preparation of autologous platelet concentrate

Plasma rich in growth factor was prepared using PRGF-Endoret Kit (BTI, Vitoria, Spain). Briefly, citrated venous blood was centrifuged at 480 g for 8 min to separate blood components. Then, the plasma column was fractionated into fraction 2 (F2) defined as the 2 ml of plasma above the buffy coat and fraction 1 (F1) defined as the plasma column above the F2. Activated fraction 1 (F1) was employed to prepare a fibrin membrane that covered the surgical area before flap closure and activated fraction 2 (F2) was injected into the implant bed and at the incision boarders. This fraction was also used to moisten the dental implants before insertion.

2.2. Flap elevation and bone drilling

Patients received 1 g of amoxicillin 1 h before surgery and 1 g of acetaminophen 30 min before surgery, respectively. Under local anesthesia, a full-thickness flap was reflected to expose the alveolar crest for implant site preparation.

Bone drilling was performed at low velocity (150 rpm) without irrigation and the drilling sequence followed for the insertion of the 8.5 mm-long implants was adapted to the bone type as to the selection of the diameter of the last bone drill used before implant placement. The diameter of the last drill was 0.2, 0.4, 0.7, 1 and 1.2 mm smaller than the diameter of the implant in bone types I, II, III, IV and V, respectively. This permitted the under-preparation of the implant socket by 3.6%, 7.3%, 12.7%, 18.2%, and 21.8% for an implant with a diameter of 5.5 mm inserted in bone types I, II, III, IV and V, respectively.