Computer Guided Implant Surgery: Is It a Holistic Solution?

Sara M Zayed*

Department of Prosthodontics, Faculty of Dentistry, Alexandria University, Egypt

***Corresponding Author:** Sara M Zayed, Department of Prosthodontics, Faculty of Dentistry, Alexandria University, Egypt.

Abstract

Digital implantology is one of the most imperative innovation drivers in dentistry and the pace keeps escalating. Computer guided implant surgery is dependent on comprehensive diagnostics and precise planning to permit stringent reverse prosthetic driven planning in order to achieve optimised surgical and prosthetic outcome. While improving the safety and efficiency of the surgical procedure computer guided implant surgery renders the restorative outcome more predictable regarding function, biology and aesthetics. Nevertheless, it carries its own risks in terms of manufacturing inaccuracies and application errors. These possible causes of error must be identified and judiciously considered to evade adverse consequences. Therefore, although computer guided implant surgery may seem to provide dental professionals with a holistic, reliable and precise solution it is still in the development stage.

***Keywords:** Digital implantology ; Guided implant surgery; Prosthetic driven implant placement*

Introduction

Currently, dental implants are reported to have high success rates and are regarded as a reliable and highly predictable treatment option to rehabilitate both partially and fully edentulous cases [1,2]. Osseointegration of dental implants is not the only factor to determine implant success, but the implant and the restoration must be surrounded by healthy and stable tissues. Since incorrect implant position can yield peri-implant soft tissue and bone loss, as well as compromise the aesthetic outcome. Therefore, osseointegration relies on adequate surgical and prosthetic handling. Thorough pre-surgical planning is a prerequisite for a successful treatment outcome and should include anatomical as well as prosthetic considerations to precisely position the implants [3]. In consequence, it can be inferred that prosthodontic restoration with dental implants necessitates accurate implant placement for predictable functional, aesthetic and hygienic results [4].

Conventional surgical implants placement involves muco-periosteal flap detachments in order to obtain adequate visibility of the underlying bone structures [5]. Presently, there is an ongoing notable trend in the medical arena towards minimally invasive and computer guided surgical procedures. In oral implantology, interest in minimally invasive surgical procedures as a standard treatment is remarkably growing, such techniques are possible thanks to the integration of computerized tomographic (CT) scans, three-dimensional (3D) surgical planning software, and computer- aided design/computer-assisted manufacture (CAD/CAM) oral appliances that transfer the computerized planning to the surgical field [6]. This even has led to the development of software and digital workflows allowing for the planning and manufacturing of a surgical guide and provisional prosthesis that can be inserted immediately after the implant surgery step [7]. Minimally invasive techniques appeal to a greater number of potential implant patients and is also frequently accompanied with reduced total rehabilitation duration and economic benefits. Implant surgery is termed "Minimally invasive" referring to exclusion of bone grafts, and/or prevention of intra- and post-operative patient morbidity in terms of pain, swelling, bleeding, or prolonged operating time [8].

Accordingly, digital implantology with computer guided implant surgery can offer a wise treatment option to satisfy the tremendously growing demands and can be regarded as one of the most imperative innovation drivers in dentistry and its pace keeps rising.

What is computer guided implant surgery?

Guided implant surgery was introduced into clinical practice over a decade ago to aid in accurate, safe, and predictable implant placement and decrease human error intra-operatively [3]. It allows the transfer of the virtually planned rehabilitation project directly to the surgical field by using a surgical guide.

According to glossary of prosthodontic terms [9] Surgical guide is: a guide used to assist in proper surgical placement and angulation of dental implants. Traditionally, implant surgical guides were prepared on models, which are separate from CT data and were employed only as a position indicator for reference of the placement position intra-operatively. The major limitation of this technique is that it does not provide information on implant placement depth [10].

On the other hand, nowadays, digitalization is one of the main current developments so fully digital and model-free approaches are now available. The computer guided surgical intervention starts with the desired prosthetic result or "Prosthetically-driven placement" in which implant inserted considering the appropriate angulation and position in relation to the adjacent teeth and underlying bone. 3D imaging techniques as CT or cone beam computed tomography (CBCT) add an extra dimension to routine preoperative radiographs so they provide more comprehensive data on bone quality and quantity as well as anatomical limitations, when integrated with 3D implant planning software the clinicians can be provided with 3D information of patient's anatomic structures, combined with data of the patient's final prosthesis [11].

Thus, with the aid of the implant simulation program, the optimal implant position is indicated by simultaneous consideration of the bone condition and prosthetic requirements. Determining the final position of the implant prior to the operation provides better predictability of prosthetic requirements. The digital data can be combined with the CAD/CAM technology and further lead to a digital workflow ending with the production of the surgical guide. The guide can be used to steer the position and direction of implants intra-operatively. Therefore, this surgical procedure in which the virtually planned implant position can be transferred to the patient and navigate the surgical procedure is termed "Computer guided implant surgery" [12,13].

The consensus statement published in 2009 [14] defined the term "Computer-guided implant surgery" as the use of a static surgical guide that reproduces the virtual implant position directly from CT data and does not allow for intraoperative modification of the implant position. It has been demonstrated to be an established treatment, which reduces the probability of damage to the adjacent critical structures such as bones, nerves, adjacent tooth roots, and sinus cavities [13].

Types of computer guided implant surgery protocols

As described in the literature computer guided implant surgery protocols can be divided generally into; "Static" and "Dynamic" protocols. Dynamic methods: also called navigation, it involves the use of a computer-guided navigation system that reproduces the virtual implant position directly from CT data and allows intra-operative changes of the implant position. It is based on motion tracking technology as it helps the clinician in real time bur tracking during the implant positioning - according to the preoperative planned trajectory -through visual imaging tools on a monitor. These methods, although very interesting in future perspective are currently not particularly widespread as they require additional expensive pieces of equipment and complicated software [15].

The "Static" methods employ static surgical guide that reproduces the virtual implant position directly from CT data, it does not permit modification of the implant position during surgery. These methods include the use of surgical guides that can be produced by conventional procedures, modifying a radiographic scan prosthesis, or by CAD/CAM technologies as milling or stereolithography [13,16].

The production of surgical guides by using a rapid prototyping technique or stereolithographic technology is based on 3D imaging and a 3D design. Guides are fabricated by photo-polymerization of an ultraviolet sensitive liquid resin [17] and are currently produced commercially by several implant suppliers. Recently, the digital production of surgical guides is based on the superimposition of digital CT data and intra-oral scanning data. Hence, mutual landmarks on both digital images, are required. These new approaches improve positioning and accuracy in terms of the relationship between virtually planned and real-life insertion of the implant. However, more clinical investigations are required to support this statement [18,19].

Typically, the surgical guide consists of two components; The guide body (contact surface) which fits either on an element of a patient's gingiva, bone or teeth. The other component is the guiding cylinder (sleeve) placed within the drill guides to aid in transferring the plan by guiding the drill in the exact location and orientation [20].

A stereolithographic guided surgery system mainly consists of; a stereolithographic surgical guide with implant system-related mounts for fixture installation, additional guide sleeves for fixation screw installation, drill keys of different heights, and depth-calibrated drills to prepare the osteotomies. Some guided systems use, for each patient, consecutive guides with different sleeves size to cope with an increasing drill diameter during surgery, while others use only one template with different adjustable drill handles [15].

The static navigation is generally based on sleeves integrated into the guides, through which drill bits of the corresponding size are passed. Sleeve-guided implants are prone to imprecision due to the nature of the method, so to warrant a clinically usable drill bit guidance in the sleeve, the fit must provide clearance, and this necessary clearance leads to unavoidable angular deviations. Since the sleeve and drill bit configuration hinges on the type of implant, the impacts on precision vary, depending on the manufacturer. This technical influence is not present with sleeveless methods. The sleeveless guide design may also lead to a reduction in the costs of the surgical guide, as there are no material costs for sleeves, and no work required to fasten them into the drill guides [15,21].

Based on their supporting surfaces, surgical guides can be tooth, bone, mucosa or special supported, with or without stabilization pins [15,22,23].

- Tooth-supported surgical guide: positioned on the remaining teeth.
- Mucosa-supported surgical guide: placed on top of the mucosa. Commonly used in fully edentulous patients.

Tooth- and mucosal-supported guides allow for application of flapless surgery.

- Bone-supported surgical guide: placed on the bone after opening a mucoperiostal flap. It is indicated in patients in whom more extensive bone surgery is required.
- Special supported, (mini) implant, pin-supported surgical guide: it is attached to implants inserted before or during the actual implant surgery.

A systematic review from the 5th International Team for Implantology (ITI) consensus conference [13] concluded that, compared with other types of guide, the bone-supported surgical guides showed the highest inaccuracy.

A further differentiation is given by level of guidance or the modality of implant screwing after implant site preparation: some systems provide fully guided implant insertion through the same drilling template which allows guided osteotomy preparation and implant placement; other methods partially guided, only allow guided osteotomy, resulting in a manual implant installation after removing the surgical template [15,22,23]. The 5th ITI consensus conference concluded that the fully guided protocols are more accurate in comparison to partially guided systems [13].

Workflow of computer-guided implant surgery

Conventional implant planning is a model-based workflow which starts with a preliminary impression and diagnostic wax-up on the plaster model [24,25]. Before the development of digital technology, a radiographic template had to be fabricated over duplicated casts of a diagnostic wax-up. In CT imaging with, radiographic templates outline the proposed ideal prosthetic outcome relative to the patient's anatomic structures and topography. The radiographic template can then be manually modified to the desired surgical template [26].

With the major accomplishments in the field of computerized implant dentistry, a digital approach is now available resulting in a more prosthetic driven orientation of the implant position. This backward planning allows the selection of an implant suitable for the specific anatomic condition and prosthetic demands. The sequence of the procedure is summarized as follows [27,28].

Prosthetic pre-planning and implant planning

The procedure begins with the acquisition of CT or CBCT imaging and intraoral scanning data. A virtual model of the patient is created by superimposing the DICOM (Digital Imaging and Communications in Medicine) from radiological imaging and STL (Standard Triangulated Language) files, allowing for a detailed visualization of the remaining dentition, surrounding intraoral soft tissue, and underlying bone structure. Then, data fusion conducted by importing the STL and DICOM data into the implant planning software and superimposition ('matching'/'registration'). Most planning software necessitates the marking of specific reference points, called fiducials preferably on residual dental hard tissue, used for the alignment of the recorded data.

The planning software features a database of common implants or allows such data to be imported. The information inherent in the existing bone situation can be used to select a suitable implant fixture, taking into consideration the anatomical condition and the planned prosthetic outcome in addition to the specific indications for each implant as approved by its manufacturer. Furthermore, a potential need for augmentation procedures can be identified at this point. Further aspects such as the eventual axis of the screw access channel, the vertical position of the implant shoulder in relation to the adjacent teeth or the thickness of the soft tissue can also be accommodated at this planning stage [29,30].

Designing the surgical guide

After the prospective implant positions identified, they are translated into the design of the surgical guide. When the implant planning has been approved, the software provides a planning report specifying the type, size and position of the planned implants. The 'drilling protocol' provides the surgeon with the relevant technical information on the correct use of the system-specific surgical instruments [27,31].

Fabricating the surgical guide

As soon as the design process has been completed, the data set can be exported as an STL file and converted directly into the physical surgical guide by means of additive or subtractive CAM procedures. Integrating the guide sleeves is a manual process, as is the removal of holding or support structures and the finishing of the surgical guide [27,31].

Benefits of computer-guided implant surgery

The demonstrated advantages include:

1. The chief benefit is preplanning the prosthetic determinants as (implants distribution, parallelism, emergence of the screw channel) and their integration into the surgical planning. This allows the practitioner to place implants in a prosthetic and biologically driven way into sufficient hard and soft tissue while evading prosthetic complications and compromised aesthetics as there is a better control of the implant axis in relation to the prosthetic tooth position. Thus, it results in more predictable prosthetic outcome and allow for production of the prosthesis before the surgery, consequently facilitating immediate loading protocols [32,33].

2. Facilitation and simplification of the technique-sensitive and operator-dependent surgical procedures these include: full-arch, multiple-implant cases, presence of anatomic restrictions, limited bone volume, difficult prosthetic considerations, trauma, extensive grafting, or medically compromised (anticoagulant, bisphosphonates, etc.) or anxious patients. Thus, it can be inferred that computer guided surgery can offer implant treatment to patients who would be excluded for conventional implant procedures. Although many practitioners consider it only for more challenging implant cases, it can also be used for single tooth restoration. It is worth noting, that techniques and armamentarium are available for the construction of provisional restorations in all types of cases, before guided implant insertion, for insertion immediately after implant placement. In addition, the pre-surgical 3D implant planning can accurately and safely be transferred into the patient to place the implants in the correct prosthetic positions while avoiding the damage of vital anatomic structures [34-36].

3. It allows operating with a minimally invasive approach (precluding flap elevation), So result in facilitated surgical procedure with reduced surgical intervention time and hence reduced postoperative sequalae and patient morbidity preserving the soft tissue architecture, and maintaining the periosteum intact on buccal and lingual aspect of the ridge and the supra-periosteal plexus is kept intact, hence preserving the osteogenic potential and the blood supply to the underlying bone and/or implant which, in turn, reduces the possibility of bone resorption [37,38]. Moreover, it seems to enhance the formation of a biologic seal between the soft tissues and the implant-abutment interface, since it eliminates the need for tissues reflection and suturing. However, the quality and quantity of the surrounding soft tissue must be carefully considered when deciding between flapped or flapless surgery. Since, in some cases, flapless surgery may result in the removal of too much required keratinized soft tissue around the implants [7,15]. Thus, an open flap approach is recommended when only few millimeters of keratinized tissue are present, another recommendation for flap approach is when osteoplasty is needed for prosthetic reasons. but, when guided surgery is applied, flap design should be as minimal as possible and must be well adapted to the clinical situation [7].

Shortcomings and limitations of computer-guided implant surgery

Guided implant placement was initially promoted by enthusiastic preliminary studies but later many doubts have risen on its usefulness.

1. Longer time is required for guided implant pre-surgical planning in comparison to conventional protocols. Economic aspects must also be evaluated regarding formation, instrumentation, surgical templates realization [23]. Where computer-guided implant surgery requires 3D imaging and additional software plus the extra costs of the surgical drill kit and guide preparation for the guided surgery [10]. Moreover, similar to all new techniques, it requires a learning period for the dentist, for the technician and in general for the entire dental team. A high level of training, experience, and skill is required to master the techniques and workflows. It is considered by many practitioners as an advanced implant placement technique and is not recommended for novice implant surgeons. The lack of visibility and tactile control during surgical procedure as bone cannot be visualized during the implant drilling and insertion; i.e. a blind technique, so it presents increased risks compared to open surgical approaches plus the inability of the surgeon to verify the accuracy of the guide intraoperatively and to compare the clinical implant position with the virtual planned position. As it would not be possible to take accurate periapical radiographs during the drilling and placement phase of the implants with a surgical guide *in situ*, and 2D images would offer very limited postoperative information regarding implant position and treatment safety, so it is necessary to take postoperative 3D images to verify good implant position and rectify any possible errors or implant malposition, before moving on to the prosthetic phase. For this reason, computer guided surgery requires greater surgical experience [3,7].

2. Bone overheating is more crucial in guided implant surgery than conventional surgery. Owing to the presence of an intimately fitting surgical guide and insertion instrumentation, concerns aroused about whether cooling irrigation is able to reach the osteotomy site when using guided surgery; if it is not, overheating the bone becomes a major concern. The internal bone temperature changes were registered during guided surgery preparations and it was found that when using surgical stents, osteotomy preparation

generated higher bone temperatures than did conventional drilling. The heat generation, however, did not reach temperature levels that were dangerous to the bone. Thus, an adequate irrigation system is critical for thermal lowering during a guided implant osteotomy mainly in the coronal and middle third of the implant site. Copious irrigation should be provided during the withdrawing process since greater thermal increases could be expected. Lower temperature increases could be achieved by reducing drill-to-bone contact, i.e. cutting surface length, due to short frictional force exposure [39].

3. The most significant problem in guided implant surgery is "Deviation" in 3D directions between planned and the actual implant placement position [26]. Therefore," Accuracy" in guided implant surgery is defined as matching the planned position of the implant in the software with the actual position of the implant in the patient's mouth [40]. Safety and effectiveness of guided surgery are closely related to its accuracy, since implants are inserted in close proximity to vital anatomic structures. Computer guided surgery includes a sequence of diagnostic and therapeutic events, and error can creep in at different stages [11]. Therefore, although seldom occurring, the cumulative loss of accuracy is the sum of the following single errors [6,27]:

    a. Error during image acquisition and data processing, on average less than 0.5 mm. These errors include spatial resolution problems in CT, merging techniques in CT, and scan data, and types of software used. Reaching the best possible registration of DICOM and STL data sets necessitates high-quality basic data. The clinical accuracy of CBCT scans is limited by artefacts, voxel size, contrast resolution, patient movements as well as the field of view, which is the anatomical section acquired by the CBCT, must be placed precisely and of adequate size to capture enough superimposable data. CBCT device itself may have an influence on the quality of data, for this reason only sophisticated systems should be utilized. In cases with severe restoration-associated artefacts it is recommended to use a scan prosthesis or radiographic template. This technique is synonymous with placing the structures to be superimposed at an adequate distance to interfering materials but is inevitably resulting in complicating the procedure [41-45].

    b. Error during manufacturing of the surgical guide, typically around 0.1 to 0.2 mm with stereolithography [30]. The precision of the conversion of the CAD data into a physical template (manufacturing accuracy); predominantly relies on the type of CAM-technology used. The typical accuracy for additive fabrication was found by Van Steenberghe., *et al.* [46] to be between 0.1 to 0.2 mm. Subtractive milling, which is more laborious and expensive, may be superior in terms of manufacturing accuracy compared with rapid prototyping technologies. Nowadays, the most popular method of surgical template production is represented by photo-polymerisation, more precisely stereolithographic technologies, which provide layer thickness ranging from about 50 to 100 microns or even less is possible [47-49].

    c. Error during surgical guide positioning and movement of the guide during the drilling. i.e inadequate stability of the surgical guide [27].

    d. Mechanical error due to the tolerance of surgical Instruments (the bur-cylinder gap). For instance, one system has surgical guide is with 5-mm-long guiding cylinders (sleeves) with an inner diameter that is 0.15 to 0.20 mm larger than the respective bur. This tolerance theoretically allows a deviation angle of approximately 2.29 degrees which, at a hypothetical distance of 20 mm from the cylinder, resulting in a lateral deviation of 1 mm approximately. These calculations cannot be generalized to other systems, because each has different tolerances between drills and guiding cylinders [6,27].

    e. Deviation from the planned axis of insertion in those instances where freehand drilling must be employed. (partially guided specially with longer implants) the implant has a tendency to follow the trajectory with the least resistance. Particularly in patients with a rather soft bone type this could lead to substantial deviations [6,27].

    f. Human error, for instance, setting the bur stop in an incorrect position [6].

In computer guided surgery, it is more common to find a large vertical error than a large horizontal error. This may be attributed to that alveolar bone superior border is difficult to differentiate in CT data during the implant planning. Consequently, after implant placement, there are usually cases that need slightly deeper positioning after guide removal [10]. A meta-analysis revealed that the mean horizontal

deviations were 1.1 - 1.6 mm but with higher maximal deviations. In particular, the higher deviations may cause nerve disturbances, may damage anatomically vital structures and additionally lead to prosthetic complications [50].

Overall, distance errors are larger in the apex than in the shoulder. This may be owing to the horizontal error that is due to angle displacement at an occlusal surface increases closer to the apex [10]. The proceedings of the 5th ITI consensus conference [13] on computer-guided surgery revealed an inaccuracy at the implant entry point of, on average, 1.12 mm (maximum 4.5 mm) and an inaccuracy of, on average, 1.39 mm at the apex of implants (maximum 7.1 mm) and the mean angular deviation was 3.9 degrees. Due to these potential errors, virtual planning should be performed judiciously, with an appropriate safety margin secured to avoid damaging the vital structures.

Accuracy can be affected also by other factors as:

Bone density

computer guided surgery performed on the mandible was shown to have a more angular accuracy than that on the maxilla a possible explanation provided by Zhou., *et al.* [11] might be the bone anatomy and bone density; where the structure of the mandible is straight with an arcuate shape, but the shape of maxilla is a circular curve, which restrains the angulation control. Moreover, the mandible bone is denser [51].

Surgical technique and surgeon's experience

Potential sources of error in surgical technique are manifold. Initially, the selection of adequate surgical equipment is important. It was found that the fully guided technique was more accurate than the partially guided one [52,53].

Comparing the precision of flapless and open-flap guided surgery, findings indicated that flapless procedures are more accurate than an open-flap approaches. The possible explanation is that guided surgery requires a more extensive flap than conventional surgery and repositioning of the guide during surgery is more difficult because of the possible interference of the reflected tissue [54,55]. It seems plausible that a sound support by teeth provides most predictability and thus accuracy. Ozan., *et al.* [19] found a mean angular deviation of 2.91° in tooth-supported placed implants, 4.51° in implants placed with mucosa-supported guides, and 4.63° in implants placed with bone-supported templates. the number and location of the remaining teeth has a certain impact too. For instance, it was shown that guided implant placement in single tooth gaps shows noticeably less deviation than in distal gaps or partially edentulous situations [56-58].

Moreover, the use of fixation pins has an important role to achieve greater precision, especially in non-tooth-supported guides. It was found that a guide with fixation screws showed greater reduction in angular deviation than a guide without fixation screws. The guide stability can explain this; a fixed surgical guide is more accurate than manual pressure or freehand placement to position it. In any case, appropriate positioning of the guide is a fundamental prerequisite for successful outcome [59].

With respect to the impact of the surgeon's experience, it can be seen that experienced surgeons tend to achieve more accurate results performing guided surgery, though practitioners of any experience level can greatly benefit from the procedure [60]. Cushen., *et al.* [61] revealed that experienced surgeons performed significantly better in terms of the alignment of planned and achieved implant position using bone-supported guides.

Implant length

In computer guided surgery, the height of the guide requires very long burs. In several sites, however, when the planned implant was long, even the longest bur could not reach the needed osteotomy depth; in other cases, the mouth opening did not allow the use of such long burs. Hence, the final bur is often placed without a guide, at least for the most apical part of the osteotomy. Thus, resulting in deviation from the planned axis of insertion in cases where freehand drilling must be employed [27]. Schneider., *et al.* [62] proved that a small gap,

a high guiding sleeve and a short drill to be beneficial in terms of overall accuracy. As the vertical positioning of the guide sleeves is often variable, it is then important to note that the increasing distance between the guide sleeve and the bone potentially reduces accuracy. Furthermore, with guide sleeves positioned very high above the mucosa, a correct insertion of the drill into the sleeve can be difficult, especially in patients with limited mouth opening. Ultimately, it can be inferred that fully guided systems using fixed screws with a flapless approach have greater accuracy and minimal cumulative errors [11].

Other factors such as mucosal thickness. smoking habit, surgery site in the arch, and guide system may also affect the accuracy. A meta-regressive analysis [11] observed that age has no significant influence on accuracy. Regarding the effect, the radiology technique comparison of CT and CBCT revealed no significant difference for the influence on accuracy [63].

Numerous reviews and systematic reviews, evaluated the accuracy of flapless guided surgery in clinical studies and generally concluded that the implant survival rate ranges from 91% to 100% [15]. Tahmaseb., *et al.* [13] concluded as part of the ITI consensus conference in 2013, that there is no evidence suggesting that computer-assisted surgery is superior to conventional surgery in terms of safety, outcome, morbidity or efficiency. Also, D'haese., *et al.* [64] concluded that guided surgery may yield a more precise implant placement than does freehand placement. Yet, from both cadaver and clinical studies it was evident that guided surgery is far from accurate. They recommend that a 2-mm safety zone should be respected apically to the planned position to avoid critical anatomic structures.

Complications associated with computer guided implant surgery

According to the literature review, complications can be related the used hardware or the technical procedure. Procedure related errors include; positioning of the surgical guide and overheating during osteotomy. Whereas the accuracy or stiffness of the guide and the supra-structure are hardware related [22]. Complications can be further categorized as early (less than 2 weeks) or late complications.

Many early surgical and prosthetic complications have been reported in the literature with computer-guided surgery. Schneider., *et al.* [50] reported an incidence of 9.1% for early surgical complications and an incidence of 18.8% for early prosthetic complications. These complications are associated with incorrect implant placement or deviations from the originally planned location. Complications are frequently reported when combining computer guided flapless surgery with an immediate loaded prefabricated prosthesis. Surgical and prosthetic complications are in most instances caused by the misfit between the inserted implants and the prefabricated prosthesis [15,22].

The most frequently reported early complications [15,22]:

- Intra-operatively broken surgical guides

- Alterations to the surgical plan

- Early implant loss because of lack of primary stability

- Prostheses not seated completely due to bony interference

- Implant incompletely placed to the planned depth.

Late prosthetic complications may be associated with the prosthesis material or improper seating [15,22]:

- Fractures of the prostheses (2.8%)

- Fracture of veneering material (1.9%)

- Screw loosening (2.8%)

- Deviations at the implant shoulder hampering correct fit of the supra-structures and could require extensive adaptations in occlusion and articulation.

A higher accuracy and reproducibility of implant position besides optimization of the prosthetic components and fabrication techniques might allow immediate final restorations in the future [50].

Conclusion

Computer guided implant surgery may seem to provide dental professionals with a holistic, reliable and precise solution to sophisticated cases bringing about new and exciting possibilities. Even though its acceptable results have been revealed in many articles, based on the available literature some imprecisions are reported with these protocols and there is no solid scientific evidence suggesting that computer guided surgery is superior to conventional approach in terms of safety, treatment outcomes, morbidity or efficiency. Long-term clinical studies and randomized clinical trials are required to identify and comprehend the factors affecting the accuracy and their mutual interaction. In addition to, further evaluation and monitoring of implant survival, bone loss and clinical complications are required to refine the procedure and the systems. Therefore, despite digital technology and computer guided surgery are still in the development stage they open a new and fascinating chapter in implantology.

Bibliography

1. Busenlechner D., *et al.* "Long-term implant success at the Academy for Oral Implantology: 8-year follow-up and risk factor analysis". *Journal of Periodontal and Implant Science* 44.3 (2014): 102-108.

2. Pjetursson BE., *et al.* "A systematic review of the survival and complication rates of fixed partial dentures (FPDs) after an observation period of at least 5 years". *Clinical Oral Implants Research* 15.6 (2004): 625-642.

3. Jones A. "Accuracy of mucosa supported guided dental implant surgery". *Clinical Case Reports* 6.11 (2018): 2131-2139.

4. Al-Harbi SA and Sun AY. "Implant placement accuracy when using stereolithographic template as a surgical guide: preliminary results". *Implant Dentistry* 18.1 (2009): 46-56.

5. Giordano M., *et al.* "Reliability of computer designed surgical guides in six implant rehabilitations with two years' follow-up". *Dental Materials* 28.9 (2012): e168-177.

6. Valente F., *et al.* "Accuracy of Computer-Aided Oral Implant Surgery: A Clinical and Radiographic Study". *The International Journal of Oral and Maxillofacial Implants* 24.2 (2009): 234-242.

7. Meloni SM., *et al.* "Implant Restoration of Edentulous Jaws with 3D Software Planning, Guided Surgery, Immediate Loading, and CAD-CAM Full Arch Frameworks". *International Journal of Dentistry* 2013 (2013): 683423.

8. Pommer B., *et al.* "Trends in techniques to avoid bone augmentation surgery: Application of short implants, narrow-diameter implants and guided surgery". *Journal of Cranio-Maxillofacial Surgery* 44.10 (2016): 1630-1634.

9. "The Glossary of Prosthodontic Terms: Ninth Edition". *Journal of Prosthetic Dentistry (*2017): 117(5S): e1-e105.

10. Moon SY., *et al.* "Clinical problems of computer-guided implant surgery". *Maxillofacial Plastic and Reconstructive Surgery* 38.1 (2016): 15.

11. Zhou W., *et al.* "Clinical factors affecting the accuracy of guided implant surgery-a systematic review and meta-analysis". *Journal of Evidence Based Dental Practice* 18.1 (2018): 28-40.

12. Chen X., *et al.* "Modular preoperative planning software for computer-aided oral implantology and the application of a novel stereolithographic template: a pilot study". *Clinical Implant Dentistry and Related Research* 12.3 (2010): 181-193.

13. Tahmaseb A., *et al*. "Computer technology applications in surgical implant dentistry: a systematic review". *The International Journal of Oral and Maxillofacial Implants* 29 (2014): 25-42.

14. Hämmerle C., *et al*. "Consensus statements and recommended clinical procedures regarding computer-assisted implant dentistry". *The International Journal of Oral and Maxillofacial Implants* 24 (2009): 126-131.

15. D'haese J., *et al*. "Current state of the art of computer-guided implant surgery". *Periodontology 2000* 73.1 (2017): 121-133.

16. Jung R., *et al*. "Computer technology applications in surgical implant dentistry: a systematic review". *The International Journal of Oral and Maxillofacial Implants* 24.2 (2009): 92-109.

17. Buser D., *et al*. "Stability of contour augmentation and esthetic outcomes of implant-supported single crowns in the esthetic zone: 3-year results of a prospective study with early implant placement post extraction". *Journal of Periodontology* 82.3 (2011): 342-349.

18. Geng W., *et al*. "Accuracy of different types of computer-aided design/computer-aided manufacturing surgical guides for dental implant placement". *International Journal of Clinical and Experimental Medicine* 8.6 (2015): 8442-8449.

19. Ozan O., *et al*. "Clinical accuracy of 3 different types of computed tomography-derived stereolithographic surgical guides in implant placement". *Journal of Oral and Maxillofacial Surgery* 67.2 (2009): 394-401.

20. Ramasamy M., *et al*. "Implant surgical guides: From the past to the present". *Journal of Pharmacy and Bioallied Sciences* 5.1 (2013): S98-S102.

21. Schnutenhaus S., *et al*. "Precision of sleeveless 3D drill guides for insertion of one-piece ceramic implants: a prospective clinical trial". *International Journal of Computerized Dentistry* 21.2 (2018): 97-105.

22. D'haese J., *et al*. "Accuracy and Complications Using Computer-Designed Stereolithographic Surgical Guides for Oral Rehabilitation by Means of Dental Implants: A Review of the Literature". *Clinical Implant Dentistry and Related Research* 14 .3 (2012): 321-335.

23. Colombo M., *et al*. "Clinical applications and effectiveness of guided implant surgery: a critical review based on randomized controlled trials". *BMC Oral Health* 13(2017): 150.

24. Higginbottom FL and Wilson TG. "Three-dimensional templates for placement of root-form dental implants: A technical note". *The International Journal of Oral and Maxillofacial Implants* (1996): 11.6 787-793.

25. Tsuchida F., *et al*. "A technique for making a diagnostic and surgical template". *Journal of Prosthetic Dentistry* 91.4 (2004): 395-397.

26. Pyo SW., *et al*. "Methods Used to Assess the 3D Accuracy of Dental Implant Positions in Computer-Guided Implant Placement: A Review". *Journal of Clinical Medicine* 8.1 (2019).

27. Schubert O., *et al*. "Digital implant planning and guided implant surgery -workflow and reliability". *British Dental Journal* 226 (2019): 101-108.

28. Tahmaseb A., *et al*. "Digital Protocol for Reference-Based Guided Surgery and Immediate Loading: A Prospective Clinical Study". *The International Journal of Oral and Maxillofacial Implants* 27.5 (2012): 1258-1270.

29. Lanis A and Alvarez Del Canto O. "The combination of digital surface scanners and cone beam computed tomography technology for guided implant surgery using 3Shape implant studio software: a case history report". *The International Journal of Prosthodontics* 28.2 (2015): 169-178.

30. Flugge T., *et al*. "Registration of cone beam computed tomography data and intraoral surface scans -A prerequisite for guided implant surgery with CAD/CAM drilling guides". *Clinical Oral Implants Research* 28.9 (2017): 1113-1118.

31. Vercruyssen M., *et al*. "Computer-supported implant planning and guided surgery: a narrative review". *Clinical Oral Implants Research* 26.1(2015): 69-76.

32. Mora MA., *et al*. "Software tools and surgical guides in dental-implant-guided surgery". *Dental Clinics of North America* 58.3 (2014): 597-626.

33. Sadid-Zadeh R., *et al*. "Prosthetic failure in implant dentistry". *Dental Clinics of North America* 59.1 (2015): 195-214.

34. Cassetta M., *et al*. "Accuracy of implant placement with a stereolithographic surgical template". *The International Journal of Oral and Maxillofacial Implants* 27.3(2012): 655-663.

35. Pozzi A., *et al*. "Computer-guided versus free-hand placement of immediately loaded dental implants: 1-year post-loading results of a multicentre randomised controlled trial". *European Journal of Oral Implantology* 7.3(2014): 229-242.

36. Jacobs R., *et al*. "Neurovascular disturbances after implant surgery". *Periodontology 2000* 66.1 (2014): 188-202.

37. Casap N., *et al*. "Intraoperative computerized navigation for flapless implant surgery and immediate loading in the edentulous mandible". *The International Journal of Oral and Maxillofacial Implants* 20.1(2005): 92-98.

38. Hahn J. "Single-stage, immediate loading, and flapless surgery". *Journal of Oral Implantology* 26.3 (2000): 193-198.

39. Sannino G and Gherlone EF. "Thermal Changes During Guided Flapless Implant Site Preparation: A Comparative Study". *The International Journal of Oral and Maxillofacial Implants* 33.3 (2018): 671-677.

40. Vercruyssen M., *et al*. "Guided surgery: accuracy and efficacy". *Periodontology 2000* 66.1 (2014): 228-246.

41. Hassan B., *et al*. "Influence of scanning and reconstruction parameters on quality of three-dimensional surface models of the dental arches from cone beam computed tomography". *Clinical Oral Investigations* 14.3 (2010): 303-310.

42. Spin-Neto R., *et al*. "Impact of voxel size variation on CBCT-based diagnostic outcome in dentistry: a systematic review". *Journal of Digital Imaging* 26.4 (2013): 813-820.

43. Widmann G and Bale R J. "Accuracy in computer-aided implant surgery a review". *The International Journal of Oral and Maxillofacial Implants* 21.2 (2006): 305-313.

44. Pettersson A., *et al*. "Accuracy of virtually planned and template guided implant surgery on edentate patients". *Clinical Implant Dentistry and Related Research* 14.4 (2012): 527-537.

45. Dreiseidler T., *et al*. "CBCT device dependency on the transfer accuracy from computer-aided implantology procedures". *Clinical Oral Implants Research* 23.9 (2012): 1089-1097.

46. Van Steenberghe D., *et al*. "A custom template and definitive prosthesis allowing immediate implant loading in the maxilla: a clinical report". *The International Journal of Oral and Maxillofacial Implants* 17.5 (2002): 663-670.

47. Park JM., *et al*. "Comparison of five-axis milling and rapid prototyping for implant surgical templates". *The International Journal of Oral and Maxillofacial Implants* 29.2 (2014): 374-383.

48. Ligon S C., *et al.* "Polymers for 3D Printing and Customized Additive Manufacturing". *Chemical Reviews* 117.15 (2017): 10212-10290.

49. Stansbury J W and Idacavage M J. "3D printing with polymers: Challenges among expanding options and opportunities". *Dental Materials* 32.1 (2016): 54-64.

50. Schneider D., *et al.* "A systematic review on the accuracy and the clinical outcome of computer-guided template-based implant dentistry". *Clinical Oral Implants Research* 4 (2009): 73-86.

51. Seo C and Juodzbalys G. "Accuracy of Guided Surgery via Stereolithographic Mucosa-Supported Surgical Guide in Implant Surgery for Edentulous Patient: A Systematic Review". *Journal of Oral and Maxillofacial Research* 9.1 (2018): e1.

52. Laederach V., *et al.* "Deviations of different systems for guided implant surgery". *Clinical Oral Implants Research* 28.9 (2017): 1147-1151.

53. Van Assche N., *et al.* "Accuracy of computer-aided implant placement". *Clinical Oral Implants Research* 6 (2012): 112-123.

54. Lal K., *et al.* "Use of stereolithographic templates for surgical and prosthodontic implant planning and placement. Part I The concept". *Journal of Prosthodontics* 15.1 (2006): 51-58.

55. Vieira DM., *et al.* "Clinical accuracy of flapless computer-guided surgery for implant placement in edentulous arches". *The International Journal of Oral and Maxillofacial Implants* 28.5 (2013): 1347-1351.

56. Farley N E., *et al.* "Split-mouth comparison of the accuracy of computer-generated and conventional surgical guides". *The International Journal of Oral and Maxillofacial Implants* 28.2 (2013): 563-572.

57. Ersoy A E., *et al.* "Reliability of implant placement with stereolithographic surgical guides generated from computed tomography: clinical data from 94 implants". *Journal of Periodontology* 79.8 (2008): 1339-1345.

58. Behneke A., *et al.* "Factors influencing transfer accuracy of cone beam CT derived template-based implant placement". *Clinical Oral Implants Research* 23.4 (2012): 416-423.

59. Arisan V., *et al.* "Implant surgery using bone and mucosa-supported stereolithographic guides in totally edentulous jaws: surgical and post-operative outcomes of computer-aided vs. standard techniques". *Clinical Oral Implants Research* 21.9 (2010): 980-988.

60. Fernandez-Gil A., *et al.* "An in Vitro Model to Evaluate the Accuracy of Guided Implant Placement Based on the Surgeon's Experience". *The International Journal of Oral and Maxillofacial Implants* 32.2 (2017): 151-154.

61. Cushen S E and Turkyilmaz I. "Impact of operator experience on the accuracy of implant placement with stereolithographic surgical templates: an in vitro study". *Journal of Prosthetic Dentistry* 109.4 (2013): 248-254.

62. Schneider D., *et al.* "In-vitro evaluation of the tolerance of surgical instruments in templates for computer-assisted guided implantology produced by 3D printing". *Clinical Oral Implants Research* 26.3 (2015): 320-325.

63. Arisan V., *et al.* "Conventional multislice computed tomography (CT) and cone-beam CT (CBCT) for computer-aided implant placement. Part II: reliability of mucosa-supported stereolithographic guides". *Clinical Implant Dentistry and Related Research* 15.6 (2013): 907-917.

64. D'haese J., *et al.* "Accuracy and complications using computer designed stereolithographic surgical guides for oral rehabilitation by means of dental implants: a review of the literature". *Clinical Implant Dentistry and Related Research* 14.3 (2012): 321-335.

Volume 18 Issue 6 June 2019