Impact of Computer-Assisted Implantology on Bone Resorption and Papilla Height: Long-Term Implant Success Over a 3- to 10-Year Follow-Up Period

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Research Article

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ABSTRACT

Objectives: Backward planning based on digital volume tomography, augmentation before implantation, and navigated implant insertion may enhance long-term implant success; however, long-term clinical data to support this claim are lacking. Additionally, whether the claim holds true for each type of prosthetic restoration, and whether the type of prosthetic restoration has a significant impact on implant success, remains unclear.

The purpose is to estimate the long-term implant success and two additional scores (peri-implant bone level and gingival papillae height) as a function of the application and manner of computer-assisted implantology.

Materials and methods: A total of 1437 implants placed in 317 patients were retrospectively analysed by examining the digital patient records from May 2009 to May 2021, allowing for a 3-year to 10-year follow-up of individual patients. The influence of the planning method, implantation protocol, and prosthetic restoration on the long-term success was evaluated using the Walton criteria.

Results: Extended backward planning, including 3D radiographs, resulted in more stable long-term bone and papilla conditions for implants placed in previously augmented areas.

Conclusion: Extended backward planning (augmentation of the implant site and navigated insertion of the implant) correlates with long-term implant success.

Clinical relevance: In the context of this study, various clinical parameters had no significant influence on long-term implant success. However, the influence may be enhanced by extended backward planning followed by augmentation and guided implant placement.

Keywords: Dental implants; Cone-beam computed tomography; Retrospective studies; Follow-up studies; Augmentation; Success-rate

INTRODUCTION

To evaluate the long-term success, different implantological procedures were investigated over a 10-year period, including augmentation using autologous bone or allogeneic bone substitutes before implantation, computer-assisted guided implantation, or freehand inserted implantation. The prosthetic Walton scale was used as a parameter for success (Table 1) [1].

Backward planning is a concept for implant insertion where implantologists and dental technicians together draft an individual dental prosthesis rehabilitation plan based on digital, 3-dimensional volume tomography [2]. Advanced backward planning (also referred to as extended backward planning) includes prior augmentation of the implant site and navigated implant placement.

Table 1. Result protocol according to Walton (own presentation based on Walton 1).

Walton category	Evaluation
Walton 1	The success of the prosthetic superstructure
Walton 2	Survival of the prosthetic superstructure (in situ rate)
Walton 3	Unknown result due to lack of follow-up
Walton 4	Patient's death
Walton 5	Successful after-treatment (repair of the prosthetic superstructure)
Walton 6	Unsuccessful after-treatment (failure of the repair of the prosthetic superstructure)

Navigated implant placement

The digital workflow of a navigated implant placement consists of three steps: First, the data acquisition of patient information, including CBCT and intraoral impression or direct digital scanning; second, the digital processing of this information and virtual planning by specialized dental Computer-Aided Design (CAD) software; and third, the Computer-Aided Manufacturing (CAM) of a drill guide by printing the casts and the template. Jung have categorized navigated implant placement into static and dynamic systems [3].

Static systems are those that transfer the calculated implant position into the patient's mouth using surgical templates. In contrast, dynamic systems transmit the selected implant positions to the surgical field using optical imaging instruments on a computer monitor instead of rigid intraoral surgical templates. Static methods can distinguish between semi-guided (template-based guided cavity preparation followed by freehand, manual implant placement) and fully-guided implant surgery (template-based cavity preparation followed by guided implant placement) [4]. All static systems were included in this study.

The benefit for the patient is that an analysis of augmentative and navigated surgical procedures is prepared to ensure long-term success with implants. Additionally, clinical and radiological research can quantify resorptive processes after implantation and augmentation.

Null hypotheses

The following three groups were defined “Group A” (planning and augmentation), “Group B” (implantation and navigation), and Group C (prosthetic superstructure). For “Group B” a total of four null hypotheses were formulated (H5-H8).

Group B: “Implantation and navigation”: Hypothesis (H5-H8)

H5: The implantation mode does not influence the implantation success (Walton 1, Walton 6)

H6: Implant type does not affect implant success (Walton 1, Walton 6)

H7: Loss of implant and region of insertion do not correlate

H8: There is no correlation between implant loss and implant diameter or length

MATERIALS AND METHODS

Study design

This study is a monocentric retrospective case series with a retrospective analysis of digital patient records, image data, and radiographs for parallelwalled and tapered dental implants. The following standardized chronological therapy protocols with defined time intervals were analyzed:

- Implantation, which was performed 6 months after augmentation, if needed.
- Loading of the prosthetics, which was performed 6 months after insertion.
- Continuous six monthly report during clinical follow-up as part of prophylaxis.

The examination period covered a 12-year period from May 2009 to May 2021. Individual patients were followed up with for 3-10 years. One maxillofacial surgeon and one prosthodontist treated all patients. One dental technician fabricated the prosthetics. The products used are shown in Table 2. Each patient took oral antibiotics (Amoxiclav 625 mg or Clindamycin 600 mg, three times a day for 3 days: The day before, the day of, and the day after a surgical intervention).

Patients

The sample size was 1437 implants in 317 patients who were assigned to four age classes.

The patients were assigned to different groups according to prior augmentation (none, autologous, allogeneic), type of implantation (freehand, guided, fully guided), implantation protocol (immediate implantation after extraction, delayed implantation in the healed bone), implant abutment connections (screwed/cemented), and other factors post hoc that are typical of a clinical population. The exclusion criteria were as follows: No systemic or bone related diseases, non-medication, no orthodontic treatment, no dental hypoplasia, no implantation or augmentation while menstruating, and noncompliant patients.

The statistical calculations presented here are based on the number of implants. Individual, patient related factors that may have influenced implant success were not considered.

Data documentation

Electronic data documentation was supported by electronic data collection based on the patient file forms or Case Record Forms (CRFs).

The interproximal papilla dimensions (papilla height) were evaluated using a periodontal probe in the midline of the buccal surface, from the bottom of the gingival pocket to the gingival border. The papilla status was preoperatively determined. The lower of the two values measured in this way was considered the measuring result and constituted the basis for the Jemt gingival papilla indices presented hereinafter. The buccal mucosa biotype was not indicated.

For evaluation of bone height, a CBCT scan before and after augmentation and implantation in case of prior augmentation or guided implantation was used. Using CBCT and OPT, freehand implantation protocols were investigated. In the case of augmentation, three dimensional extensions in the oro buccal, vertical, and mesiodistal directions was measured. In addition to vertical height, these values provide helpful information when using customized bone blocks, including

1. CAD design based on the imaging data,
2. Made of standard allogeneic blocks by CAM processing, and
3. Those delivered to the practice. We used 1.5 mm diameter screws for block fixation or anatomical landmarks for better orientation and evaluation.

Data protection

The data were anonymized for evaluation, and only internal data were used. All patients signed a surgical information sheet. The identification of each subject was unknown to all study participants and researchers, with the exception of the doctor performing the treatment. Each patient was entitled to view the information stored about her or his treatment, which was provided by the treating doctor. All patients were comprehensively informed about their treatment alternatives and decisions, and they were informed that they were free to either participate or refuse participation in this study.

Statistics

The following descriptive and inductive evaluations were performed using IBM Statistical Product and Service Solutions (SPSS) Statistics 27.0. The significance level for all the statistical tests used was 0.05. The significance level was considered missed if the p value was >0.05. Generally, highly significant results were obtained at $p<0.01$. Significant results were obtained at $0.01<p<0.05$. A value between 0.05 and 0.1 was considered slightly significant. Chi square tests examined the relationships between nominal variables. Mann–Whitney test, or, in the case of more than two groups, Kruskal–Wallis test, was conducted to examine ordinal or non-normal group differences.

The implants were restored with the following prosthetic superstructures: Single crown restoration (n=677), partial fixed dental prosthesis (n=555), telescopic crowns (n=54), and bar constructions (n=79) for removable dentures. Partial fixed dental prostheses that connect implants to existing teeth are called splinted crowns (n=72).

Ethical approval

The Ethics Committee of the Medical Association of Westphalia Lippe and Münster University has no fundamental ethical or legal objections to the implementation of the research project (file number: 2020086fS).

The products used are shown in Table 2.

Table 2. Products used in this study in the order in which they are mentioned here in after.

Product	Description (optionally)	Manufacturer
SIC ace	Parallel-walled and tapered dental implant with a self-tapping thread.	SIC invent, Basel, Switzerland
SIC max	Parallel-walled and tapered dental implant with a basic cylindrical implant shape with crestal double microthread	SIC invent, Basel, Switzerland
SIC step drill	Drilling system for atraumatic preparation	SIC invent, Basel, Switzerland
Maxgraft bonebuilder	Allogeneic blank with standard dimensions	Botiss biomaterials, Zossen/Institut Straumann, Basel, Switzerland
Maxgraft granulat	Processed allogeneic bone particles	Botiss biomaterials, Zossen/Institut Straumann, Basel, Switzerland
Allogeneic grafts from voluntary bone donors	CAM-processed allogeneic bone	C+TBA/Cells and Tissue Bank Austria gemeinnützige GmbH, Krems/Donau

RESULTS

Implantation mode and implantation success

H5: The implantation protocol has no influence on the implantation success (Walton 1, Walton 6).

Walton 1: There is no significant association between the implantation protocol and the success rate (chi^2 =0.206, p=0.650) (Figure 1).

Walton 6: There is no significant association between the implantation mode and failure rate (chi^2 =0.965, p= 0.617) (Figure 1).

H5 was confirmed.

Implant type/implant success

H6: Implant type has no influence on implant success (Walton 1, Walton 6).

In the context of this study, two implant types were used: The first had a self-tapping thread design for all indication areas, a basic cylindrical shape with apical, conical taper, and an internal hexagon with long guide surfaces; this implant type is recommended particularly for bone of grades D1 to D3 [5]. The second implant type had a basic cylindrical implant shape with crestal double microthread; this type is recommended especially for "soft bone" (D2, D3, D4), as a high primary stability implant for immediate placement, and, in particular, as a maxillary posterior implant, including all forms of sinus lift [5].

Walton 1: No significant correlation was found (chi^2=0.192, p=0.662) (Figure 2).

Walton 6: No significant effect was found (chi^2=1.727, p=0.422 (Figure 2).

H6 was confirmed. The implant type was not related to the success rate ($chi^2=0.192$, $p=0.662$).

Figure 1. Relationship between implantation mode and implant success according to Walton1, 6. No statistically significant difference between immediate and delayed placement. **Note:** Yes ; NO.

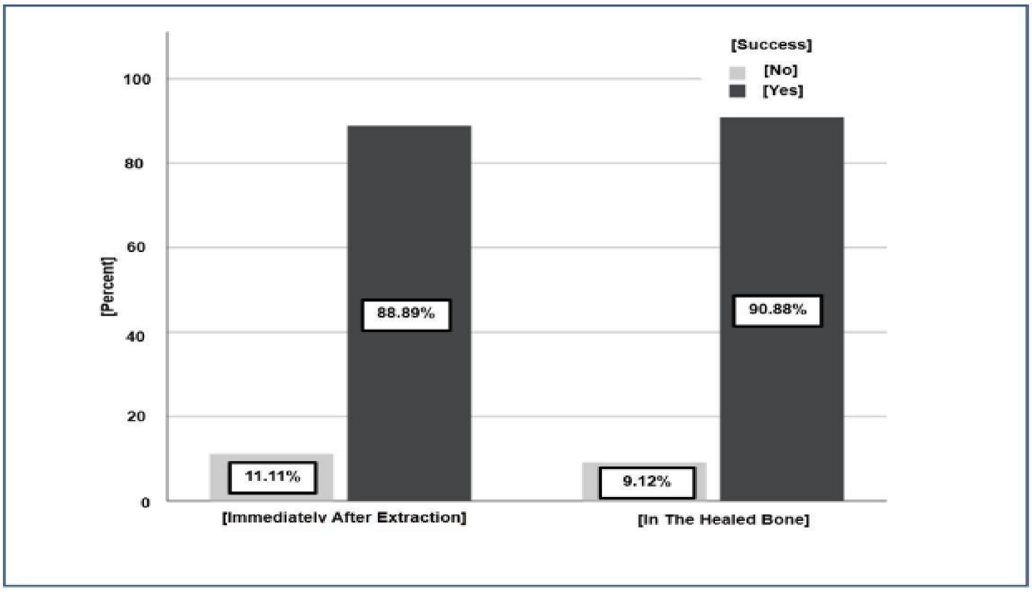
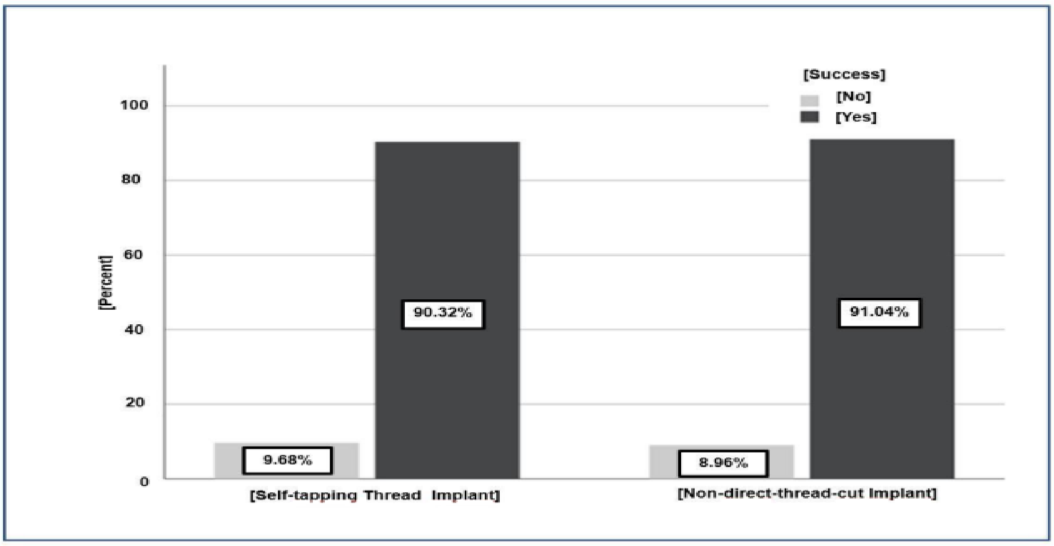


Figure 2. Relationship between implant type and implant success according to Walton1, Walton 6. No significant difference between implant types with different geometries (left: basic cylindrical shape with apical, conical taper/self-tapping thread vs. right: basic cylindrical shape with crestal double microthread/greatly rounded implant tip without a direct thread cut). **Note:** Yes ; NO.



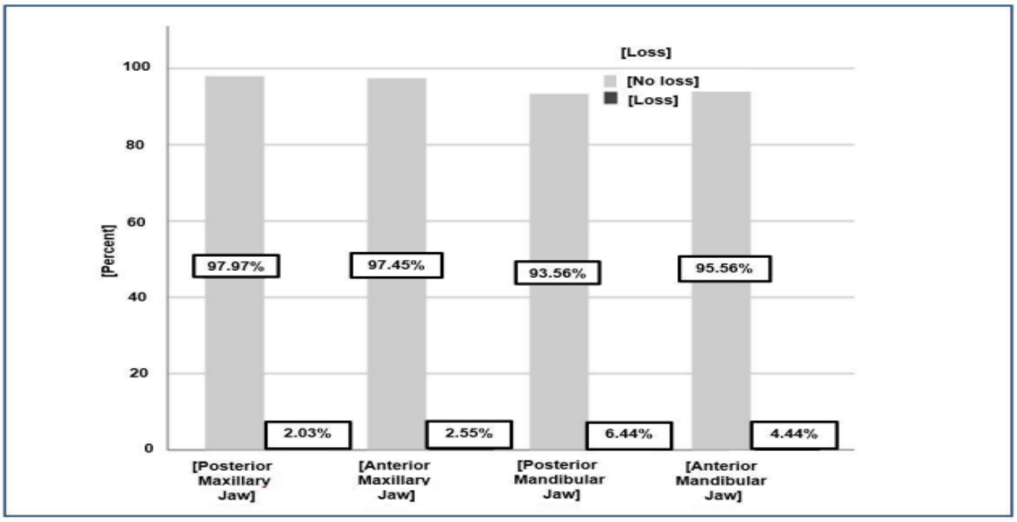
Implant loss/region of insertion

H7: The implant loss rate and the region of insertion do not correlate.

Given the low number of patients for the individual tooth regions, the following four categories were formed: Posterior and anterior maxilla and posterior and anterior mandible. Overall, implant loss was higher in the mandible than in the maxilla, although the differences were not significant (Figure 3).

H7 was confirmed.

Figure 3. Connection between implant loss and the region of insertion. Implant loss was higher in the mandible than in the maxilla, but not significantly higher. **Note:** Loss ; No loss.



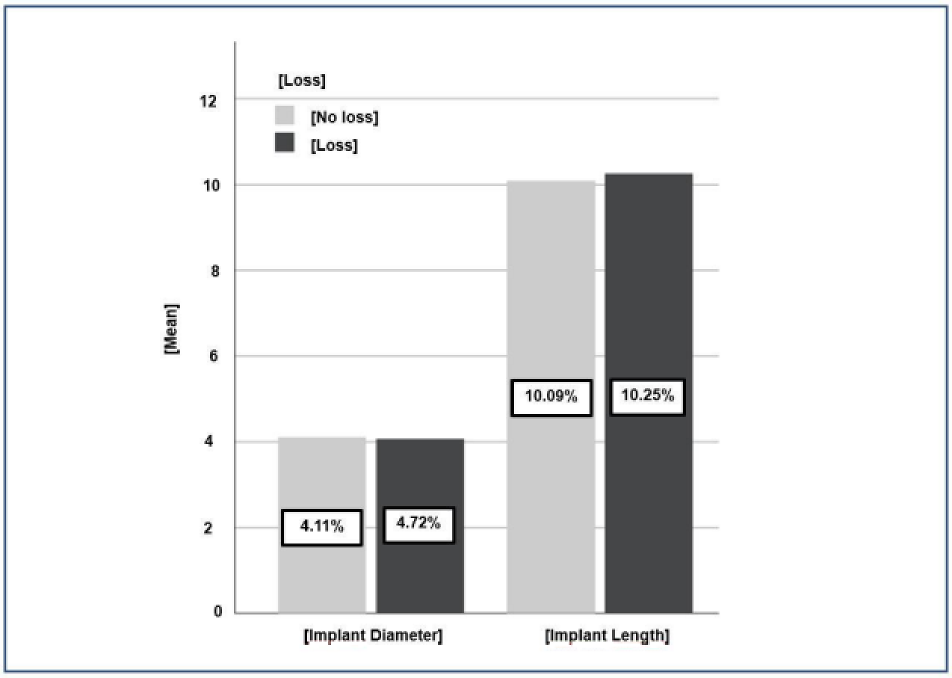
Implant loss/implant diameter or implant length

H8: Implant loss and the implant diameter or the implant length do not correlate.

No significant differences were found (Figure 4).

H8 was confirmed; no significant effects were derived from the associated U-Tests, p>0.05.

Figure 4. Relationship between implant loss and implant diameter or length. No correlation found between implant loss and implant diameter or implant length. **Note:** Loss ; No loss.



The results of the statistical evaluation are summarized in Table 3

Table 3. Table of statistical evaluation results.

Hypothesis	Results
H5	The implantation protocol has no influence on the implantation success.
H6	The implant type has no influence on implant success.
H7	The region of insertion has no influence on implant loss.
H8	Implant loss and the implant diameter or length do not correlate.

DISCUSSION

In this study, we aimed to determine whether it is possible to estimate the long-term implant success and peri-implant bone height and gingival papillae height as a function of implantation protocol or the mode of implantation, respectively. The follow-up extended over a minimum of 3 and a maximum of 10 years. The success criteria were based on the Walton protocol for implant-supported superstructures, with a focus on implantation and navigation.

Discussion of the hypotheses

The study results showed that augmentation of the insertion area had a positive influence on implant success. However, it could not be documented whether the higher implant success with augmentation was due to extended backward planning. The superiority of this planning protocol compared to conventional planning was shown. However, the differences in simple backward planning were not significant. After all, extended backward planning provides more stable bone conditions and higher, or more stable papilla ratios in the long term.

The general superiority of a backward planning protocol was also noted by Mangano who tested a fully digital eight-phase protocol for ceramic single crowns with excellent results [6].

CONCLUSION

Augmentation and extended backward planning are crucial considerations that should be discussed with patients so that they can give informed consent on a reliable and sound basis. Other influencing factors, such as whether to opt for a navigated implantation or not, will have a minor or negligible impact. In a given clinical situation, the practitioner should consider the specific implications of this particular situation.

AUTHORS CONTRIBUTIONS

Manfred Nilius: Data curation, Formal analysis, Project administration, Writing.

Minou Hélène Nilius: Conceptualization, Investigation, Methodology, Resources,

Guenter Lauer: Validation, Supervision.

ETHICAL APPROVAL

The Ethics Committee of the Medical Association of Westphalia-Lippe and Münster University has no fundamental ethical or legal objections to the implementation of the research project (file number: 2020-086-fS).

PATIENTS CONSENT

All patients gave written consent to this study.

FUNDING

No funding was obtained for this study.

CONFLICT OF INTERESTS

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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