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Efficacy of autogenous tooth roots for lateral alveolar ridge augmentation and staged implant placement. A prospective controlled clinical study.

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Conflict of Interests and Source of Funding

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Abstract

Objectives: To assess and compare the efficacy and safety of autogenous tooth roots (TR) and autogenous bone blocks (AB) for lateral alveolar ridge augmentation and two-stage implant placement.

Material & Methods:

A total of 30 patients in need of implant therapy and lateral ridge augmentation were allocated to parallel groups receiving either 1) healthy autogenous tooth roots (e.g. retained wisdom or impacted teeth) (n=15), or 2) cortical autogenous bone blocks harvested from the retromolar area. After 26 weeks of submerged healing, the primary endpoint was defined as the crestal ridge width (mm) (CW26) being sufficient to place an adequately dimensioned titanium implant at the respective sites.

Results: Soft tissue healing was uneventful in both groups. CW26 at visit 6 allowed for a successful implant placement in all patients of both TR (15/15) and AB groups (15/15). Mean CW26 values amounted to 10.06±1.85 mm (median: 11.0) in the TR and 9.20±2.09 mm (median: 8.50) in the AB group, respectively. The difference between both groups did not reach statistical significance (P=0.241).

Conclusions: TR may serve as an alternative graft to support lateral alveolar ridge augmentation and two-stage implant placement.

Clinical Relevance

Scientific rationale for the study: Recent experimental studies have indicated that dentin reveals a structural and biological potential to support the regeneration of osseous defects.

Principal findings: At 26 weeks, TR grafts were as effective as AB grafts in obtaining a clinically sufficient CW to insert adequately dimensioned titanium implants in the former defect area. Secondary performance endpoints revealed significantly higher CWg values and lower GR values in the TR group.

Practical implications: TR grafts may be associated with a better maintenance of the grafted volume than AB grafts.

Introduction

Various experimental studies provide evidence that extracted teeth reveal a structural and biological potential to support osseous defect regeneration (Catanzaro-Guimaraes et al. 1986; Andersson et al. 2009, 2010; Bormann et al. 2012; Atiya et al. 2014; Qin et al. 2014). This was particularly true for dentin, which constitutes about 90% type- I collagen, and a similar anorganic (69.3% vs. 62%) and organic (25% vs. 17.5%) composition as bone (Brudevold et al. 1960; Linde 1989; Leonhardt 1990).

A recent series of animal studies employing a canine model investigated the efficacy of extracted tooth roots (TR) for lateral alveolar ridge augmentation and two-stage implant placement (Schwarz et al. 2016a, 2016c; Becker et al. 2017). In particular, the roots were separated from either healthy, endodontically treated, non-infected, or periodontally diseased upper premolars and used as block grafts at chronic-type horizontal alveolar ridge (0-wall) defects. Cortical autogenous bone (AB) blocks harvested from the retromolar area served as controls. Histological, immunohistochemical and micro-computed tomographic analyses of various outcome measures did not reveal any significant differences between the groups investigated and pointed to a gradual replacement resorption of both TR and AB grafts (Schwarz et al. 2016a, 2016c; Becker et al. 2017).

These outcomes have recently been confirmed in a proof-of-concept human case report. Clinical re-entry at 24 weeks revealed, that the transplanted root derived from a retained upper wisdom tooth was homogeneously incorporated at the former defect site. The gain in ridge width amounted to 4.5 mm and allowed for a successful implant placement (Schwarz et al. 2016b). All these data may justify a further investigation of this treatment concept.

Therefore, the aim of this prospective clinical study was to assess and compare the efficacy and safety of autogenous TR and AB blocks for lateral alveolar ridge augmentation and two-stage implant placement.

Material and Methods

Study design and participants

In this prospective controlled clinical monocenter study, a total of 30 patients, each exhibiting either tooth gaps or free-end situations with an insufficient horizontal ridge width and being in need of an implant supported fixed restoration were included. In the presence of one or more caries-free wisdom teeth (i.e. partially/ fully retained or impacted) without signs of local pathologies (e.g. cysts), the respective patient was allocated to the TR group (n=15; mean age: 41.93 years; range between 19 and 60 years). In the absence of any suitable wisdom teeth, the patient was allocated to the AB group (n=15; mean age: 44.53 years; range between 21 and 60 years). The study design also included a third parallel group. In these patients, TR (i.e. canines, premolars and molars) were used to simultaneously augment bone deficiencies noted at the buccal aspect of the respective extraction socket. Due to differences in the surgical protocol, these data will be reported elsewhere.

Each patient was given a detailed description of the procedure and was required to sign an informed consent before participation. The study protocol was approved by the ethics committee of the Heinrich Heine University, Düsseldorf, Germany and registered via the Internet Portal of the German Clinical Trials Register (DRKS00009586).

The present reporting considered the checklist items as proposed in the STROBE statement.

Sample size calculation

For the power analysis, a standard normal distribution was assumed. The probability of a Type I error was set at .05, while the probability of a Type II error was set at .20. Sigma was estimated based on the standard deviations observed in a recent preclinical animal study (Schwarz et al. 2016a). Defining clinical width of the alveolar ridge as primary outcome variable, a clinically relevant difference was set at 2 mm. In order to achieve 95% power, a sample size of 15 patients was calculated (Power and Precision, Biostat, Englewood, USA).

Inclusion criteria

The patient had to be fully able to understand the nature of the proposed surgery and able to sign an ethics committee-approved informed consent form. Patients were included in the study if they presented all of the following conditions: 1) Age 18 to 60 years, 2) candidate for lateral ridge augmentation, 3) insufficient bone ridge width at the recipient site for implant placement, 4) sufficient bone height at the recipient site for implant placement, 5) healthy oral mucosa, at least 3 mm keratinized tissue.

Exclusion criteria

The patients were not included in the study if they presented one of the following conditions: 1) general contraindications for dental and/or surgical treatments, 2) inflammatory and autoimmune disease of the oral cavity, 3) uncontrolled diabetes (HbA1c > 7%), 4) history of malignancy requiring chemotherapy or radiotherapy within the past five years, 5) previous immunosuppressant, bisphosphonate or high dose corticosteroid therapy, 6) smokers, 7) pregnant or lactating women.

Outcome assessments

The primary endpoint was defined as the clinical width (CW) of the alveolar ridge being sufficient for the placement of an adequately dimensioned dental implant without the need for a secondary grafting at 26 weeks after surgery in either group. CW was assessed immediately before (CWb) and after (CWa) augmentation, as well during re-entry at 26 weeks (CW26). Measurements were performed to the nearest 0.25 mm at 2 mm below the crest by using a caliper. Secondary endpoints considered performance (i.e. gain in ridge width (CWg) (mm) = CW26 - CWb, graft resorption (GR) (mm) = CWa – CW26) and safety (soft tissue dehiscences (yes/ no), wound infections (yes/ no)) assessments. Safety outcomes were recorded at day 10 as well as at weeks 4, 13, and 26 weeks after surgery.

According to the clinical standard procedure, appropriate radiographs were taken before and after the respective surgical interventions (i.e. alveolar ridge augmentation and implant placement). All measurements were performed by one previously calibrated investigator. The study outline and the follow-up visits are summarized in Table 1.

Treatment procedures

Lateral ridge augmentation was accomplished according to a standardized procedure (Schwarz et al. 2016b).

Under local anesthesia, mucoperiosteal flaps including respective adjacent teeth were prepared using micro-blades and elevated (2 vertical releasing incisions) to expose the respective target sites. This was followed by a careful removal of all granulation tissue from the defect area.

In the TR group, a second mucoperiosteal flap was elevated to surgically remove the respective wisdom tooth (Fig. 1a). After its removal and during the same surgery, the crown was decapitated at the cemento-enamel junction using a rotating carbide bur under gentle water (i.e. sterile saline) cooling and the exposed pulp was preserved. The separated tooth root was adapted to match the size and shape of the defect area (Fig. 1b). To improve ankylosis between the graft and the defect site, the layer of cementum at the respective downward aspects of the root was carefully removed using a diamond bur until the underlying dentin was entirely exposed (Schwarz et al. 2016a) (Fig. 1b).

In the AB group, the monocortical block grafts were harvested from the retromolar region (i.e. linea obliqua) by using a combination of rotating (i.e. carbide burrs) and piezoelectric (mectron, Cologne, Germany) instruments (Fig. 2a). The precise location of the donor site was selected based on preoperative radiographic assessments of relevant anatomical structures (e.g. course of the mandibular canal, availability of bone).

To improve the contact between both TR and AB grafts, the recipient site was gently flattened using a round carbide bur under meticulous water (i.e. sterile saline) cooling.

Subsequently, both TR and AB grafts were predrilled and fixed using one to two titanium osteosynthesis screw (1.5 x 9 mm, Medicon, Tuttlingen, Germany) (Figs. 1d and 2c). Periosteal-releasing incisions were performed to advance the mucoperiosteal flaps, which were repositioned coronally and fixed with vertical double sutures in a way to ensure a submerged healing condition (Fig. 2d). All patients were provided with a perioperative antibiotic- (1 x Amoxicillin 2 g) as well as a peri- and postoperative (2 days) antiphlogistic prophylaxis (Prednisolon, total of 40 mg). Analgetics (Ibuprofen 600 mg) were prescribed and used as necessary. Suture removal was performed at 10 days.

After 26 weeks of healing, a mucoperiosteal flap was elevated to expose the target site in the respective groups. After a gentle removal of the osteosynthesis screw, commercially available titanium implants (Bone Level® Tapered SLActive®, Institut Straumann AG, Basel, Switzerland) were inserted in an epicrestal position.

Postoperative care

Following surgery, patients were instructed to rinse twice daily with chlorhexidine mouth rinse (0.12%) for 1 week and were instructed not to brush or floss at the surgical site for the first 3 weeks and then only gently with a soft bristle brush, avoiding the grafted area.

Statistical analysis

The statistical analysis of the pseudonymised data sets was accomplished using a commercially available software program (IBM SPSS Statistics 24.0, IBM Corp., Armonk, NY, USA).

Mean values, standard deviations, medians, 95% confidence intervals (CI) and frequency distributions were calculated for all primary and secondary outcomes assessed. The data rows were examined with the Shapiro-Wilk test for normal distribution. Between group comparisons were accomplished using the unpaired t-test. Linear regression analyses were used to depict the relationship between CWg and CWb as well as graft thickness (GT) values in both groups. The alpha error was set at 0.05.

Results

Mean CWb values were comparable (P=0.164) in both groups and amounted to 4.53±1.54 mm (median: 4.50; 95% CI: 3.68;5.38) in the TR and 5.26±1.25 mm (median: 5.00; 95% CI: 4.57;5.95) in the AB group, respectively. Graft thickness (GT) was also comparable in both groups (P=0.22), revealing 5.66±1.75 mm (median: 5.0; 95% CI: 4.69;6.64) in the TR and 4.96±1.75 mm (median: 5.0; 95% CI: 4.24;5.68) in the AB group.

The primary and secondary performance endpoints assessed in both groups are summarized in Table 2.

Primary endpoint

In all patients of both TR (15/15) and AB groups (15/15), CW26 at visit 6 allowed for a successful placement of an adequately dimensioned titanium implant (diameter: 4.1 mm) at respective sites. In particular, mean CW26 values amounted to 10.06±1.85 mm (median: 11.0; 95% CI: 9.03;11.09) in the TR and 9.20±2.09 mm (median: 8.50; 95% CI: 8.04;10.35) in the AB group, respectively. The difference in mean CW26 values between both groups did not reach statistical significance (P=0.241) (Table 2).

Secondary endpoints

Secondary performance endpoints

Mean CWa values were not significantly different between both groups (P=0.955) and amounted to 10.20±1.70 mm (median: 10.00; 95% CI: 9.24;11.14) at TR and 10.23±1.52 mm (median: 10.00; 95% CI: 9.39;11.07) at AB sites, respectively. At 26 weeks, the resulting GR values were significantly lower (P=0.029) in the TR (0.13±0.97 mm; median: 0.00; 95% CI: -0.4;0.67) when compared with the AB group (0.13±0.97 mm; median: 0.00; 95% CI: -0.4;0.67). This was associated with significantly higher (P=0.014) CWg values at TR (5.53±1.88 mm; median: 5.00; 95% CI: 4.48;6.57) over AB (3.93±1.41 mm; median: 4.00; 95% CI: 3.15;4.71) treated sites (Table 2). At one implant site in the AB group, graft remodeling necessitated a secondary simultaneous augmentation of a dehiscence-type defect (Fig. 4d).

Secondary safety endpoints

Soft tissue wound healing was commonly considered as uneventful in both groups. None of the sites investigated neither revealed any signs of primary or secondary soft tissue dehiscences nor graft exposures (Figs. 3a and 4a). An exposure of the screw head was noted in two patients at Visit 6 (TR=1; AB=1) but not associated with any signs of wound infection.

Clinical Observations during Re-entry

In some patients, preoperative (i.e. before implant placement) cone-beam CT scans were obtained as part of the clinical standard procedure. The radiographic images of the target areas revealed a homogeneous density of both TR and AB blocks without showing any signs for a graft separation from the recipient site. Clinical re-entry at Visit 6 confirmed a homogeneous integration of both TR and AB grafts in the former defect area. This was evidenced by a firm graft connection to the host bone and a circumferential, overgrowing hard tissues formation (Figs. 3b-d and 4b).

While AB grafts were frequently associated with a moderate to pronounced graft resorption at the outer surface (Figs. 4b-d), the peripheral contour of TR grafts was commonly well preserved (Figs. 3b and d). In both groups, implant bed preparation revealed comparable bleeding characteristics within the grafted hard tissue areas. At TR grafted sites, this was commonly associated with an undermining replacement of the dentinal matrix by a newly formed hard tissue. All implants could be inserted with good primary stability (i.e. no clinical mobility).

Regression analysis

The linear regression analysis failed to reveal a significant correlation between CWg and CWb values (Figs. 5a and b), but pointed to a significant correlation between CWg and GT values (Figs. 5c and d) in both TR (Coef: 0.92; P=0.00) and AB groups (Coef: 0.694; P=0.01), respectively.

Discussion

The aim of the present study was to assess and compare the efficacy and safety of TR and AB grafts for lateral alveolar ridge augmentation and two-stage implant placement.

Basically, the assessment of primary and secondary performance endpoints revealed, that both TR and AB grafts resulted in clinically important CW26 and CWg values, thus allowing the insertion of adequately dimensioned titanium implants in all patients (100%/ 100%) investigated. In both groups, mean CWg values were significantly correlated with GT.

When further analyzing the present data, however, it was noted that TR grafts were associated with significantly higher (P=0.014) CWg values than AB grafts. This difference was mainly due to a less pronounced graft resorption and associated lower GR values in the TR group.

The gain in CW basically corroborates the outcomes noted in a recent proof-of-concept human case report employing the same surgical protocol (Schwarz et al. 2016b). In particular, CW changed from 4.5 mm at baseline to 11.0 mm at 24 weeks, thus resulting in a gain of 6.5 mm. The clinical follow-up examination at about 8 months revealed healthy peri-implant tissue conditions, as indicated by the absence of BOP and PD values ranging between 3 and 4 mm (Schwarz et al. 2016b). Recently, the clinical performance of TR grafts for lateral alveolar ridge augmentation has also been confirmed in a prospective case series (Pohl et al. 2017). In four patients, TR blocks were derived from impacted teeth and used for lateral grafting. After a healing period of 3 to 6 months, all sites were healed without complications and the surgical procedure allowed for a successful implant placement. Radiographic bone levels and PD scores remained almost unchanged during a follow-up period of 2 years (Pohl et al. 2017).

Similarly, mean CWg values (3.93±1.41 mm) noted in the AB group at 26 weeks also corroborate previous clinical data investigating lateral alveolar ridge augmentation using different types of intraoral block grafts (i.e. ramus, chin) (Buser et al. 1996; Cordaro et al. 2002; von Arx & Buser 2006; Acocella et al. 2010; De Stavola & Tunkel 2013).

In particular, after 7 to 13 months of submerged healing, Buser et al (1996) reported on a gain of 3.5 mm to 7.1 mm, when AB grafts were covered by expanded-polytetrafluoroethylene membranes. Similarly, Cordaro et al. (2002) reported on a mean gain of 3.67 mm at 4 months following AB (i.e. ramus) application, with a higher gain of 3.93 mm when AB grafts were protected by a bovine derived xenograft and covered by a native collagen membrane. The latter approach (i.e. contour augmentation) was also investigated by von Arx & Buser and resulted in a mean gain of 4.6 mm (range 2-7 mm; ramus and chin grafts) and only a minor GR of about 0.36 mm after a mean healing period of 5.8 months. In contrast, Acocella et al. (2010) and De Stavola & Tunkel (2013) reported on significant gains in horizontal ridge and only minor graft resorptions (0.25 ± 0.29 mm) at 3 to 9 months following application of unprotected AB (i.e. ramus) blocks.

All these findings, taken together with the results of the present study seem to indicate that, after a healing period of 4 to 9 months, GR values vary considerably at unprotected AB grafts. The pronounced graft remodeling might be explained by the substantial amount of non-vital bone areas along with a weak vascular organization noted at AB blocks following grafting (Acocella et al. 2010). In contrast, the lower GR values noted at TR grafted sites may be mainly due to the preservation of the cementum layer, which in turn may have supported a collagen fibre attachment and prevented a superficial root resorption (Nyman et al. 1980). As opposed to the preservation of the outer contour of TR grafts, recent histological analyses have pointed to a basal ankylosis and subsequently replacement resorption of the exposed dentinal matrix facing the alveolar bone (Schwarz et al. 2016a; Schwarz et al. 2016c; Becker et al. 2017). The latter finding was also confirmed during re-entry and implant drilling at 26 weeks, clearly pointing to an undermining replacement of the dential matrix of TR grafts by a vital (i.e. bleeding) bone-like tissue structure. Due to ethical concerns, the present study did not consider the harvesting of core biopsies for further histological analyses.

When further interpreting the present analysis, it was also noted that the soft tissue wound healing over 26 weeks was uneventful in both groups, thus pointing to the high biocompatibility and safety of TR grafts.

In this context, it must be emphasized that a compromized soft tissue healing with premature graft exposures is one of the major complications associated with the application of AB blocks, thus compromizing the overall gain in CW (Aloy-Prosper et al. 2015; Sanz-Sanchez et al. 2015). Nevertheless, the stability of the augmented TR sites after loading and its influence on implant survival and success needs to be carefully addressed in future studies.

In conclusion and within its limitations, the present clinical study revealed that TR may serve as an alternative graft to support lateral alveolar ridge augmentation and two-stage implant placement.

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Figure legends

Fig. 1**.** Lateral ridge augmentation - surgical procedure in the TR group.

a. TR grafts were derived from either partially/ fully retained or impacted wisdom teeth.

b. Following crown decapitation, the most suitable root was separated and shaped to match the defect size.

c. To improve ankylosis at the defect site, dentin was exposed at the downward aspect of the root. The exposed pulp was preserved as part of the TR grafts.

d. Graft positioning and adaptation using an osteosynthesis screw. No further contour augmentation was provided.

***Fig. 2*.** Lateral ridge augmentation - surgical procedure in the AB group.

a. Mono-cortical bone blocks were harvested from the retromolar area.

b. Shaped and predrilled AB block to match the size and configuration of the defect site.

c. Block immobilization using a central osteosynthesis screw. No further contour augmentation was provided.

d. AB and TR grafts were left to heal in a submerged position – suture removal was accomplished at Visit 3.

***Fig. 3*.** Representative clinical outcomes in the TR group.

a. Soft tissue wound healing was uneventful in all patients (Visit 6 - refers to the case shown in Fig. 1d).

b. Homogeneous graft integration at the former defect site. The outer contour of TR grafts was commonly well preserved (Visit 6 - refers to the case shown in Fig. 1d).

c. Clinical situation following TR graft adaptation and fixation (Visit 2).

d. Firm graft integration and partial substitution by a newly formed hard tissue (Visit 6).

Fig. 4. Representative clinical outcomes in the TR group.

a. Soft tissue wound healing was also uneventful in all patients (Visit 6 - refers to the case shown in Fig. 2).

b. AB grafts were well integrated at the former defect site, however, commonly revealed a pronounced peripheral resorption (Visit 6).

c. Clinical situation following AB graft adaptation and fixation (Visit 2).

d. An almost entire resorption of AB necessitated a secondary simultaneous grafting at implant placement (Visit 6).

Fig. 5 Linear regression plots to depict the relationship between CWg and CWb/ GT values.

a. CWb (TR group)

b. CWb (AB group)

c. GT (TR group)

d. GT (AB group)

Tables

Table 1.

Study design and follow up visits (D=day; W=week).

Visit 1	Visit 2	Visit 3	Visit 4	Visit 5	Visit 6
Recruitment	**Surgery**				**Re-entry**
	D0	D10	W4	W13	W26

Table 2.

Primary and secondary performance endpoints (in mm).

a) TR Group (n= 15 patients)

	CWb	CWa	CW26	GR	CWg
Mean	4.53	10.20	10.06	0.13*	5.53**
SD	1.54	1.70	1.85	0.97	1.88
Median	4.50	10.00	11.00	0.00	5.00
95% CI	3.68;5.38	9.24;11.14	9.03;11.09	-0.4;0.67	4.48;6,57

b) AB Group (n= 15 patients)

	CWb	CWa	CW26	GR	CWg
Mean	5.26	10.23	9.20	1.03	3.93
SD	1.25	1.52	2.09	1.15	1.41
Median	5.00	10.00	8.50	1.50	4.00
95% CI	4.57;5.95	9.39;11.07	8.04;10.35	0.39;1.67	3.15;4,71

Comparisons between groups (unpaired t-test): * P=0.029; ** P=0.014

CW=clinical width of the alveolar ridge

b=immediately before augmentation (D0)

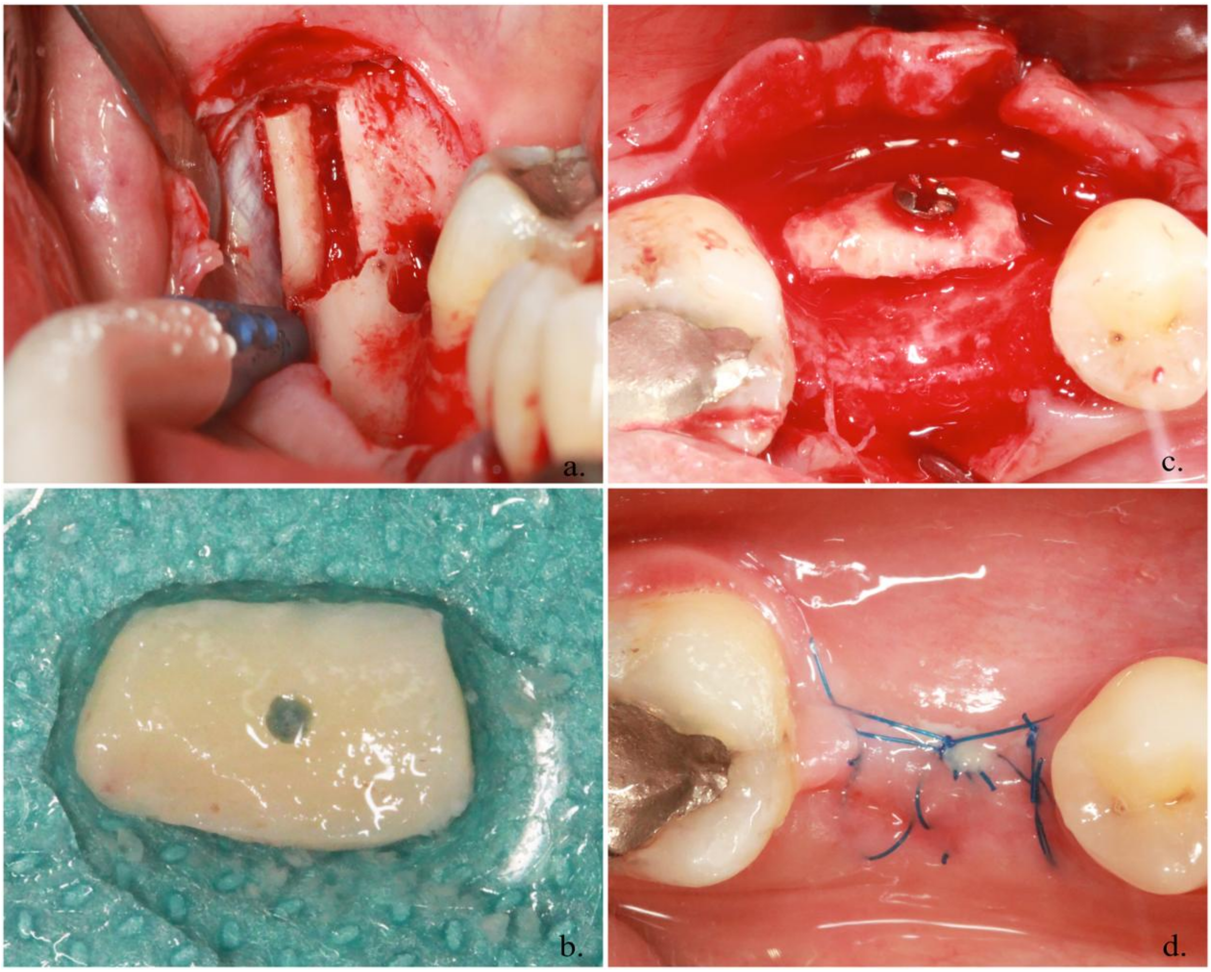
a=immediately after augmentation (D0)

26=during re-entry at 24 weeks (W26)

GR=graft resorption

CWg=gain in ridge width


a.
c.
b.
d.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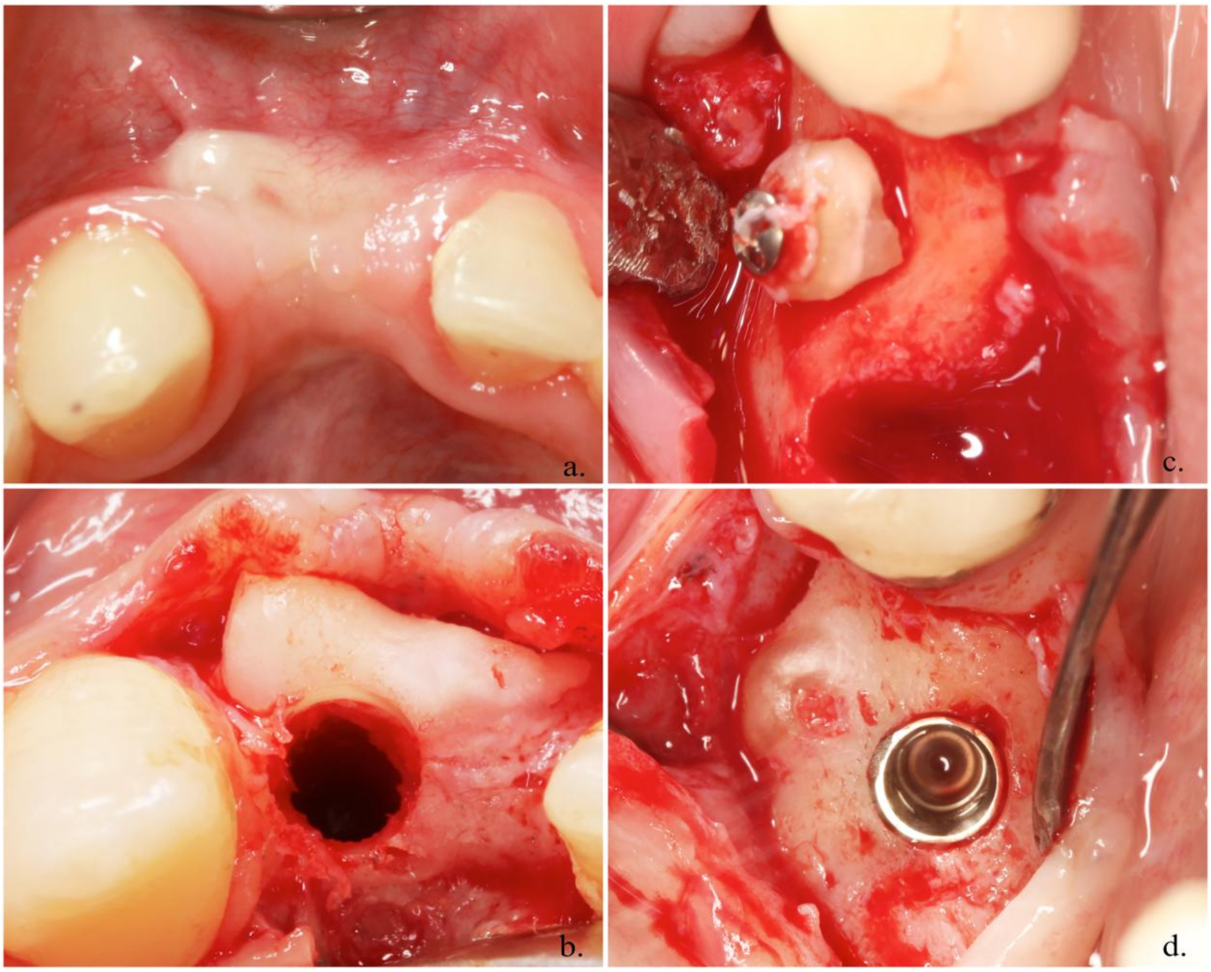
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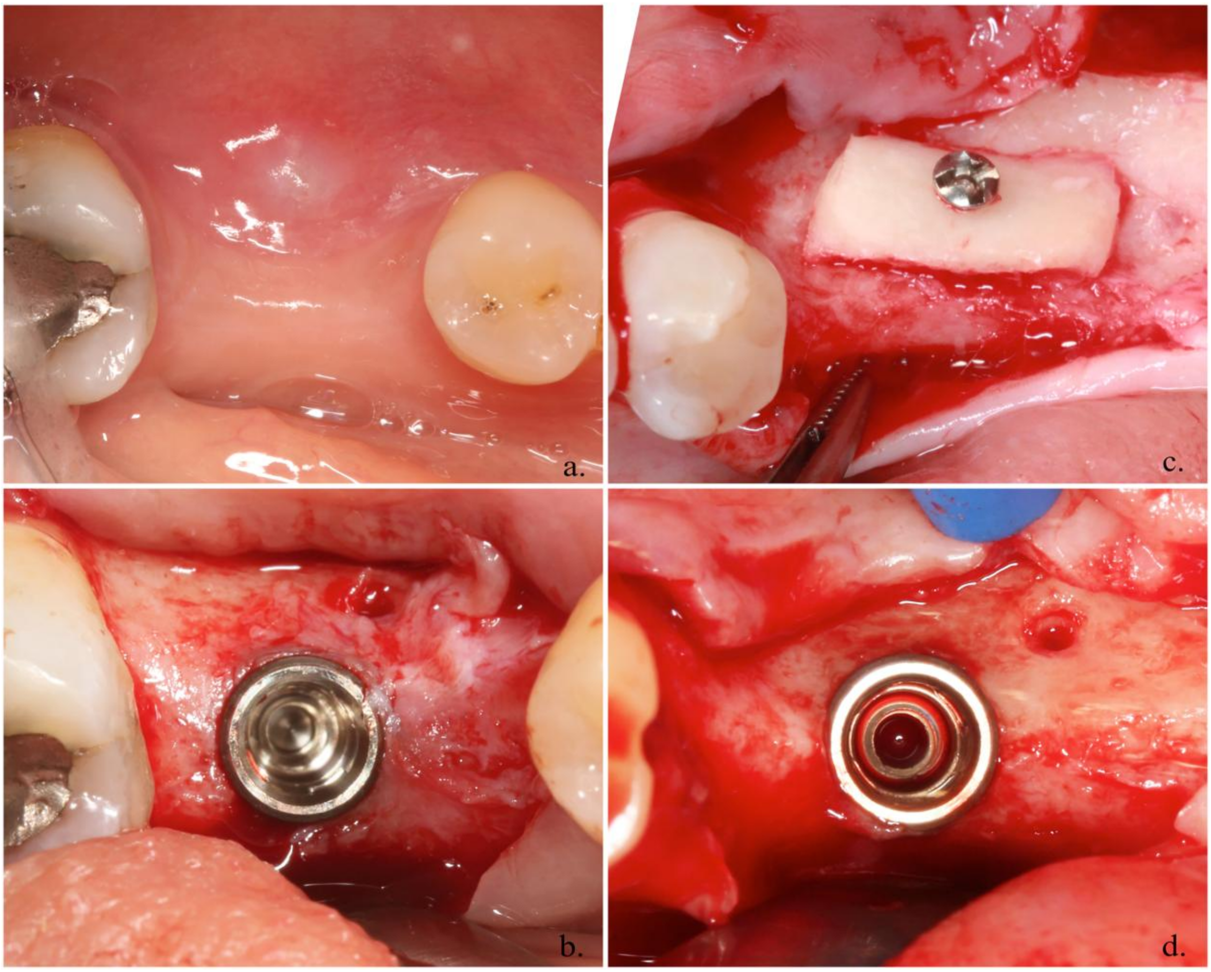
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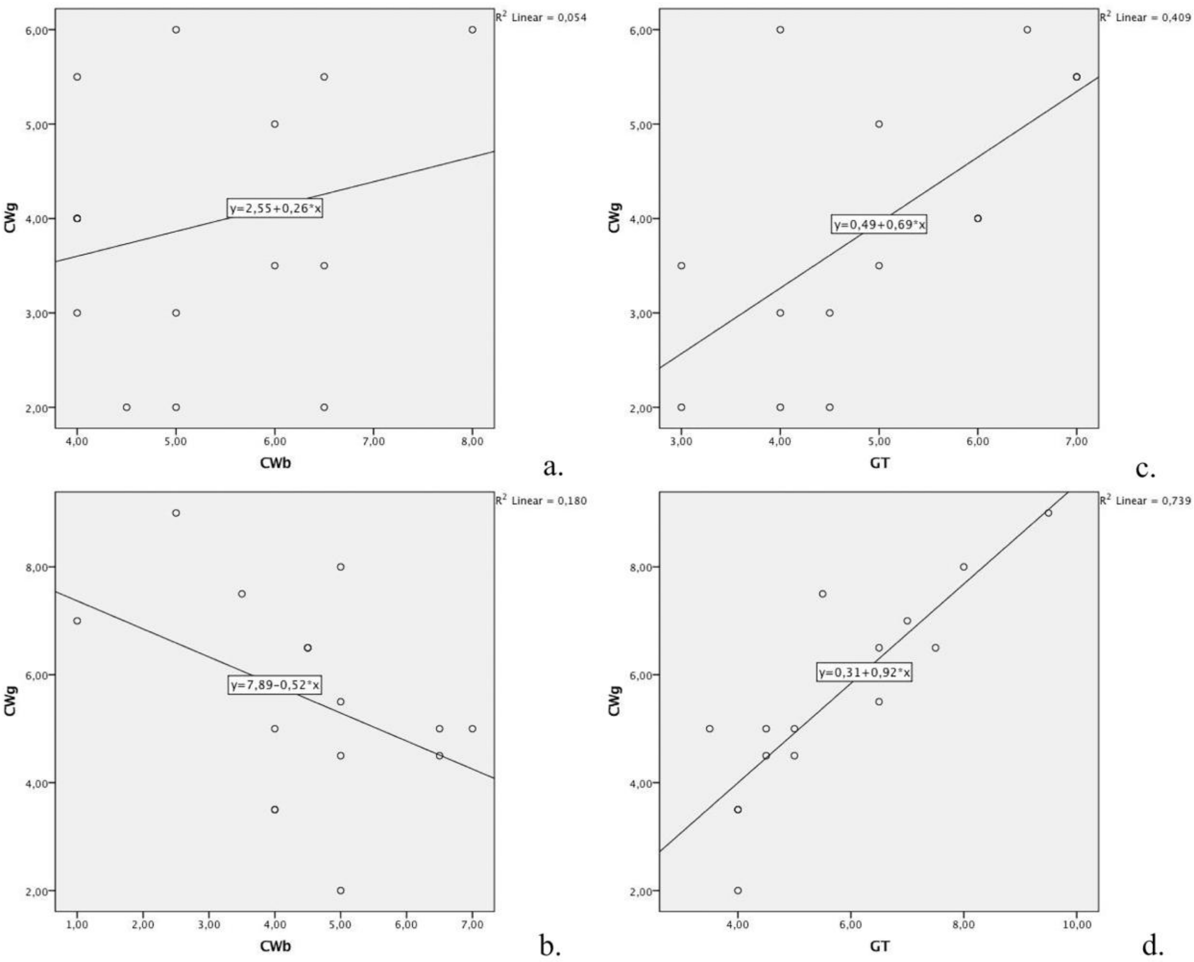
R² Linear = 0,054
y=2,55+0,26*x
CWg
CWb
a.
R² Linear = 0,180
y=7,89-0,52*x
CWg
CWb
b.
R² Linear = 0,409
y=0,49+0,69*x
CWg
GT
c.
R² Linear = 0,739
y=0,31+0,92*x
CWg
GT
d.