Use of CBCT bone densitometry for pre-surgical decision-making regarding immediate implant loading

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Introduction

A high prevalence of oral diseases, a growing geriatric population and rapidly increasing awareness of tooth replacement with dental implants force dentists, oral and maxillofacial surgeons to respond to such promises made by implant manufacturers as new teeth in one hour. While implant manufacturers seek to maximise their sales by such marketing strategies, it will always be the practitioner’s full responsibility to treat patients according to strictly evidence-based treatment protocols, especially when it comes to immediate functional loading of dental implants.

Esposito et al., Javed and Romanos, Walker et al. and Cannizzaro et al. proved in reviews, Cochrane studies and split-mouth randomised clinical trials that primary implant stability—represented by insertion torque values (ITVs)—shows a significant correlation between the biomechanical quality of bone and the risk of immediate and long-term implant failure when implants are loaded functionally at the time of insertion.1–4 Furthermore, experimental and clinical studies by Turkyilmaz et al., Pommer et al. and Wada et al. proved a significant correlation between primary implant stability measured by ITV and Cat-Scan based bone densitometry in native alveolar bone.5–7

Since alveolar bone loss caused by natural atrophy or destructive iatrogenic procedures at the time of tooth extraction demands immediate (alveolar ridge preser-
vation) or later (guided bone regeneration) bone augmentation procedures, Di Lallo et al. and Troedhan et al., in randomised clinical studies, found a significant difference in primary implant stability between augmented alveolar bone and native alveolar bone. Recently, a randomised clinical study was performed by Troedhan et al. to investigate whether a significant correlation between pre-surgical CBCT bone densitometry performed with X-Mind trium (ACTEON) and primary implant stability in augmented sinus sites could be proved.

Study design

A randomised clinical study was conducted on 128 patients. Of these patients, 101 with a sub-antral crest height of less than 4 mm underwent a unilateral or bilateral trans-crestal sinus lift using the hydrodynamic ultrasonic Piezotome-sinuslift (INTRALIFT, ACTEON) with four different and randomly allocated bone grafting materials (monophasic or biphasic mouldable and self-hardening biomaterial, and granular synthetic and xenogeneic bone substitute) in 114 INTRALIFT sites.
The trans-crestal Piezotome INTRALIFT procedure provides the least risk of membrane perforation and has proved to detach the periosteum of the sinus membrane cleanly from the bony base of the antrum, thus preventing a study bias already at the stage of the surgery. The clean detachment of the periosteum from the bone base does not interfere with regular bone regeneration in the sub-antral scaffold by dissection or laceration of the periosteal layer of the sinus membrane, which carries the pre-osteoblastic cell layer.\textsuperscript{10–15}

Figure 1 shows a split-mouth case of a bilateral INTRALIFT procedure. After a small crestal booklet flap of approximately 7 $\times$ 7 mm was detached, the sinus floor was safely opened with ultrasonic Piezotome tips (Figs. 2 & 3). The sinus membrane was then detached by the hydrodynamic cavitation effect of the Piezotome TKW5 tip plugged into the approach canal (Figs. 4 & 5), the sub-antral scaffold was filled with 2 ml of randomly assigned biomaterial (Figs. 6 & 7) and the wound was sutured closed (Fig. 8).

After a mean healing period of 8.4 months, CBCT scans were performed with X-Mind trium, the digital set-up of the future bridge was constructed with the AIS 3D App software and the bone density was determined in the sinus lift site around the virtual implant (Fig. 9). A standardised implant ($\phi$ 4 mm, 12 mm) was then inserted in the position of the virtual implant and the ITV was measured intra-surgically (test groups; Fig. 10).
Twenty-seven patients with sufficient native sub-antral crestal bone (minimum crestal width: 6 mm; height: 12 mm) were screened with X-Mind trium for bone density around the virtual implant (Fig. 11). The standardised implant was inserted and the ITV recorded (control group). Figure 12 depicts the final result after implant insertion in the patient case shown in Figures 1–9.

Study outcomes

As can be seen in Figure 13, the mean CBCT bone density values in Hounsfield units (HUs) at the implant site differed significantly (p < 0.05) between all four test groups and the control group. The precise numerical HUs are converted by the AIS 3D App software to colour gradations for easier interpretation (Fig. 14). The brighter green the CBCT voxel matrix appears around the virtual implant, the higher the bone density. The virtual neutral threshold is 500 HU. In contrast, the more reddish the CBCT voxel matrix around the digital implant, the worse the biomechanical bone quality.

The corresponding ITVs of the inserted standardised implants measured at the location of the trans-crestal INTRALIFT approach (Fig. 2) differed significantly as well between all test groups and the control group. Figure 15 depicts the cumulative result of the correlation between HUs and ITVs for all test groups and the control group.

Clinical implications

As the presented study proved, contemporary CBCT technology adds another outstanding feature to the general CBCT-based digital workflow as the only tool with which to safely determine the grade of primary implant stability to be expected at each individual implant site already in the planning phase before the treatment or surgery is performed (Fig. 16). Using CBCT-based bone densitometry as an integrated diagnostic step in the digital workflow, the clinician for the first time can decide individually for each patient and each implant site whether implant insertion with immediate prosthetic loading might bear an unacceptable risk of early or delayed implant loss and therefore can inform the patient accordingly based on evidence.

Additionally, the results of this study lead to another interesting conclusion: since different biomaterials lead to significantly different biomechanical bone qualities of regenerated bone with precisely correlated higher values in CBCT-based bone densitometry and ITVs, the scientific dispute of whether autologous, xenogeneic or synthetic bone grafts should be considered the gold standard needs to now take a different pathway. Native maxillary bone, especially, demonstrates a very weak biomechanical quality, which can obviously be substantially improved by biomaterials used for augmentation. Therefore, the clinician might be better advised to seek the highest possible biomechanical quality of regenerated bone in guided bone regeneration sites instead of seeking complete bone regeneration by only native bone (which—as has been histologically proved—is never the case even when using only autologous bone).

High-resolution CBCT devices such as X-Mind trium as used for this study seem to have become an indispensable, non-invasive and patient-friendly, tool not only for enhanced diagnosis, treatment planning and the digital workflow but also for clinical research to add new knowledge to evidence-based dentistry.

Editorial note: A list of references is available from the publisher.

about

Dr Dr Angelo Trödhan is a specialist in cranio- and maxillofacial surgery with a focus on traumatology, and reconstructive and cosmetic surgery of the face, and in dentistry. As a leading ultrasonic surgeon and scientist in ultrasonic surgery, dental implantology, bone augmentation and maxillofacial surgery, he is regularly invited to lecture at universities and congresses worldwide and to present at international workshops.