THE PUBLISHING HOUSE
OF THE ROMANIAN ACADEMY

DIGITAL TOOLS AND TECHNIQUES IN IMPLANT-PROSTHETIC THERAPY

Norina FORNA[1], Claudiu TOPOLICEANU[2,*] and Doriana AGOP-FORNA[3]

[1] Univ.Prof., PhD, Head of Department of Implantology and Removable Prostheses, Faculty of Dental Medicine, U.M.F. "Grigore T. Popa" Iasi; member of AOSR, ASM
[2] Lecturer, Department of Odontology-Periodontology and Fixed Restorations, Faculty of Dental Medicine, U.M.F. "Grigore T. Popa" Iasi; member of AOSR, ASM
[3] Assoc Prof, PhD, Department of Oral and Oro-Maxillo-facial Surgery, Faculty of Dental Medicine, U.M.F. "Grigore T. Popa" Iasi; correspondent member of AOSR

Correspondent author: Topoliceanu Claudiu; e-mail: claudiutopoliceanu@yahoo.com

Accepted December 27, 2022

The digital systems include expert systems and CBCT-based systems for the analysis of the alveolar bone support and planning of the surgical proimplant procedures, intraoral scanners (IOS), software applications for implant planning and manufacturing of the surgical guide, CAD/CAM systems for manufacturing of the surgical guides and provisional restorations, software systems for an ideal prosthetic restoration design, CAD/CAM systems for the manufacturing of the implant-supported restorations. Components of the digital workflow are as follows: data collection, computer aided design/computer aided manufacturing (CAD/CAM), and implant placement. Digital tools and technologies assist diagnosis, case planning and surgical execution in the implant surgical stage. Digital treatment planning allows the design of the surgical template and implant-supported prosthetic restoration, to improve the accuracy of implant insertion in a prosthetically driven position during the surgical stage. The use of the digital workflows in implant-prosthetic therapy led to more predictable and successful implant outcomes in the long term.

Key words: implant therapy, diagnosis, planning, digital tools, digital techniques.

INTRODUCTION

The increase in the popularity of and the demand for the use of dental implants to replace teeth has encouraged the development of new digital technologies to improve the clinical success as well as the patients' acceptance and compliance to maintenance sessions (Patel, 2010).

Modern techniques in implanto-prosthetic rehabilitation involve the use of software applications that allow optimizing the diagnosis and treatment plan, as well as the use of minimally invasive surgical and prosthetic techniques by increasing efficiency and accuracy (Moy *et al.*, 2008; van der Zel, 2008).

New digital tools have fundamentally changed the patients' evaluation, treatment planning in proimplant and implant stage, surgical implant stage, and even the design of the implant-supported fixed and removable prosthetic reconstruction. Expert systems allow supporting clinical decisions and planning treatment stages based on causal and probabilistic reasoning within theoretical decision schemes (Forna N., 2008).

The great advantages of digital technology are the improvement of the implant and prosthetic success as well as saving chairtime (Conejo *et al.*, 2021; Patel, 2010). The digital systems include expert systems, CBCT-based systems for the analysis of the alveolar bone support and planning of the surgical proimplant procedures, intraoral scanners (IOS), software applications for implant planning and manufacturing of the surgical guide, CAD/CAM systems for manufacturing of the surgical guides and provisional restorations, software systems for an ideal prosthetic restoration design (3D digitally restorative software), CAD/CAM systems for manufacturing of the definitive implant-supported restorations (Conejo *et al*., 2021; Guichet, 2015).

The integration of computer-aided design /computer-aided manufacturing (CAD/CAM) and CBCT data was a breakthrough in the implantology field (Patel, 2010). The technique CAD/CAM can be used not only for the manufacturing of surgical guides and provisional prosthetic restorations but also for fabricating custom implant abutments (Patel, 2010). Van der Zel (2008) described the digital systems CADDIMA, which combines computerized tomographic (CT) and optical laser-scan data for planning and manufacturing of surgical guides, implant abutments, and prosthetic restorations.

Workflow in implantology has also significantly improved after the release of software integrating CEREC Acquisition Center with Bluecam (Sirona Dental Systems, Charlotte, N.C.) chairside CAD/CAM and Galileos CBCT imaging (Sirona Dental Systems) allowing dentists to plan implant placement, increase accuracy of implants insertion and provide predictable results by using chairside IPS e.max CAD (Patel, 2010).

The aim of this paper was to investigate the data and research in the field of the digital tools used in the implant-prosthetic therapy in the analysis of the prosthetic field, planning of the proimplant procedures and virtual implants positioning, manufacturing of the surgical guide, assistance of the surgical implant stage, optical impression, as well as the design of the implant-supported prosthetic restoration.

WORKFLOW IN IMPLANTOLOGY

Components of the digital workflow are exposed in Figure 1 (data collection, computer aided design/ computer aided manufacturing (CAD/CAM), and implant placement) (Table 1) (Alqallaf *et al.*, 2021).

The digital workflow starts with data collection performed by cone beam computed tomography (CBCT) and optical scanning of the prosthetic field (intraoral scanning; extraoral model scanning).

Various digital tools (PlanmecaRomexis, OnDemand3D, coDiagnosticX) use CBCT images due to the identification of pathology and vital anatomical structures as well as the evaluation of the alveolar bone quality and quantity. 3D CBCT images are reconstructed with special software to supply projections in axial, sagittal and coronal plans (Fokas *et al.*, 2018). The accuracy level of CBCT images depends of various factors and error can exceed 1 mm when linear measurements are performed for alveolar bone and other anatomical structures (Tyndall *et al.*, 2012). To avoid clinical complications during the surgical implant stage, the clinician must consider a 2-mm safety zone between implant and vital anatomical structures. Also, errors are associated to factors related to CBCT system and reconstruction algorithms (Alqallaf *et al.*, 2021).

The intraoral/extraoral optical scan represents teeth and soft tissue as a digital STL file that is sent to a virtual implant planning software.

STL file is merged with DICOM files obtained from the CBCT imaging for the next stages:

1. the planning of the future implant position according to proper anatomical and prosthetic criteria;
2. design and manufacturing of the surgical guide (Alqallaf *et al.*, 2021).

These stages are followed by the manufacturing of the surgical templates and implant-supported prosthetic restorations using the CAD-CAM technology (Arunyanak *et al.*, 2016).

Various research groups reported some degree of deviations between actual and virtual implant positions due to errors of one or more stages of the digital workflow (data collection, transfer, processing, virtual implant treatment planning, surgical execution) (Van Assche *et al.*, 2012; Tahmaseb *et al.*, 2018). Data collection by CBCT can be a reason for this inaccuracy due to device features, degree of radiation exposure, software used to view DICOM data, or even artifacts (Halperin-Sternfeld *et al.*, 2016). *In vivo* comparative studies between conventional impressions and optical scans are requested to evaluate the role of the inaccuracy of optical impression (Alqallaf *et al.*, 2021). A review performed by Flügge *et al.* (2018) highlighted that conventional implant impressions of the angulated implants are significantly less accurate compared to those of the parallel implants while the scan protocol has an impact on the accuracy and precision of the digital impressions.

Table 1

Workflow components in implant-prosthetic therapy (Alqallaf *et al.*, 2021)

	Workflow stage
1.	Viewing of radiographic data
2.	Merging radiographic data and surface scans
3.	Prosthetic setup of implant-supported restorations
4.	Anatomical and surgical considerations in the implant insertion
5.	Selection of surgical protocol
6.	Design of drill-guide support

Software systems for interactive planning of implant and prosthetic treatments are as follows: Implant 3D (Universe, USA), NobleGuide (Nobel Biocare, USA), Digital Smile Design (DSD), SimPlant (Materialise Dental). These systems allow the simulation of implant positioning on virtual two-dimensional and three-dimensional models, the reconstruction of three-dimensional bone models (based on CT and radiographic images), the identification of the mandibular canal, the presentation of three-dimensional sections of the jaw and mandible, the calculation of bone density (Forna D., 2017).

Virtual implant position can be planned using digital applications (DDS, X-Guide) to design the future implant position, in relation to the anatomical positions of adjacent teeth or implants and vital structures, such as the inferior alveolar nerve, mental nerve, maxillary sinus and nasal floor. Clinicians must consider the anatomical positions of adjacent teeth or implants and vital structures (inferior alveolar nerve, mental nerve, maxillary sinus, nasal floor). Davarpanah *et al.* (2011) reported four parameters that influence the distance between the real position of the implant and the virtual one four parameters: the deviation of the point of impact of the drill (the neck of the implant), the deviation of the apex of the implant, the deviation in relation to the corono-apical axis, the deviation of the angulation of the implant in oro-vestibular or mesio-distal plane. Ozan *et al.* (2009) determined for the deviations of the position of the implant collar the following average values: 0.87 mm for the surgical guide with dental support, 1.06 mm for the surgical guide with mucosal support, respectively 1.28 mm for the surgical guide with support bone. Regarding the surgical guide with dental support, in relation to mucosal and bone support, the deviation values are 1 mm for the implant neck, 1.6 mm for the implant apex at an angulation deviation below 5-6^0 (Davarpanah *et al.*, 2011).

Once the implant position is planned according to the proper anatomical and prosthetic criteria, the clinician can start the design of the surgical template in relation to the type of support (bone, mucosa, tooth), sleeve-to-bone height, drilling distance, as well as the number of teeth used as support if a tooth-supported template is designed (Alquallaf *et al.*, 2021).

The digital impressions can replace conventional impression to transfer data related to teeth, soft tissue and implant position data into virtual models that are used for treatment planning and prosthetic reconstruction CAD-CAM manufacturing. Various manufacturers provide optical scanning devices: Omnicam (Sirona), Trios 4 (3D Shape), True Definition (3M ESPE), CS3600 (Carestream), Planmeca Emerald™ (Planmeca).

Digital impressions produce a virtual model in STL format that does not include teeth or mucosa color. However intraoral scanning technique contains colors in OBJ geometry format or polygon file format. Nowadays digital impressions are spreading in routine dental practice due to their accuracy, higher patient acceptance as well as less time-consuming technique compared to conventional impressions in terms of impression material storage, handling, and stone pouring (Karl *et al.*, 2012; Papaspyridakos *et al.*, 2016). Limits of intraoral scanning techniques are related to possible cumulative errors due to the alignment and stitching of the images taken during the scanning process., especially in edentulous patients with lacks of the distinctive anatomy and when extended prosthetic field areas are scanned (Gan *et al.*, 2014). Also, other factors that decrease accuracy are the limited intraoral space for the scanner head as well as the reflection due to metallic restorations or salivary flow (Abduo *et al.*, 2018). To eliminate reflection, Flügge *et al.* (2018) recommends the use of titanium dioxide powder on reflective surfaces. An alternative technique is represented by the combination between the transfer of the details of a conventional impression onto a stone cast model and extraoral scanning of the stone cast by using intraoral scanning devices or dental laboratory scanners (Alqallaf *et al.*, 2021). When this technique is used, some errors can be provided only from conventional impression-taking stage and pouring of the stone cast (Kernen *et al.*, 2019).

DICOM files are used to display cross-sectional images in bucco-lingual (sagittal), anterior-posterior (axial), and mesiodistal (coronal) plans that allow the set-up of 3D model of bone and teeth (Kernen *et al.*, 2019). Merging 3D reconstructed model with STL data (derived from optical scan) is requested due to the inaccuracy of 3D volumetric model reconstructed by CBCT data. The merging stage must be done as accurately as possible considering that errors in merging data sets will lead to improper implant positioning during surgical execution (Flügge *et al.*, 2017). In cases with radiopaque restoration materials, clinicians must manufacture standardized fiducial markers on a radiographic template to be used as reference points for the recording of the multiple datasets (Katsoulis *et al.*, 2009). When these markers are used, CBCT scans are taken with the patient wearing the radiographic template and with the template on its own (Alqallaf *et al.*, 2021).

The implant-supported prosthetic restoration must be designed prior to implant surgical stage to ensure a prosthetically driven implant position. The design of the future implant-supported prosthetic restorations can be set up by various CAD software that will provide standard teeth shapes, additional shaping tools, and virtual articulators to facilitate tooth setup. An additional STL files can be provided from a conventional wax-up on a stone model that is scanned extraorally before being incorporated in the implant planning software.

Regarding the surgical implant stage, the digital planning of implant position and prosthetic set-up must consider the following anatomical and prosthetic parameters.

To avoid implant surgical complications related to the damage of vital anatomical structures, the planning of virtual implant must ensure a minimum of 1.5 mm of buccal bone in order to achieve optimal esthetics and peri-implant soft tissue stability. If clinician predicts less than 1,5 mm of buccal bone, after the digital planning of implant stage, guided bone regeneration procedure must be performed in the proimplant stage to avoid future soft peri-implant tissue recession (Farronato *et al.*, 2020). Also, a 3 mm mesiodistal distance will be planned between adjacent implants (Tarnow *et al.*, 2000). The implant must be placed fully in bone and 3 to 4 mm apical to the planned prosthesis margin (bone level design), or 1 to 2 mm apical from the planned prosthesis margin (tissue-level design) (Grunder *et al.*, 2005).

The surgical templates, assisting clinicians both in the initial pilot drill and fully guided protocols, are recommended due to the higher accuracy of implant placement (Van Assche *et al.*, 2012).

After the virtual implant position planning, the surgical template is designed according to the type of support: bone, mucosa, tooth (Gallardo *et al.*, 2017). Whenever the clinical situation allows, a tooth-supported template will be preferred, especially when can be used more than two adjacent teeth as support for the template, to increase stability (Tahmaseb *et al.*, 2018; El Kholy *et al.*, 2019). The use of bone-supported templates must be avoided, when possible, to avoid the exposure of the underlying bone, increased postoperative discomfort and future alveolar bone resorption (Rosenfeld *et al.*, 2006). When tooth support cannot be used, mucosa-supported templates are recommended due to less invasive features, reduced postoperative pain and discomfort, lower surgical time, and postoperative healing time (Rosenfeld *et al.*, 2006). The mucosa-supported templates have some disadvantages related to mucosal thickness and resilience (Cassetta *et al.*, 2013).

Some factors related to the implant system, clinician experience, implant planning software, can affect the drill guidance and deviation range: sleeve height, drilling distance or guided key height (ALqallaf *et al.*, 2021). To avoid or reduce inaccuracy, El Kholy *et al.* (2019) recommend a protocol involving a shorter drill, lower sleeve height and longer drill key. Inaccuracies due to the drill or implant macrodesign can lead to higher deviation between planned virtual implant position and the real implant position at the end of the surgical stage. El Kholy *et al.* (2019) reported that tapered implant macrodesign has significantly higher positional accuracy when compared to parallel implant macrodesign due to the design of the drill, thread, or insertion geometry (El Kholy *et al.*, 2019).

The virtual design of the prosthetic restoration will be used by CAM technology in the manufacturing of the future implant-supported reconstruction by additive or subtractive technology (Alqallaf *et al.*, 2021). The subtractive processes use shaping of the reconstruction material (zirconia, ceramic) by cutting instruments; 3D printers (additive technology) use special ink materials to build up layer by layer the prosthetic reconstruction (Duda *et al.*, 2016; Beuer *et al.*, 2008). These two technologies have similar accuracy and within a clinically acceptable range (Henprasert *et al.*, 2020).

Nowadays surgical templates can be fabricated in 3D-printed resin with higher accessibility ease of fabrication, and lower cost. (Stansbury *et al.*, 2016). The thickness of the resin surgical template is a disadvantage, bulkier templates limiting the accessibility and surgical view. Despite higher cost and manufacturing time, many clinicians prefer metal and zirconia surgical templates due to lower thickness, which enhances surgical visibility and access (Stansbury *et al.*, 2016).

Figures 1–5 show digital devices and tools used in the workflow of the implant-prosthetic therapy.

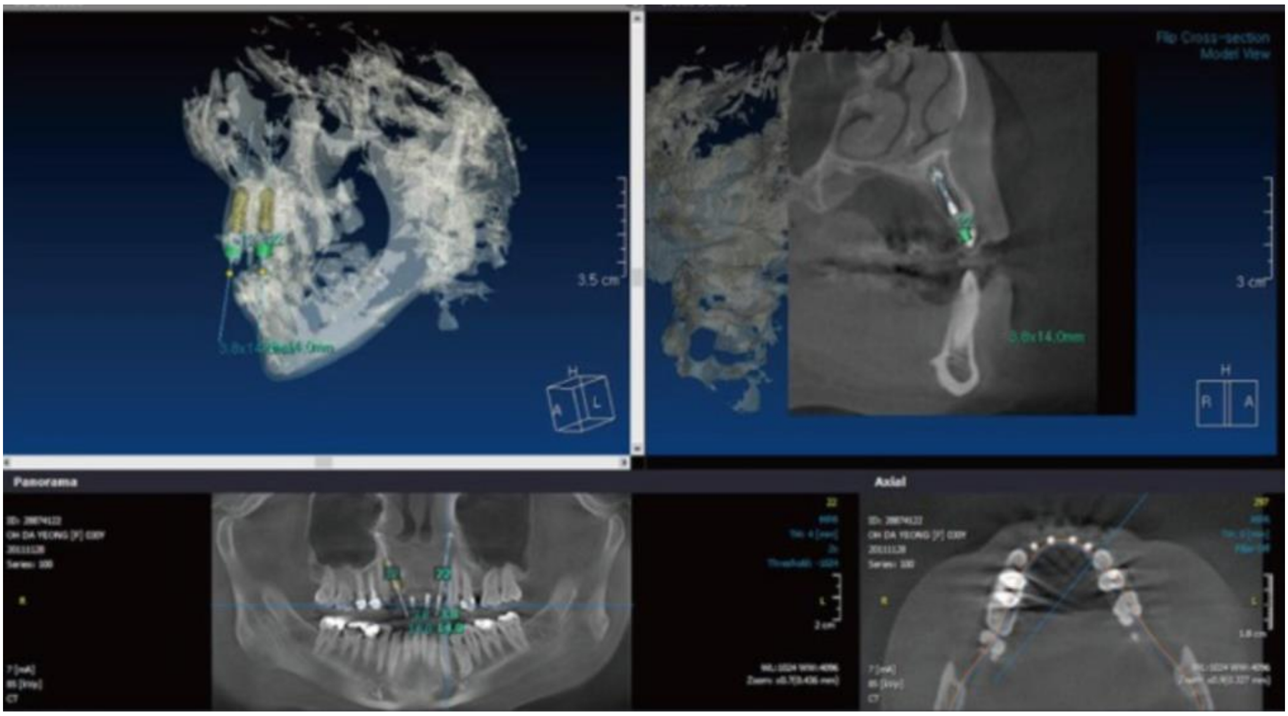

Figure 1. Alveolar bone analysis and planning of virtual implant positioning by software OnDemand (Lee *et al.*, 2013).

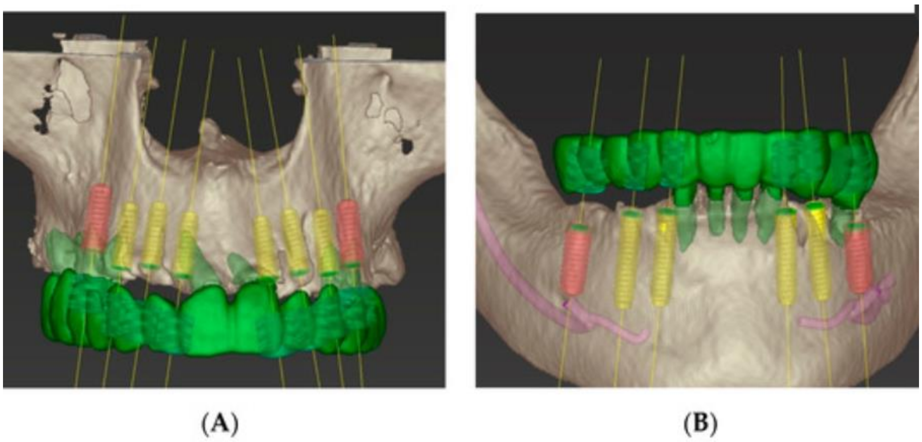

Figure 2. Planning of virtual implant positioning by software coDiagnostiX
(Straumann USA, LLC, Andover, MA, USA) (Lee *et al.*, 2019).

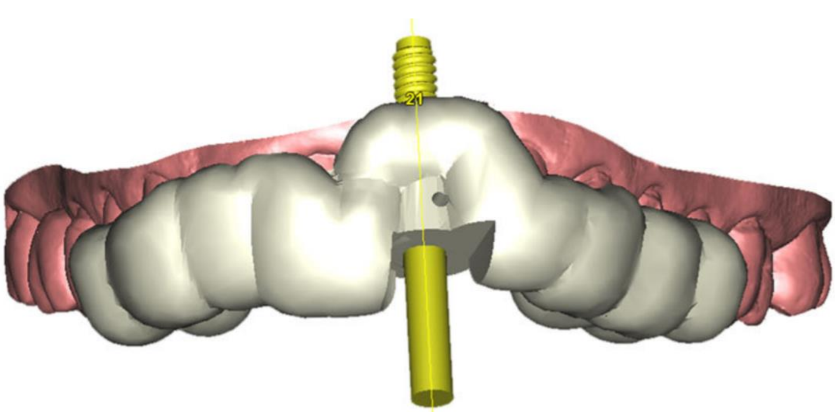

Figure 3. Planning of surgical template by software SMOP (Kernen *et al.*, 2020).

Figure 4. Surgical guide fabricated by CAD-CAM technique (Forna D., 2017).

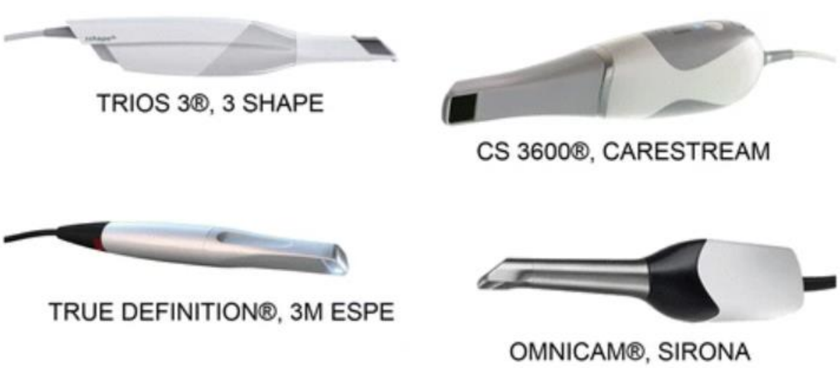

Figure 5. Intraoral scanning devices (Imburgia *et al.*, 2017).

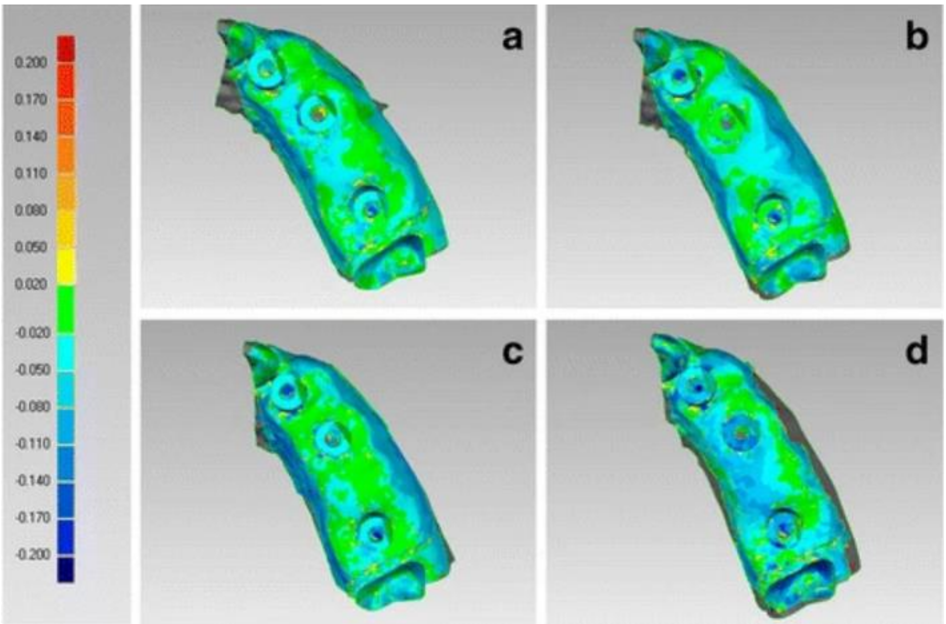

Figure 6.a-d. Intraoral scans of the edentulous area (Imburgia *et al.*, 2017).

CONCLUSIONS

- Digital tools and technologies improve diagnosis, case planning and surgical execution in implant surgical stage.
- Digital treatment planning allows the design of the surgical template and implant-supported prosthetic restoration, to improve the accuracy of implant insertion in a prosthetically driven position during the surgical stage.
- The use of the digital workflows in implant-prosthetic therapy led to more predictable and successful implant outcomes.
- Limits are related to the accuracy in collecting CBCT data or merging data sets (radiographic viewing, optical intraoral scanning, extraoral scanning of the conventional impression).

REFERENCES

1. Abduo J, Elseyoufi M. Accuracy of intraoral scanners: a systematic review of influencing factors. *Eur J Prosthodont Restor Dent.* 2018; 26:101–121.
2. Alqallaf H, Su F-Y, Goel A, Lin W-S. Utilizing a Digital Workflow for Implant Treatment Planning. https://decisionsindentistry.com/article/utilizing-digital-workflow-implant-treatment planning.2021.
3. Arunyanak SP, Harris BT, Grant GT, Morton D, Lin WS. Digital approach to planning computer-guided surgery and immediate provisionalization in a partially edentulous patientJ *J Prosthet Dent*. 2016; 116:8–14.
4. Beuer F, Schweiger J, Edelhoff D. Digital dentistry: an overview of recent developments for CAD/CAM generated restorations. *Br Dent J.* 2008; 204:505–511.
5. Cassetta M, Di Mambro A, Giansanti M, Stefanelli LV, Cavallini C. The intrinsic error of a stereolithographic surgical template in implant guided surgery. *Int J Oral Maxillofac Surg.* 2013; 42:264–275.
6. Conejo J, Atria PJ, Schweitzer D, Blatz MB. Digital Implant Planning and Surgical Guides: Tools for Clinical Success. *Compend Contin Educ Dent.* 2021 Jul-Aug;42(7):400-401.
7. Davarpanah M, Szmukler-Moncler S, Davarpanah K, Rajzbaum P. Implantologie assistée par ordinateur. Éditions CdP .2011.
8. Duda T, Raghavan LV. 3D metal printing technology. *IFAC-PapersOnLine*. 2016; 49:103–110.
9. El Kholy K, Ebenezer S, Wittneben JG, *et al.* Influence of implant macrodesign and insertion connection technology on the accuracy of static computer-assisted implant surgery. *Clin Implant Dent Relat Res*. 2019; 21:1073–1079.
10. Farronato D, Pasini PM, Orsina AA, *et al.* Correlation between buccal bone thickness at implant placement in healed sites and buccal soft tissue maturation pattern: a prospective three-year study. Materials (Basel). 2020; 13:511.
11. Flügge T, van der Meer WJ, Gonzalez BG, *et al.* The accuracy of different dental impression techniques for implant-supported dental prostheses: a systematic review and meta-analysis. *Clin Oral Implants Res*. 2018; 29 (Suppl 16):374–392.
12. Flügge T, Derksen W, Te Poel J, *et al.* Registration of cone beam computed tomography data and intraoral surface scans – a prerequisite for guided implant surgery with CAD/CAM drilling guides. *Clin Oral Implants Res.* 2017; 28:1113–1118.
13. Fokas G, Vaughn VM, Scarfe WC, Bornstein MM. Accuracy of linear measurements on CBCT images related to presurgical implant treatment planning: a systematic review. *Clin Oral Implants Res.* 2018;29(Suppl 16):393–415.
14. Forna D. Teza Doctorat "Sisteme de planificare computerizată de pregătire chirurgicală preimplantară și implantară (laser *versus* clasic)" UMF «Grigore T. Popa» Iasi. 2017.
15. Forna N. Tratat de Protetica Dentară. Editura Enciclopedică, 2011.
16. Forna N. Actualități în clinica și terapia edentației parțial întinse. Tratat de protetică dentară. Edit. "Gr. T. Popa" Iasi, 2008.
17. Gallardo YN, da Silva-Olivio IR, Mukai E, *et al.* Accuracy comparison of guided surgery for dental implants according to the tissue of support: a systematic review and meta-analysis. *Clin Oral Implants Res*. 2017; 28:602–612.
18. Gan N, Xiong Y, Jiao T. Accuracy of intraoral digital impressions for whole upper jaws, including full dentitions and palatal soft tissues. *PLoS One*. 2016; 11:e0158800.
19. Ganz SD. Three-dimensional imaging and guided surgery for dental implants. *Dent Clin North Am.* 2015 Apr;59(2):265-90.
20. Grunder U, Gracis S, Capelli M. Influence of the 3D bone-to-implant relationship on esthetics. *Int J Periodontics Restorative Dent*. 2005; 25:113–119.
21. Guichet D. Digitally enhanced dentistry: the power of digital design. *J Calif Dent Assoc*. 2015 Mar;43(3):135-41.
22. Halperin-Sternfeld M, Machtei EE, Horwitz J. Diagnostic accuracy of cone beam computed tomography for dimensional linear measurements in the mandible. *Int J Oral Maxillofac Implants*. 2014; 29:593–599.
23. Henprasert P, Dawson DV, El-Kerdani T, *et al.* Comparison of the accuracy of implant position using surgical guides fabricated by additive and subtractive techniques. *J Prosthodont*. 2020; 29:534–541.
24. Imburgia, M., Logozzo, S., Hauschild, U. *et al.* Accuracy of four intraoral scanners in oral implantology: a comparative in vitro study. *BMC Oral Health* 2017; 17, 92. https://doi.org/10.1186/s12903-017-0383-4.
25. Karl M, Graef F, Schubinski P, Taylor T. Effect of intraoral scanning on the passivity of fit of implant-supported fixed dental prostheses. *Quintessence Int.* 2012; 43:555–562.
26. Katsoulis J, Pazera P, Mericske-Stern R. Prosthetically driven, computer-guided implant planning for the edentulous maxilla: a model study. *Clin Implant Dent Relat Res*. 2009; 11:238–245.
27. Kernen FF. Pre-operative analysis and treatment planning in digital implant dentistry. *Forum Implantologicum*. 2019; 15:8.
28. Moy P, Palacci P, Ericsson I. Immediate Function& Esthetics in Implant Dentistry. Quintessence Books. 2008.
29. Ozan O, Turkyilmaz I, Ersoy AE, McGlumphy EA, Rosenstiel SF. Clinical accuracy of 3 different types of computed tomography-derived stereolithographic surgical guides in implant placement. *J Oral Maxillofac Surg*. 2009 Feb;67(2):394-401.

30. Papaspyridakos P, Gallucci GO, Chen CJ, *et al.* Digital versus conventional implant impressions for edentulous patients: accuracy outcomes. Clin Oral Implants Res. 2016; 27:465–472.
31. Patel N. Integrating three-dimensional digital technologies for comprehensive implant dentistry. *J Am Dent Assoc*. 2010 Jun;141 Suppl 2:20S-4S.
32. Rosenfeld AL, Mandelaris GA, Tardieu PB. Prosthetically directed implant placement using computer software to ensure precise placement and predictable prosthetic outcomes. Part 2: rapid-prototype medical modeling and stereolithographic drilling guides requiring bone exposure. *Int J Periodontics Restorative Dent*. 2006; 26:347–353.
33. Rosenfeld AL, Mandelaris GA, Tardieu PB. Prosthetically directed implant placement using computer software to ensure precise placement and predictable prosthetic outcomes. Part 3: stereolithographic drilling guides that do not require bone exposure and the immediate delivery of teeth. *Int J Periodontics Restorative Dent*. 2006; 26:493–499.
34. Stansbury JW, Idacavage MJ. 3D printing with polymers: challenges among expanding options and opportunities. *Dental Materials*. 2016; 32:54–64.
35. Tahmaseb A, Wu V, Wismeijer D, Coucke W, Evans C. The accuracy of static computer-aided implant surgery: a systematic review and meta-analysis. *Clin Oral Implants Res*. 2018;29(Suppl 16):416–435.
36. Tarnow DP, Cho SC, Wallace SS. The effect of inter-implant distance on the height of inter-implant bone crest. *J Periodontol*. 2000; 71:546–549.
37. Tyndall DA, Price JB, Tetradis S, *et al.* Position statement of the American Academy of Oral and Maxillofacial Radiology on selection criteria for the use of radiology in dental implantology with emphasis on cone beam computed tomography. *Oral Surg Oral Med Oral Pathol Oral Radiol.* 2012; 113:817–826.
38. Van Assche N, Vercruyssen M, Coucke W, Teughels W, Jacobs R, Quirynen M. Accuracy of computer-aided implant placement. *Clin Oral Implants Res.* 2012; 23 (Suppl 6):112–123.