Radioographic comparisons of crestal bone levels around implants placed with low-speed drilling and standard drilling protocols: Preliminary results

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Abstract  Background: The present study aimed to investigate the mean crestal bone loss (CBL) by placing implants using two different drilling-protocols, i.e., standard drilling with saline irrigation and low-speed drilling without saline irrigation.

Material and Methods: The patients were enrolled in the present study from a university teaching institute. Patients who fulfilled the inclusion criteria were randomly placed in two study groups: 1) control group: Standard drilling with saline irrigation and 2) test group: low-speed drilling without saline irrigation. The radiographic mean crestal bone loss (CBL) was evaluated at 3 months of follow-up before implant loading. Data analysis was performed using SPSS 20.0 (IBM product, Chicago, USA) and a p-value ≤ 0.05 was considered statistically significant.

Results: Sixteen patients (10 males and 6 females) participated in the study. Thirty Camlog®-screw-line implants were placed (15 implants per study group). After 3 months of follow-up, the means CBL of implants placed with standard drilling and low-speed drilling protocols were 1.01 ± 0.49 mm and 0.74 ± 0.62 mm, respectively. No statistically significant difference could be recorded between two groups (p = 0.206).

Conclusions: Dental implants placed with low-speed drilling without saline irrigation exhibited a similar CBL to implants installed with the standard drilling protocol. However, further randomised clinical trials are recommended to obtain stronger evidence and a better understanding of the effect.
1. Introduction

Osseointegration is defined as the development of a close contact between the surface of the titanium implant and the host bone. The resulting bone-implant-interface is capable of bearing the normal occlusal forces produced during mastication (Albrektsson et al., 1983; Brånemark et al., 1977). Bone healing after implant placement may be delayed or even prevented if the bone cells are damaged by the frictional heat produced during the implant-site preparation (Eriksson and Albrektsson, 1983; Eriksson and Adell, 1986). It has been demonstrated that a significant temperature increase can cause heat-induced bone necrosis (Eriksson and Albrektsson 1983).

Several studies have reported temperature changes in bone during osteotomy preparation (Benington et al., 2002; Misir et al., 2009; Scarano et al., 2011; Stelzle et al., 2014). The standard-drilling-protocol, with a drilling speed of 800–1200 rpm and with saline-irrigation, is considered the gold-standard for implant placement (Augustin et al., 2008). Nevertheless, a novel alternative drilling technique of low-speed-drilling (50–150 rpm) without irrigation has been introduced by Anitua et al (2007). It has been reported by several authors that the low-speed-drilling protocol is safe to employ for implant-site preparation, as it minimizes frictional heat generation (Anitua et al., 2007; Flanagan, 2010; Giro et al., 2011; Kim et al., 2010), and a histologically similar bone healing
response has been observed (Gaspar et al., 2013; Giro et al., 2011; Tehemar, 1999). The major advantage of this surgical technique is that it allows for the collection of vital autogenous bone, which can be used for bone augmentation procedures (Augustin et al., 2008; Tabassum et al., 2020).

Most of the studies on bone overheating using different drilling protocols such as low-speed-drilling without irrigation or hybrid drilling are performed in vitro; however, the findings of these studies cannot be directly translated to an in vivo or clinical environment. To analyse the clinical impact of low-speed-drilling techniques without saline-irrigation on dental implants, further in vivo (percentage bone implant contact) and clinical studies (crestal bone loss) should be performed. Therefore, the aim of this study was to compare the conventional-drilling-protocol (according to manufacturer’s instructions, i.e. a drilling-speed of 800–400 rpm with saline irrigation) versus low-speed-drilling (a drilling-speed of 50–150 rpm) without saline-irrigation for placement of Camlog®-Screw-line implants. The null hypothesis for the current study was that there was no difference in mean crestal-bone-loss (CBL) three months after implant installation.

2. Material and methods

2.1. Study design

The protocol of this study was prepared according to the World Medical Association Declaration of Helsinki. The Medical Ethical Committee of Vrije University, Amsterdam, has approved the present study (Ethical-approval-number: 2013/151). The CBL was considered the primary variable.

2.2. Patient screening and recruitment

The participants were enrolled in the study from a university teaching institute (Academic Centre for Dentistry Amsterdam [ACTA], the Netherlands) (Fig. 1). All implant surgeries were performed at the Department of Oral Implantology and Prosthetic-Dentistry at ACTA. The inclusion-criteria for the participants (screw-retained and metal-ceramic restorations) were as follows: 1) each an age of at least 18 years; 2) completely edentulous or partially edentulous patients (Implant placement at least two months after extraction); and 3) enough bone height/width at the time of surgery. The exclusion criteria were: 1) active periodontal infection (no periodontal pocket depth greater than 3 mm at the time of implant placement); 2) unresolved extraction wounds or inadequate bone at the time of implant placement; 3) lack of motivation/understanding; 4) moderate/heavy smoking; 5) severe bruxism; 6) a medical condition that contraindicated surgery; and 7) pregnancy. Written informed consent was obtained prior to inclusion. All implant surgeries and follow-up were performed by a single investigator (AT). All implants placed were Camlog®-screw-line implants with Promote® or Promote® Plus surface. All implants had Tube-in-Tube® inner configuration and the platform-switching option was used.

2.3. Surgical procedure

All implant surgical procedures were performed under local anaesthesia (Ultracain® D-S Forte; Frankfurt, Germany). A full-thickness flap was reflected after a mid-crestal and intra-sulcular incision on the adjacent teeth. All the patients were randomly allocated to the standard (according to manufacturer instructions) or low-speed-drilling groups by the use of the closed-envelope technique. Before the start of surgery, one envelope was randomly picked and opened in front of the patient. Implants were placed using two different drilling protocols, as follows.

(1) In the standard drilling protocol (control) group, the implant osteotomy preparation was carried out according to the manufacturer’s protocol with profuse saline-irrigation. Drilling was initiated with a round-drill 2.3 mm in diameter (to pierce the cortical-bone), and a pilot-drill (2.0 mm) at a speed of 800 rpm. Subsequently, the preparation was widened by a consecutive series of drills, with intermittent drilling at the different speeds, as recommended by the manufacturer, i.e., predrill (600 rpm), 3.3 (550 rpm), 3.8 (500 rpm), or 4.3 (400 rpm) depending on the final diameter of the implant.

(2) In the low-speed-drilling protocol (test) group, the round-drill and a pilot-drill were used with saline-irrigation at 800 rpm. However, a consecutive series of drills was used at a speed of 50–150 rpm with intermittent drilling without irrigation, for an uninterrupted-drilling-time < 60 s. The implants were placed into the prepared osteotomy using a contra-angle handpiece/torque wrench. A healing-screw or healing-abutment was placed, and all surgical sites were closed with polypropylene 5/0-sutures (Hu-Friedy, Chicago, IL, USA).

2.4. Postsurgical care and follow-up

The sutures were removed two weeks postoperatively. Three-months after implant placement, the final impression was taken (Dentamid-Lightplast-Baseplates, Dreve) using polyether impression material (Impregum™ F-3 M–ESPE) with an open tray technique at implant level. All patients’ restorations (screw-retained and metal-ceramic restorations) were designed and fabricated at the same dental laboratory (Zutphen-Tandtechnisch Laboratorium, Zutphen, The Netherlands). After placement of the restorations, the access hole of all the screw-retained restorations was closed with Teflon tape and sealed with composite. Complete oral hygiene instructions were given to all patients.

2.5. Peri-implant radiographic evaluation

Radiographs were taken immediately after implant insertion (T1) and three months after implant placement, on the day of final restoration placement (T3) (Fig. 2). To ensure reproducibility, all radiographs were taken with phosphor-plates (Henry-Schein Supplies ScanX®) and X-ray film-holders (Rinn-holder with 1 mm-Biolon-Dentamid, Dreve) using the long-cone paralleling technique with similar settings for each patient. ImageJ software (v. 1.47, Wayne-Rasband National Institutes of Health, USA) was utilised to evaluate crestal bone -levels on the mesial as well as a distal side of each implant, as it is a reliable software to measure the crestal bone-level (van Eekeren et al., 2016). Two examiners evaluated all the radiographic images in a dark room for precise measurements. All radiographic images were given a unique code, and both the examiners were blinded for the employed surgical-technique or time-point (T1 or T3). The width of the
implant was used as a reference to set the scale and calibrate the measurements, and this yielded a pixel/mm ratio. A straight line was traced at the neck of the dental implant to mark two reference points, and this line was drawn to represent zero. A perpendicular line was traced on the mesial as well as the distal side of the implant to measure the alveolar bone level. The difference between the values recorded at T3 and T1 was used to calculate mesial as well as distal crestal bone loss (Fig. 1). The mean of mesial and distal crestal-bone-loss of each implant was considered as a mean CBL for that particular implant for final analysis.

2.6. Statistical analysis

Data analysis was performed using SPSS 20.0 (IBM, Chicago, USA). All data were presented as mean and standard deviations, and normality was checked (Kolmogorov-Smirnov-test). A 10% sample of the total sample size was randomly selected for inter-rater concordance, consistency and reliability (IRR). The Chi-square-test was utilised for proportions of patients’ characteristics between the test and control groups. Each implant was considered as a statistical-unit. An Unpaired T-test was applied to evaluate the significance of the difference of mesial, distal and mean crestal-bone-loss between control and test groups and between mandibular and maxillary sites within control and test groups. An analysis of variance (ANOVA) test was applied to see any significance of tooth type within each group for bone loss. A p-value ≤ 0.05 was considered statistically significant.

3. Results

Sixteen-patients (10 (62.5%) males and 6 (37.5%) females) were recruited in the present study. The mean age of the patients was 55.34 ± 11.2 (ranging from 37 to 73) years. Each patient received one or more implants according to the inclusion-criteria. Thirty implants were placed, and each surgical site was randomised. All surgical-sites healed uneventfully, and no complications were recorded during the healing period. One patient (control-group), who lost one implant was retreated 3 months later, and the implant was excluded from further analysis. The patients were followed up prospectively for a period of 3 months. Data showed normal distribution (Kolmogorov-Smirnov-test). IRR correlation was $r = 0.982$, and high internal-consistency and item-reliability were revealed, with an item-reliability coefficient-alpha = 0.927. The patients’ characteristics with regards to age, jaw and tooth position were non-significant ($p = 0.851$), ($p = 0.700$) and ($p = 0.471$) and are presented in Table 1.

The mean CBL of the standard-group was 1.01 ± 0.49 mm (mesial = 1.01 ± 0.50 mm and distal = 1.03 ± 0.48 mm), and for low-speed-drilling group, it was 0.74 ± 0.62 mm (mesial = 0.76 ± 0.53 mm and distal = 0.72 ± 0.72 mm). Regarding mean CBL, no statistically significant difference was observed between standard and low-speed-drilling groups. In addition, no significant difference was observed between the two groups with respect to mesial and distal implant sites or mandibular versus maxillary jaws, at a 95% level of confidence (Table 2). The mean CBL of mesial and distal sites according to tooth positions between the standard and low-speed drilling group were also found to be statistically non-significant using multivariate ANOVA, at $p = 0.634$ and $p = 0.706$, respectively. The data is shown in Fig. 3.

4. Discussion

The measurement of crestal-bone-loss after implant placement is considered a reliable tool for appraising long-term implant success (Albrektsson et al., 2012). The factors that affect early CBL are: 1) implant-related factors, such as surface characteristics, implant design, platform switching, and loading protocol; 2) clinician-related factors such as surgical technique employed, type of restoration and clinician skills; and 3) host-related factors such as bone density and quality, and patients’ systemic and oral/periodontal health (Oh et al., 2002; Tatarakis et al., 2012). There is a need for well-controlled randomized-clinical-trials to estimate the role of each contributing factor (Oh et al., 2002). Therefore, in the present study, mean radiographic crestal-bone changes were recorded before occlusal-loading to investigate the sole effect of the employed drilling-protocol on initial bone remodelling.

The results of the present pilot-study demonstrated that there was no significant difference in mean CBL between standard-drilling and low-speed-drilling groups at 3-months' follow-up. Eriksson and Albrektsson (1983) have observed the effects of overheating on bone and reported that if the bone is exposed to a temperature of 47 °C for 1 min during implant-site preparation, resorption or bone necrosis is evi-
dent. The major concern of clinicians while choosing the drilling-protocol without irrigation is the potential of temperature increase due to mechanical friction between drill and host-bone. Several in vitro (Augustin et al., 2008; Benington et al., 2002; Kim et al., 2010; Scarano et al., 2011; Stelzle et al., 2014; Tabassum et al., 2020), and in vivo (Flanagan, 2010; Gaspar et al., 2013 Giro et al., 2011) studies have been performed to study the relationship between drilling-speed, irrigation system and thermal osteonecrosis. In addition, Kim et al. (2010) investigated the temperature threshold using infrared thermography by employing low-speed-drilling (50 rpm). They did not notice a temperature exceeding 47 °C in pig cortical-bone, which is considered as the critical temperature for bone resorption and necrosis. Furthermore, Kim et al.(2010) demonstrated that the recorded temperature ranges at the drilling-speed of 188 rpm and 462 rpm without external irrigation were 35.2 °C to 43.0 °C and 31.4 °C to 36.9 °C, respectively. To avoid excessive heat generation, as well as its detrimental effects on bone whenever saline-irrigation is avoided, the drilling-speed must be lowered to reduce mechanical friction.

The main outcome of this study was mean CBL around dental implants at 3-months follow-up before loading of the dental implants. The rationale for the follow-up period was that after loading, many additional factors, such as implant-abutment connection (Schwarz et al., 2014), restoration type (Hameed et al., 2018), overloading (Naveau et al., 2019) and the oral-hygiene-status of the patient (Monje et al., 2019; Naveau et al., 2019), play significant roles and affect peri-implant marginal bone-level changes. In addition, it has been reported that due to the remodelling process, after three-months of installation, complete healing of the implant site and new bone formation could be observed around dental implants (Iezzi et al., 2013). The amount of mean CBL recorded in the present study after 3-months of follow-up is congruent with the recently performed in vivo study. Calvo et al. (2015) utilised a simplified biologic drilling protocol (test group) to place 3.75-mm-diameter implants in the mandibles of dogs. A 2-mm-diameter pilot-drill at drilling-speed of 100 rpm and subsequently a 3.6-mm drill at a speed of 50 rpm without saline-irrigation was employed to prepare the implant-site. After 90-days, no significant difference with respect to CBL was reported between test (1.173 ± 0.187 mm) and control groups (1.205 ± 0.122 mm) (P > 0.05) (Calvo et al., 2015). In addition, the results of this study are in accordance with a recently performed clinical study that demonstrated no statistically significant difference with respect to mean CBL between standard-drilling (0.83 ± 0.73 mm) and low-speed-drilling (0.70 ± 0.62 mm) at 12-months of follow-up (Pellier-Chover et al., 2017).

The main reason surgeons are interested in employing a low-speed-drilling protocol in their daily routines is the main advantage of this protocol i.e., collection of autogenous bone generated during the drilling (Tabassum et al., 2020). The bone-chips remain attached to the drill flutes/threads due in the absence of saline-irrigation, and higher osteogenic efficacy of these bone-particles as compared to the bone collected by using a standard-protocol has been reported (Liang et al., 2017; Tabassum et al., 2020). Saline-irrigation and high-drilling-speed can affect the vitality of cells and reduce the number of growth factors (Liang et al., 2017; Tabassum et al., 2020). Therefore, the bone-chips/particles collected without saline-irrigation could be used for minor bone grafting procedures alone, or could be mixed with other osteoconductive bone substitutes to provide osteogenic cells and osteoinductive growth factors (Tabassum et al., 2020). In addition, low-speed-drilling can offer clearer field of view, which can give the clinician better manual dexterity due to a more precise perception of the pathway of the drill (Tabassum et al., 2020).

The main limitation of the present study was that the sample-size used was not large. Despite the limited sample size

| Measurements                      | Control (n = 14) | Test (n = 15) | P-value |
|----------------------------------|-----------------|--------------|---------|
| Crestal Bone loss (total)        | 1.01 ± 0.49     | 0.74 ± 0.62  | 0.206   |
| Mesial Crestal bone loss         | 1.01 ± 0.50     | 0.76 ± 0.53  | 0.226   |
| Distal Crestal bone loss         | 1.03 ± 0.48     | 0.72 ± 0.72  | 0.190   |
| Mesial mandibular Crestal bone loss | 0.90 ± 0.52     | 0.66 ± 0.51  | 0.302   |
| Mesial maxillary Crestal bone loss | 1.20 ± 0.45     | 1.33 ± 0.28  | 0.719   |
| Distal mandibular Crestal bone loss | 0.85 ± 0.44     | 0.74 ± 0.74  | 0.678   |
| Distal maxillary Crestal bone loss | 1.35 ± 0.41     | 0.68 ± 0.76  | 0.187   |

Non-significant difference of mean bone loss between standard group versus low-speed drilling group. In addition, non-significant difference was observed with respect to mesial versus distal sites and mandibular versus maxillary jaws at 95% level of confidence.
(16 patients and 30 implants), this study improves the existing evidence regarding the use of a low-speed drilling protocol without saline irrigation. However, further randomised clinical trials with larger sample sizes and extended follow-up times should be conducted to provide stronger evidence.

5. Conclusion

Within the limitation of the present study, it is concluded that implants installed with low-speed drilling without saline irrigation have exhibited similar mean crestal bone loss when compared to implants placed with standard drilling with saline irrigation. In the present study, the follow-up was 3 months after implant fixture insertion, and the implants were not loaded. Additional benefits, such as osteogenic potential and quantity of the collected autologous bone chips and clear field of view, must be considered to enumerate the benefits of a low-speed-drilling protocol. However, further clinical studies with greater sample sizes and long-term follow-up should be conducted to evaluate the effect of low-speed-drilling without irrigation on peri-implant bone changes and implant success.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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