NEW PERSPECTIVES IN ALVEOLAR RIDGE RECONSTRUCTION AND GUIDED IMPLANT PLACEMENT
– NOVEL SURGICAL AND EVALUATION CONCEPTS

PhD thesis

Kristóf Orbán

Doctoral School of Károly Rácz Clinical Medicine

Semmelweis University

Supervisor: Bálint Molnár DMD, PhD

Official reviewers: Márton Kivovics DMD, PhD
Kristóf Boa MD, PhD

Head of the Complex Examination Committee: Árpád Joób-Fancsaly DMD, PhD

Members of the Complex Examination Committee: Judit Borbély DMD, PhD
József Szalma DMD, PhD

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1. INTRODUCTION

The era of modern implant dentistry started by the innovative concept of osseointegrating screw-type titanium implants by Per-Ingvar Brånemark. One of the most important key factors for success is the adequate amount of alveolar bone around implants at the time of insertion, as well as long term tissue stability. In the beginning, predominantly edentulous patients with healed extraction sites were rehabilitated with dental implants, fixture placement was limited by the extent of remaining alveolar bone.

With the development of various bone augmentation techniques, the indication field of dental implant placement was expanded. Nowadays implant dentistry has reached a new era, where single-, multiple tooth gaps and total edentulism with severe hard- and soft tissue deficiencies can be restored with adequate surgical methods followed by implant placement.

Dimensional changes of hard tissues following tooth extraction was a well-known phenomenon compromising dental rehabilitation of patients. The amount of bone resorption depends on the patient's local anatomy, trauma related- or inflammatory conditions around teeth to be extracted, wound healing characteristics and iatrogenic factors, or patients' related factors, such as systematic diseases, low compliance, smoking habit or bad oral hygiene.

To prevent the postextractional socket resorption, several ridge preservation methods were described in the literature. Most of the techniques are based on socket grafting with various regenerative materials, resulting decreased alveolar resorption. On the other hand, newly formed hard tissue will be histologically and clinically different from the native bone. Therefore, periimplant tissue stability may be reduced.

One of the key factors for postextractional hard tissue resorption is the presence and width of buccal bony wall around extracted tooth. If the buccal bone is 1 mm, or narrower, or incomplete due to trauma or inflammation, the alveolar resorption rate will be increased.

Following tooth extraction, without any ARP method the most unwanted biological process is the three-dimensional ridge resorption. Various hard tissue augmentation methods can be applied to increase hard tissue volume. The first “gold standard” of augmentation procedures was the transplantation of autogenous bone blocks. Nowadays, the use of Guided Bone Regeneration (GBR) is also recommended with non-resorbable membranes. The non-resorbable membranes rigidity is frequently increased by titanium reinforcement to reach a more stable space maintenance, thus risk for graft compression during the healing can be reduced. Main disadvantage of non-resorbable membranes is the bacterial colonization of exposed membrane surfaces in case of flap perforation, which can lead to tissue inflammation and graft disintegration requiring premature membrane removal before the completion of the healing.

Various incision-, flap preparation- and suturing techniques are described in the literature for the GBR approach. To achieve an optimal, undisturbed healing the most important factors during surgery are adequate flap preparation, flap mobilization and wound closure. Without tension-free wound closure, flap perforation and membrane exposure may develop. The conventional flap preparation techniques are based on full-thickness flap design with vertical releasing incisions and periosteal releasing incisions. If the periosteal releasing incision is too deep, periosteal blood supply may be dissected and blood circulation of the flap may be harmed. The reduced blood circulation can negatively affect the wound healing and increase the risk of flap perforation and membrane exposure.

A tension-free flap closure can be achieved by a split-thickness flap design with the respect of blood supply. During split-thickness flap preparation, the mucosal layer is dissected from the periosteum, which facilitates flap advancement by the tension-free nature of the design, since the tension originates from the periosteal layer. The lack of vertical releasing incisions may be beneficial for early wound healing, since the loop anastomoses between vertical branches are unharmed. On the other hand, double-layer wound closure can also achieve, which increase membrane stability over the graft and flap stability.

Adequate amount of hard tissue is suitable for implant placement. One of the key elements for long-term implant success is the maintenance of hard tissues around dental implants. However, crestal bone stability can only be achieved, if the implant borne restauration is in an optimal position, which depends on ideal 3D implant guidance. Digital dentistry has become a new standard in implant position planning and navigation for implant placement. Combining a computer-aided design software with cone-beam computed tomography (CBCT) scans to allow for digital implant positioning and fabricating stents for static navigation, called as guided implant placement. The half- (or partially) guided protocol uses the template for the complete drilling sequence, but implant insertion is performed without the stent.

In the literature, there is no clear recommendation for the method of implant insertion. During manual implant insertion, a torque wrench is connected to the implant driver, while during machine-driven implant insertion, a surgical handpiece is connected to the implant.

2. OBJECTIVES

The goal of my PhD dissertation is to present novel treatment approaches and digital planning- and diagnostic methods in implant dentistry feasible for the complex implant-prosthodontic rehabilitation of periodontal patients. The present thesis reports on three human clinical studies; a retrospective comparative case series and two prospective case series.

These different, but methodologically related topics may help clinicians in the daily practice to improve their treatment outcomes and to raise patient's satisfaction. For this purpose, following the removal of hopeless teeth ridge preservation is recommended, in healed alveolar ridges horizonto-vertical reconstruction by GBR is proposed, both followed by late guided implant placement for optimal prosthetic outcomes and long-term crestal bone stability.

In the first study, a minimally invasive ridge preservation technique with a split-thickness flap design is presented to avoid extensive augmentation after tooth extraction. In the second study, the split-thickness flap design during GBR procedures is presented to treat severe horizonto-vertical defects. In the third study, the implant placement accuracy is evaluated by a half-guided surgical protocol with machine-driven or manual implant insertion. The data collected in the present research will be assessed by novel digital comparison methods to evaluate hard tissue changes after regenerative surgical approaches as well as the accuracy after guided implant placement.

3. METHODS

Study I

A novel extraction-site development (XSD) technique was compared with spontaneous healing after tooth extraction. Hopeless teeth with advanced alveolar defects were removed; alveolar sockets of 33 single-rooted teeth were treated by XSD (test group), while 21 extraction sites of single-rooted teeth were left for spontaneous healing (control group). In the test group simultaneously with tooth extraction, two vertical incisions were performed into the alveolar mucosa at the level of neighbouring teeth. After split-thickness flap preparation beyond the mucogingival junction the periosteum was elevated and xenogeneic long-term resorbable membrane was fixed by titanium pins. In addition, subepithelial connective tissue graft was inserted into the supraperiosteal tunnel to increase the soft tissue volume. In the control group after extraction no additional therapy was performed. After an average 7.5 months healing control postoperative CBCT scans were performed, pre-, and postoperative CBCT data sets were compared to each other by a digital measurement process. Orovestibular, vertical socket dimensions and socket areas were assessed.

Study II

Horizonto-vertical GBR procedures were performed with split-thickness flap design to evaluate horizontal and vertical hard tissue changes and demonstrate the efficiency of the split-thickness flap. 19 patients with severe 3D hard tissue volume loss were selected and treated; in 6 surgical sites implants were inserted simultaneously with GBR (simultaneous group), while 18 surgical sites were treated by staged protocol, implants were inserted 9 months after GBR (staged group). After midcrestal incision on the keratinized mucosa at the edentulous area, full-thickness flap preparation was followed by split-thickness flap preparation beyond the mucogingival junction. Periosteal layer was elevated from bone surface, composite graft (1:1 mixture of particualted autogenous bone + bovine-derived xenograft) was placed laterally and supracrestally to the alveolar ridge covered by a non-resorbable dense-polytetrafluorethylene (d-PTFE) membrane fixed by titanium pins. In the simultaneous group implants were inserted before the grafting procedure. Double layer wound closure without periosteal incisions was performed. After 9 months healing, membranes and titanium pins were removed and in the simultaneous group implant uncovery, while in the staged group implant placement was performed. During the surgical interventions, horizontal and vertical hard tissue dimensions were measured with periodontal probe, in the staged group additional digital measurements of hard tissue changes were performed based on pre-, and postoperative CBCT data sets.

Study III

Following digital implant position planning and half-guided implant placement with surgical motor, or torque-wrench, the reached implant position was compared to the planned implant position to evaluate the implant placement accuracy. Full-thickness flap preparation and implant osteotomy was performed as a part of a haf-guided surgical protocol. Forty implant placements were performed, 20 implant insertions were carried out by a contra-angled surgical handpiece (machine-driven group), while another 20 implants were inserted by a torque-wrench (manual group). Duration of implant insertion and final insertion torque were registered. After the healing, preoperative CBCT data sets were aligned to the postoperative digital intraoral scans to evaluate implant placement accuracy, based on the differences between planned and the actual implant positions. Following parameters were recorded: global coronal and global apical deviations, coronal and apical x,y,z deviation vectors, horizontal coronal and apical deviations, angular deviation.

4. RESULTS

Study I

In the test group after XSD approach healing was uneventful. At reentry, expected amount of hard tissue was observed, which seemed vital during implant osteotomy. Implant placement was performed in 14 cases without any additional hard tissue augmentation method, 5 cases received implants with minor simultaneous GBR procedure, while 6 sites treated first with GBR procedure and after 6 months healing implants were inserted. Four patients from the remaining 8 patients received fixed partial dentures with pontics at the treated site, while 4 patients received their prosthetic rehabilitation elsewhere. In the control group, clinical data were not recorded, only radiographic evaluation was performed.

Since postextractional alveolar hard tissue changes were mainly observed close to the crestal level, thus horizontal hard tissue change evaluations were only reported on the coronal third of the socket, further data are not shown. In the test group, baseline hard tissue dimensions were considerably less in the midbuccal section compared to the control group. For example, in the midbuccal section the mean orovestibular dimension ranged from 1.4 - 4.8 mm in the test group compared to 4.7 - 7.5 mm in the control group. A similar baseline situation was observed in terms of vertical dimension and socket area. In the test group, baseline midbuccal vertical dimension averaged 11.6 ± 4.4 mm buccally, compared to 17.5 ± 5.6 mm was in the control group. Mean baseline midbuccal socket area was 122.8 ± 50.5 mm^2 in the test group, 163.8 ± 52.7 mm^2 in the control group.
Hard tissue dimension changes were calculated with subtraction: preoperative values were subtracted from postoperative values, thus negative outcomes indicate hard tissue gain, while positive result point towards hard tissue loss. In the midbuccal section, orovestibular dimension, vertical dimension and socket area changes were significantly less in the test group compared to the control group. In the test group orovestibular dimension changes were significantly less in most sections compared to the control group. Vertical hard tissue dimension changes are best seen in the midbuccal section: in the buccal site vertical dimension changes were almost the same in both groups, but while in

the control group an average 2.26 ± 2.41 mm hard tissue loss was observed, in the test group an average 2.23 ± 3.35 mm hard tissue gain was detected. In the test group, socket area yielded an average 11.34 ± 23.74 mm^2 hard tissue gain, while an average 26.34 ± 20.13 mm^2 hard tissue loss was found in the control group.

Study II

The healing of the GBR procedures was uneventful in 23 out of 24 cases, moderate pain and swelling as reported by the patients. Only 1 site from the staged group showed early membrane exposure without bacterial contamination, in this case, 6 weeks after GBR procedure the d-PTFE membrane was replaced by a resorbable collagen membrane after healing the surgical site was suitable for implant placement with additional connective tissue graft augmentation to compensate tissue loss.

In the simultaneous group, 9 implants were placed in 5 patients' 6 surgical sites. Average clinical vertical dimension change was 3.19 ± 1.88 mm, while average clinical horizontal dimension change was 6.48 ± 0.46 mm. The GBR procedure's success rate was expressed in the simultaneous group, where 100% success rate refers to implant surfaces completely covered with newly formed hard tissue. The success rate of GBR was 92.6% in the simultaneous group. Around 7 of 9 implants were fully covered with hard tissue, around 1 implant a 1 mm buccal bone dehiscence was observed, while around 1 implant a mean 2 mm bone dehiscence was recorded. In this case, the success rate was 50%.

In the staged group, after GBR procedure, 36 implants were inserted in 15 patients' 18 surgical sites. Mean clinical vertical and horizontal dimension gain and was 4.50 ± 2.15 mm and 8.72 ± 2.30 mm, respectively. In the staged group percentage-based success rate was not reported, since all implants were placed in a submerged position determined by the newly formed crestal bone level.

In the staged group, pre-and postoperative CBCT data sets were available to evaluate hard tissue changes. After data set alignment, linear radiographic measurements were performed at the planned implant positions. Mean radiographic vertical and horizontal dimension gain was 4.22 ± 2.03 mm and 8.53 ± 2.37 mm, respectively.

3D volumetric measurements were performed in 11 of 13 surgical sites, pre-and postoperative volume of the surgical area was calculated and subtracted. The average radiographic volume gain was 1.11 ± 0.42 cm^3.

Study III

Tooth-supported surgical templates created by the SMART Guide workflow were accurate and precisely fitted to the dental arch during half-guided implant placement. After implant osteotomy, in the manual group, implant insertion duration was an average 36.40 ± 8.15 s. In the machine-driven group, duration of implant insertion averaged 9.25 ± 1.86 s, which is significantly faster compared to the manual group.
At the end of implant insertion, insertion torque was measured, in the manual group mean insertion torque was 18.75 ± 7.05 Ncm, compared to 21.75 ± 9.75 Ncm in the machine-driven group. No significant difference was found between the groups.

Global deviation parameters were averaged, and results were the following: in the machine-driven group mean global coronal deviation was 1.20 ± 0.46 mm, compared to 1.13 ± 0.38 mm in the manual group, while mean global apical deviation in the machine-driven group was 1.45 ± 0.79 mm, compared to 1.18 ± 0.28 mm in the manual group. No significant difference was found between the groups.

Results of horizontal deviation are the following: horizontal coronal deviation averaged 1.06 ± 0.52 mm in the machine-driven group and 0.92 ± 0.40 mm in the manual group, while a mean horizontal apical deviation was 1.28± 0.83 mm in the machine-driven group and 0.99 ± 0.28 mm in the manual group. No significant difference was found between the groups.

Vertical dimension deviation was measured in the apical end of the implant, mean vertical deviation was 0.55 ± 0.28 mm in the machine-driven group compared to 0.62 ± 0.21 mm in the manual group. No significant difference was found between the groups.

Angular deviation was an average 4.82 ± 2.07° in the machine-driven group and 4.11 ± 1.63° in the manual group. No significant differences were observed between the groups.

5. CONCLUSIONS

Study I

The presented novel XSD approach is based on the recreation of the buccal bony wall after tooth extraction, which proved to be beneficial in maintaining both horizontal and vertical alveolar socket dimensions. This surgical technique is supremely effective in case of EDS class 3 and 4 socket morphologies, therefore many cases presented not only less ridge reduction, but also horizontal and vertical hard tissue gain. This unique phenomenon was confirmed by pre-, and postoperative CBCT data sets with a digital measurement process.

By applying the XSD approach, the need for extensive hard tissue augmentation procedures may avoided or reduced. On the other hand, the quality of newly formed hard tissue was clinically equivalent with native bone, since socket was not filled with xenogeneic material, only collagen sponge was used. The XSD approach showed an excellent post-operative healing with low complication rate, which can be explained with the maintained blood circulation due to the non-conventional, split-thickness flap preparation technique from a remote vestibular incision.

Study II

Based on our findings, it can be concluded that the GBR procedure in combination with a split-thickness flap design delivered optimal outcomes in the treatment of chronic horizonto-vertical alveolar defects. Excellent wound healing with low patient morbidity and low rate of membrane exposures was observed. The bilaminar flap allows for clinicians to achieve extensive buccal flap advancement and the double-layer suturing technique increases flap closure stability over non-resorbable membranes. The applied d-PTFE membrane and composite graft promoted favourable hard tissue formation. These tissue alterations were not only evaluated clinically, but also by a digital radiographic measurement process presenting quantitative data indicating sufficient amount of newly formed hard tissues, creating optimal periimplant conditions.

Study III

The reported prospective, randomized clinical study demonstrated the proof-of-concept that half-guided implant placement with tooth-supported surgical guides can result in an accurate implant positioning either with a surgical motor, or a torque wrench. No significant difference was found between the study groups in implant placement accuracy and insertion torque, therefore the clinicians should choose the applied method based on their own preference. However, implant insertion duration can be significantly reduced with a surgical motor, which may be beneficial for the patient. To evaluate implant placement accuracy, deviation of planned and actual position was broken down to vectors in the three-dimensional space, thus detailed deviation parameters were presented, compared to the literature. The evaluation protocol of implant placement accuracy was based on preoperative CBCT data sets and postoperative intraoral scan files to reduce patients' irradiation dose. This imaging process should replace the conventional radiographic imaging protocol during investigation of implant placement accuracy to minimize irradiation dose.

6. BIBLIOGRAPHY OF THE CANDIDATE'S PUBLICATIONS

Related publications

Study I

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