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Basics of navigation implant prosthetics planning

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SUMMARY

Due to the development of digital technologies, the modern concept of prosthetic-guided implantology is based on non-invasive surgical and restorative techniques. Computer-aided planning, computer-guided workup and computer-guided surgery have largely ensured the predictability of the therapeutic outcome. This is supported by research data related to the frequency of implant therapy, according to which in the first half of 2020 there was an increase of 9.7%. However, anatomical limitations remain a challenge for the implant team. The most common problem related to implant therapy in edentulous patients is limited edentulous space in one or more spatial planes. Improving the design of surgical guides facilitates implantation in spatially limited and complex cases. By introducing interactive computed tomography into the field of implantology, a three-dimensional approach to every aspect of planning and implantation has become possible.

Keywords: prosthetic-guided implantology; computer-aided planning; computer-guided surgery

INTRODUCTION

Positioning implants according to the requirements of prosthetics, while respecting the capacity of bone structures and anatomical risk zones, requires detailed analysis and radiological visualization of a three-dimensional implant projection [1]. In order to ensure the optimal position of the implant, the procedure of "backward planning" is used in practice, i.e. implant placement according to prosthetic needs [2]. As the part of pre-surgical treatment, a clinician takes medical history, performs clinical examination, makes diagnosis, and plans the type and design of prosthetic restoration with an emphasis on the transmission of occlusal forces, as it dictates the number, type and position of implants. When creating a treatment plan, the clinician pays special attention to the quality of the remaining hard and soft tissue, which directs surgical positioning of the implants and subsequent bone remodeling. Clinical examination requires detailed extraoral, intraoral and radiographic analysis.

It is known that radiological diagnostics is the basis for planning implant therapy. *The American Academy of Oral and Maxillofacial Radiology* recommends conventional radiological methods as a starting point for planning [3]. Orthopantomography is used as part of the initial assessment of the patient, while intraoral radiograms are an additional element for a more accurate presentation of a particular segment. The main disadvantages of orthopantomography are: image deformation, which is 20-30% vertically and as much as 60-70% horizontally, supraposition of anatomical structures in the frontal region, lack of "third dimension", as well as lack of information on bone quality [4, 5]. This implies that the precise creation of a surgical plan is not possible with two-dimensional radiographic methods and requires the use of cone beam computed tomography (Cone Beam Computer Tomography-CBCT). One of the most significant achievements in CBCT technology is interactive computed tomography (ICT) [6]. Most therapists agree that a correct diagnosis is the foundation of therapeutic success. In implant prosthetics, the foundations are defined by the precision of implant position. Ideal position of the implant is precisely planned spatial orientation in relation to the adjacent anatomical structures and / or the adjacent implant. Data on the comparison of the precision of the implant placement using conventional method of free-hand surgery and computer-guided implantation are available in the literature [7–9]. Table 1 shows the results of the research by Sun et al. [7].

According to the results, to meet these requirements, different static and dynamic navigation systems are available to clinicians. Due to the high costs of dynamic navigation, surgical templates are more widely used in practice as the main representatives of statically guided implant placement. Guides can be categorized according to different parameters. Based on the supporting tissues, they can be supported by teeth, bone or soft tissue structures, determined for toothless fields or edentulous jaws, depending on the indication [10]. The second division, based on materials for making surgical guides, refers mainly to self-bonding / light-curing acrylate resins, although they can be made of an alloy of CoCr and titanium. The third division of the guide refers to the design and can be open or closed [11, 12].

The aim of this paper is to present chronologically procedural planning steps in implant prosthetics with reference to the pre-prosthetic aspect of planning.

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Table 1. Deviations of the longitudinal and angular position of implants comparing free hand guided and computer guided surgery
Tabela 1. Odstupanja uzdužnog i ugaonog položaja implantata ugrađenih tradicionalnom i kompjuterski navođenom hirurgijom

	Jaw Vilica	Longitudinal error (mm) Greška u vertikalnom položaju (mm) Mean ± SD	Angular error (degree) Greška u angulaciji (stepeni ugla) Mean ± SD Aritmetička sredina ± SD
Eksperimental group (computer guided surgey) Eksperimentalna grupa (kompjuterski navođena hirurgija)	Maxilla Gornja	0.63 ± 0.24	3.07 ± 0.99
	Mandible Donja	0.88 ± 0.22	3.59 ± 0.99
Control group (traditional free hand surgery) Kontrolna grupa (tradicionalna hirurgija vođena slobodnom rukom hirurga)	Maxilla Gornja	1.21 ± 0.09	6.02 ± 0.04
	Mandible Donja	1.63 ± 0.17	6.22 ± 0.09

(CONE BEAM COMPUTERIZED TOMOGRAPHY) CBCT

CBCT provides the possibility of volumetric imaging of bones and preoperative collection of large amounts of information, of which the most important in toothless and edentulous jaws are: available bone volume and quality, position of anatomical structures and the presence of pathological changes [13]. Having in mind the oldest ethical principle of ancient medicine "primum non nocere (do not harm)", with the advent of modern methods of radiography, and in connection with the radiation dose, the so-called ALARA principle (As Low As Reasonable Achievable) was introduced, i.e. the application of the lowest possible radiation dose to obtain the characteristics of anatomical structures of interest [13]. The American Academy of Periodontology (AAP), by consensus in 2017, made recommendations for the rational use of CBCT radiography in oral and maxillofacial surgery [13]. As CBCT images have a high diagnostic capacity, the radiation dose for CBCT imaging per jaw is equal to 2 to 10 orthopantomograms. There are different sizes of fields of view depending on the indication. In the basic categorization, three types of fields of view are distinguished: limited (small), medium and large. The large field of view, which covers a wider anatomical region, requires a higher dose of radiation, creating an image of lower resolution. The limited field of view captures a small region, up to 15 cm, applying a lower effective dose of radiation, and provides a higher resolution image [14]. Reducing the radiation dose is achieved by choosing smaller recording volume, i.e. smaller FOV (Field Of View) [14]. Bornstein et al. [14] provided data for effective radiation doses (Table 2). Table 2 is provided with modifications from "Cone Beam Computed Tomography in Implant Dentistry: A Systematic Review Focusing on Guidelines, Indications, and Radiation Dose Risks" [14].

ANALOG AND DIGITAL PLANNING

The preoperative segment of analog planning begins with the development of a diagnostic cast (Figure 1). Preliminary tooth placement on the diagnostic cast can be realized through the use of a set of fabricated PMMA teeth (set up) or by modeling the teeth in wax (wax up). The choice is a matter of the clinician's choice. However, there is a recommendation that factory-made teeth be used in edentulous patients, while wax modeling is easier to implement in cases of minor edentulousness [15]. Preliminary tooth placement on diagnostic model is the basis for making a radiological guide.

In a narrower sense, digital planning encompasses the domain of software tools of CBCT and CAD-CAM machines. The image created during the volumetric recording of the anatomical structures of the face and jaws is processed in the software program of the device in Digital Imaging and

Table 2. Values of effective dose of CBCT radiation and panoramic radiography
Tabela 2. Vrednosti efektivnih doza zračenja izraženih u mikrosivertima za CBCT i panoramsko radiografisanje

Study Studija	Radiographic technique Radiografska terapija	Field of view Polje pregleda	Effective dose Efektivna doza (μSv)
Theodorakou et al. 125 ref	CBCT **(< 40 cm²)**	4 × 4 cm²	32
Pauwels et al. Ref 127	CBCT **(< 40 cm²)**	5 × 3.7 cm²	40 40
Suomalainen et al. REF 119	CBCT **(< 40 cm²)**	6 × 6 cm²	91
Jeoung et al.	CBCT	8 × 5 cm²	83
Pauwelset al.	CBCT **(40–100 cm²)**	10 × 5 cm²	54
Koivisto et al.	CBCT **(40–100 cm²)**	8 × 8 cm²	153
Qu et al.	CBCT **(40–100 cm²)**	8 × 8 cm² Mala/velika/ standardna doza zracenja	30/306/197
Ludlow et al	CBCT **(40–100 cm²)**	16 × 6 cm²	74 74
Ludlow et al.	CBCT **(> 100 cm²)**	10 × 10 cm²	283
Pauwels et al.	CBCT (> 100 cm²)	15 × 15 cm²	194 194
Okano et al.	CBCT (> 100 cm²)	15 × 15 cm²	511
Ludlow et al.	CBCT (> 100 cm²)	20 × 20 cm²	1073
Theodorakou et al.	Panoramic Ortopan tomografija	15 × 10 cm²	6
Silva et al.	Panoramic Ortopan tomografija	15 × 11 cm²	10
Carrafiello et al.	Panoramic Ortopan tomografija	15 × 23 cm²	50
Grünheid et al.	Panoramic Ortopan tomografija	15 × 30 cm²	21.5

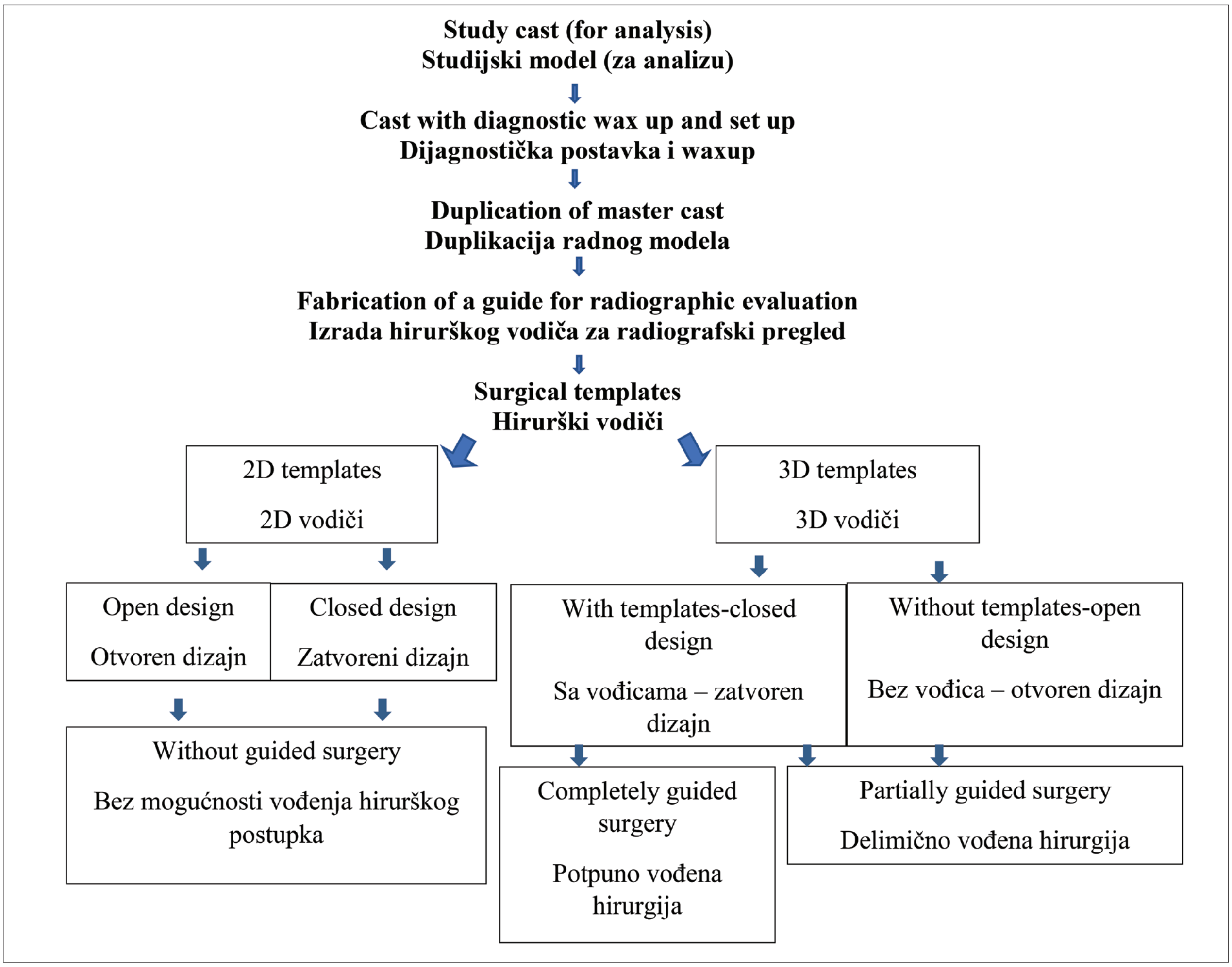

Figure 1. Chronological procedures from analog planning to implant surgery.
Slika 1. Postupci prikazani hronološkim redom od analognog planiranja to implantacije

Communications in Medicine (DICOM) format [16]. The data thus obtained are combined with the data on the modeled wax-up. An important segment of planning includes the analysis of intermaxillary relations. With the introduction of the so-called Bari techniques the transfer of intermaxillary and occlusal relationships in all three spatial planes is enabled, and that in a digital environment. The method is based on the fabrication of a prosthetic stent that aims to transmit occlusal relations recorded by a temporary diagnostic prosthesis within the final prosthetic restoration on the implants [17]. Based on the above data, the therapist has clearly defined requirements for the prosthetic component and approaches virtual implant position planning including the length, diameter, inclination and depth of the implant. This is followed by the design of a surgical guide. Technological procedures for making surgical guides are divided into additive and subtractive (stereolithographic) methods [15].

RADIOLOGICAL GUIDE FOR SUCCESSFULLY DESIGNED SURGICAL TEMPLATE

The purpose of radiological guide is to enable the transfer of information about the position of the crown part of future restoration to the CBCT image. Good guide stability on supporting tissues is mandatory. Any imprecise fit can result in the conductor moving during radiography, resulting in displacement of the reference object. If the surgical guide is based on the information obtained that way, the clinician will find difficult to place the surgical guide and the entire procedure can be compromised [15]. In order to fulfill radiological visualization of prosthetic part of the dental compensation successfully, various radiopaque materials can be put within the radiographic guide. Numerous authors [15, 18] have compared opacity of the materials most commonly used for that purpose. The research results have shown that the biggest opacity has barium sulfate ($BaSO_4$), gutta-percha and the materials used for fixing the crowns based on zinc oxide. The radiological stent is most often made on a base of a master cast. The templates are made of hard vacuum foil of 1 mm in diameter. When it comes to edentulous patients, the old denture, if retained well on the supporting tissues, can also be used for the purpose of the radiographic guide. It is advised that adhesives should be applied on the mucosal side of the prosthesis before radiography as well. Perforations, in which the radiopaque materials are placed, are formed within acrylic teeth [19, 20]. The other option is fabricating the master cast based on complete denture.

The master cast represents the working cast for making the radiographic guide, most often of the vacuum foil [15].

DYNAMIC AND STATIC NAVIGATION

Dynamic navigation is computer-guided implant placement. This method refers to applying the intraoperative navigational system which constructional solution is usually based on the optical tools for measuring the position of the implants. Some of the currently available on the market are: Blue Sky Bio Plan Software, Fusion Nobel Biocare, CoDiagnostic software, M-Guide, DentalWings, Simplant Software, SMOP Swisseda etc. As indications for applying the dynamic navigation, Block and Emery have named mostly all those situations where relative or absolute restrictions to applying the surgical guide are possible: the patients with limited mouth opening, the implantation in hardly accessible regions of the side segments of the jaws, where mesiodistal dimension of toothless space does not allow placing the static guide due to the cylinder width [21]. The clinician follows on the computer screen moving of the surgical drill during the intervention [22]. The dynamic navigation advantages are: the cost-effectiveness procedure for the patient, the possibility of constant irrigation of the surgical area and more possibilities for the clinician to lead the surgical drill intraoperatively. The high expenses of tools are stated as the main disadvantage. The dynamic navigation is not advised as a part of the edentulous patient treatment [21]. The static navigation is based on applying the surgical template. The main function of the template is to enable transferring the analogous or digital therapeutic plan into three-dimensional intraoral surrounding. The vacuum foils, identical to those applied to the radiological templates, were used as the first guides. Such guide provides the insight into the future crown position, so, according to that, the surgeon can map the implantation place. Further implantation course is guided by the clinician and depends on his experience and skills.

Speaking of the contemporary static template, the implantation of virtually planned installation of the implants can be realized through semi-guided or fully guided and depending on the design of the sleeves (cylinders) which are integrated into the guide [15, 23, 24]. Fully guided surgery refers to applying the surgical template which design provides precisely planned position, angulation, diameter and implants' depth. The template is placed in the patient's mouth during the entire surgical procedure, not allowing the therapist to intraoperatively lead the drill to any other position apart from the one defined by the cylinders integrated within the guide. Due to the properties of the materials from which the templates are made (polymethyl methacrylate or metal alloys), as well as sleeves, which can be made from metal alloys or zirconium, rigidity of the guide is insured and therefore the greater safety for the clinician [15]. In order to provide greater safety during the procedure, the template should be retained well on the supporting tissues. This is also the reason why it is not justified to use poorly retained and old complete denture as the surgical template.

The term of semi-guided surgery refers to the templates that are in favor of the therapist only during the first implantation phases. These guides use cylindrical sleeves that can accept the first, and perhaps second surgical drill. When there is no enough space in the mesiodistal direction, the preference should be given to the sleeves for the semi-guided surgery since the cylinders have narrower diameter compared to fully guided surgery sleeves [15].

Fully guided approach has the advantage in cases of weak quality of the bone, considering that the light arm movement during the placement of the implants can result in greater deviation for the semi-guided surgery [24]. Considering the advantages and disadvantages of the both systems, the authors [24] who have analyzed the difference between fully and semi-guided surgery precision, have concluded that the statistically significant difference in accuracy is evident only in the position of the apical third of implants. The advantages of the fully guided surgery are: lower risk of anatomic structure damages, performing the surgical procedure without opening the flap (flapless surgery) and therefore shortening the postsurgical period of recovery, the possibility of individualization of the abutment design according to the surgical guide position etc [15]. However, even if the concept of applying the surgical guide considers simple protocol, these solutions contain certain disadvantages. Major ones are: insufficient surgical area visibility, impossibility of applying the surgical guide in case of the little inter-occlusal space, the risk of damaging or contaminating the drill when it passes through sleeve [23]. In order to compensate these disadvantages, nowadays the method of placing the implants applying the open guide has been considerably developing (TWIN-Guide®, 2Ingis, Brussels, Belgium). The open design compensates the mentioned disadvantages of the closed system of the guide, and it is compatible with all dental implant systems. Besides, surgical procedure is performed with continuous irrigation of the osteotomy site. The guide uses the pattern of the open frame, giving the clinician the guidelines for the implantation in the form of two reference cylindrical bushings places on the vestibular and oral sides of the surgical guide [23, 25].

CONCLUSION

Ideal position of the implants implies the spatial orientation in relation to adjacent anatomic structures and/or adjacent implants. Wrong positioning can have functional, technical, biological or esthetic consequences. Using computer-guided implantology provides predictability of the therapeutic results. Although the results of the wrong implant placement can lead to clinically manifested complications only in a few months or years, the first difficulties can arise even in the phase of impression taking when the deviation from the implant angulation prevents correct placing of the transfers. Wide ranges of surgical templates that differ according to the design and their purpose have enabled the clinicians to induce their purpose in the complex cases as well. Yet, the restrictions to the concept of the fully guided implantology are related to its application only in the case of partially edentulous patients. The implant-prosthetic rehabilitation of the edentulous patients is realized by conventional methods partly or entirely guided by the surgeon.

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Osnove planiranja navigacione implantat-protetike

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KRATAK SADRŽAJ

Zahvaljujući razvoju digitalnih tehnologija, savremeni koncept protetskom nadoknadom vođene implantologije bazira se na neinvazivnim hirurškim i restaurativnim tehnikama. Kompjutersko planiranje i kompjuterski vođena ugradnja implantata su u velikoj meri obezbedili predvidivost terapijskog ishoda. U prilog tome govore podaci istraživanja vezanih za učestalost implantološke terapije prema kojima je u prvoj polovini 2020. godine ostvaren porast za 9,7%. Međutim, anatomska ograničenja i dalje predstavljaju izazov za implantološki tim. Najčešći problem u vezi sa implantološkom terapijom kod krezubih pacijenata jeste ograničen bezubi prostor u jednoj ili više prostornih ravni. Unapređenjem dizajna hirurških vodiča olakšana je implantacija u prostorno ograničenim i kompleksnim slučajevima. Uvođenjem interaktivne kompjuterizovane tomografije u sferu implantologije, omogućen je trodimenzionalni pristup svakom aspektu planiranja i implantacije.

Ključne reči: protetskom nadoknadom vođena implantologija; kompjutersko planiranje; kompjuterski vođena hirurgija

UVOD

Pozicioniranje implantata prema zahtevima protetike, uz poštovanje kapaciteta koštanih struktura i anatomskih zona rizika, zahteva detaljnu analizu i radiološku vizuelizaciju trodimenzionalne projekcije moguće pozicije implantata [1]. Da bi se osigurala optimalna pozicija implantata, u praksi se koristi procedura „planiranja pozicije implantata unazad" (*eng. backward planning*), odnosno ugradnja implantata prema protetskim potrebama [2]. U okviru predhirurškog tretmana, kliničar uzima anamnezu, vrši klinički pregled, postavlja dijagnozu i planira vrstu zubne nadoknade sa akcentom na način prenošenja okluzalnih sila i dizajn same nadoknade, s obzirom na to da to diktira broj, vrstu i položaj implantata. Prilikom izrade plana terapije terapeut posebnu pažnju posvećuje kvalitetu preostalog tvrdog i mekog tkiva koji usmeravaju hirurško pozicioniranje implantata i naknadnu remodelaciju kosti.

Klinički pregled zahteva detaljnu ekstraoralnu, intraoralnu i radiografsku analizu.

Poznato je da radiološka dijagnostika predstavlja osnovu u planiranju implantološke terapije.

The American academy of oral and maxillofacial radiology preporučuje konvencionalne radiološke metode kao polaznu osnovu planiranja [3]. Ortopantomografski snimak se koristi u okviru inicijalne procene pacijenta, dok intraoralni radiogrami predstavljaju dopunski element radi preciznijeg prikaza određenog segmenta. Kao glavni nedostaci ortopantomografije navode se: deformacija slike, koja po vertikali iznosi 20-30%, a po horizontali čak 60-70%, suprapozicija anatomskih struktura u frontalnoj regiji, nedostatak „treće dimenzije", kao i izostanak informacija o kvalitetu kosti [4, 5].

Navedeno implicira da precizno kreiranje hirurškog plana nije moguće uz dvodimenzionalne radiografske metode i da zahteva primenu računarske tomografije konusnog snopa (*eng. Cone Beam Computer Tomography).* Jedno od najznačajnijih dostignuća u tehnologiji CBCT je interaktivna računarska tomografija (*eng. interactive computed tomography – ICT*) [6].

Većina terapeuta slaze se sa konstatacijom da je pravilna dijagnoza temelj terapijskog uspeha. U implantat-protetici temelji su definisani preciznošću položaja implantata. Idealna pozicija implantata podrazumeva precizno isplaniranu prostornu orijentaciju u odnosu na susedne anatomske strukture i/ili susedni implantat. U literaturi su dostupni podaci o poređenju preciznosti položaja implantata ugrađenih konvencionalnom metodom vođenja rukom hirurga (*eng. free-hand surgery*) i kompjuterski vođenom ugradnjom [7, 8, 9]. Prema rezultatima ovih istraživanja, postoji statistički značajna razlika u preciznosti položaja. Tabela 1 prikazuje rezultate istraživanja Sana i saradnika [7].

Radi ostvarivanja zahteva preciznosti, kliničarima su na raspolaganju različiti sistemi statičke i dinamičke navigacije. Zbog velikih troškova dinamičke navigacije, veću primenu u praksi nalaze hirurški vodiči kao glavni predstavnici statički vođene ugradnje implantata.

Vodiči mogu biti kategorizovani prema različitim parametrima. Na osnovu nosećih tkiva, mogu biti podržani zubima, koštanim ili mekotkivnim strukturama, određeni za krezuba polja ili bezube vilice, zavisno od indikacije [10]. Druga podela, zasnovana na materijalima za izradu hirurških vodiča, odnosi se uglavnom na samovezujuće/svetlosnopolimerizujuće akrilatne smole, iako mogu biti od legure CoCr i titana. Treća podela vodiča odnosi se na dizajn i mogu biti otvoreni ili zatvoreni [11, 12].

Cilj rada je da prikaže hronološki procedurane korake planiranja u implantat-protetici sa osvrtom na predprotetski aspekt planiranja.

CBCT

CBCT daje mogućnost volumetrijskog snimanja kostiju i preoperativnog prikupljanja velikih količina informacija, od kojih su kod krezubih i bezubih vilica najznačajniji: raspoloživi volumen i kvalitet kosti, položaj anatomskih struktura i prisustvo patoloških promena [13]. Imajući u vidu najstariji etički princip antičke medicine „*primum non nocere*", sa pojavom savremenih metoda radiografisanja, a u vezi sa dozom zračenja, uveden je takozvani ALARA princip (*eng. As Low As Resonable Achievable*), odnosno primena najmanje moguće doze zračenja uzimajući u obzir karakteristike anatomskih struktura koje želimo da prikažemo [13]. Američka akademija za parodontologiju (AAP) konsenzusom je iz 2017. godine dala preporuke za racionalnu primenu CBCT radiografije u oralnoj i maksilofacijalnoj hirurgiji [10].

Kako CBCT slike imaju visok dijagnostički kapacitet, doza radijacije za CBCT snimak po vilici je kao za 2 do 10 ortopana. Postoje različite veličine vidnih polja zavisno od indikacije. U osnovnoj kategorizaciji razlikuju se tri tipa vidnog polja: ograničeno (malo), srednje i veliko. Veliko vidno polje, koje obuhvata širu anatomsku regiju, zahteva veću dozu zračenja, stvarajući sliku manje rezolucije. Ograničeno vidno polje zahvata malu regiju, do 15 cm, primenjujući manju efektivnu dozu zračenja, i pruža sliku veće rezolucije [14]. Smanjenje doze zračenja postiže se izborom manjeg volumena snimanja, tj. manjeg FOV (*eng. Field Of View*) [14]. Autori [14] su dali podatke za efektivne doze zračenja (Tabela 2).

Preuzeto uz modifikacije iz „Cone Beam Computed Tomography in Implant Dentistry: „*A Systematic Review Focusing on Guidelines, Indications, and Radiation Dose Risks*“ [14].

ANALOGNO I DIGITALNO PLANIRANJE

Preoperativni segment analognog planiranja započinje izradom dijagnostičkog modela (Slika1). Preliminarna postava zuba na dijagnostčkom modelu može se realizovati kroz upotrebu garniture gotovih PMMA zuba (eng. *set up*) ili modelovanjem zuba u vosku (eng. *wax up*). Odabir je stvar izbora terapeuta. Ipak, postoji preporuka da se fabrički gotovi zubi koriste kod bezubih pacijenata dok se voštano modelovanje jednostavnije realizuje u slučajevima manjih krezubosti [15]. Preliminarna postava zuba na dijagnostičkom modelu je osnova za izradu radiološkog vodiča.

U užem smislu, digitalno planiranje obuhvata domen softverskih alata CBCT aparata i CAD-CAM mašina. Zapis koji nastaje tokom volumetrijskog snimanja anatomskih struktura lica i vilica se obrađuje u softverskom programu aparata u formatu Digital Imaging and Communications in Medicine (DICOM) [16]. Tako dobijeni podaci se objedinjuju sa podacima na izmodelovanom „wax-up“-u. Važan segment planiranja obuhvata i analiza međuviličnih odnosa. Sa uvođenjem tzv. Bari tehnike omogućen je transfer intermaksilarnih i okluzalnih odnosa u sve tri prostorne ravni, i to u digitalnom okruženju. Metoda se zasniva na izradi protetskog stenta koji ima za cilj da prenese okluzalne odnose zabeležene privremenom dijagnostičkom protezom unutar konačne protetske nadoknade na implantatima [17]. Na osnovu navedenih podataka, terapeut ima jasno definisane zahteve protetske komponente i pristupa virtualnom planiranju položaja implantata uključujući dužinu, promer, nagib i dubinu implantata. Nakon toga sledi dizajniranje hirurškog vodiča. Tehnološki postupci izrade hirurških vodiča dele se na aditivne i subtraktivne (stereolitografske) metode [15].

RADIOLOŠKI VODIČ KAO PUTOKAZ ZA USPEŠNO DIZAJNIRAN HIRURŠKI VODIČ

Svrha radiološkog vodiča jeste da omogući prenos informacije o položaju kruničnog dela buduće restauracije na CBCT snimak. Dobra stabilnost vodiča na nosećim tkivima je obavezna. Svako neprecizno naleganje može rezultirati pomeranjem vodiča tokom radiografisanja, što za posledicu ima pomak referentnog objekta. Ukoliko se hirurški vodič izradi na bazi tako dobijenih informacija, kliničar će imati poteškoće da postavi hirurški vodič i celokupna procedura može biti kompromitovana [15]. Da bi se izvršila uspešna radiološka vizuelizacija protetskog dela zubne nadoknade, unutar vodiča se mogu postaviti različiti radioopakni materijali. Mnogobrojni autori [15, 18] poredili su opacitet najčešće korišćenih materijala u te svrhe. Rezultati istraživanja saglasni su da je najveći opacitet zabeležen kod barijum-sulfata ($BaSO_4$), gutaperke i materijala za fiksiranje nadoknada na bazi cink-oksida. Radiološki stent se najčešće izrađuje na bazi dubler modela. Vodiči su od tvrde vakuum folije promera ne većeg od 1 mm. Kod bezubih pacijenata se u svrhu radiološkog vodiča može koristiti i stara proteza pod uslovom da je dobro retinirana na nosećim tkivima. Takođe, savetuje se nanošenje adheziva sa sluzokožne strane proteze pre radiografisanja. Unutar akrilatnih zuba prave se perforacije u koje se postavlja radioopakni materijal [19, 20]. Druga opcija je izlivanje dubler modela na bazi totalne zubne proteze. Dubler model predstavlja radni model na kom se izrađuje radiološki vodič, najčešće od vakuum folije [15].

DINAMIČKA I STATIČKA NAVIGACIJA

Dinamička navigacija je kompjuterski vođena ugradnja implantata. Ova metoda podrazumeva primenu intraoperativnih navigacionih sistema čije se konstrukciono rešenje uglavnom zasniva na optičkim alatima za izračunavanje pozicije implantata. Neki od trenutno prisutnih na tržištu su: Blue Sky Bio Plan Software, Fusion Nobel Biocare, CoDiagnostic software, M-Guide, DentalWings, Simplant Softwere, SMOP Swisseda…

Block i Emery su kao indikacije za primenu dinamičke navigacije naveli uglavnom sve one situacije gde postoje relativna ili apsolutna ograničenja za primenu hirurških vodiča: kod pacijenata sa ograničenim otvaranjem usta, implantacija na teško pristupačnim regijama bočnog segmenta vilica, situacije gde meziodistalna dimenzija krezubog prostora ne dozvoljava postavljanje statičkog vodiča zbog širine cilindra (vođice)… [21]. Terapeut prati kretanje hirurškog instrumenta u toku izvođenja intervencije na monitoru kompjutera [22]. Prednosti dinamičke navigacije su: smanjenje troškova za pacijenta s obzirom na to da se sprovodi bez upotrebe hirurškog vodiča, mogućnost kontinuiranog hlađenja hirurškog polja, veće mogućnosti za kliničara da intraoperativno usmerava hirurški instrument. Kao glavni nedostatak navode se veliki troškovi aparature. Dinamička navigacija se ne preporučuje u terapiji bezubih pacijanata [21]. Statička navigacija bazira se na primeni hirurškog vodiča. Osnovna uloga vodiča je da omogući prevođenje analognog ili digitalnog terapijskog plana u trodimenzionalno intraoralno okruženje. Kao prvi vodiči koristile su se vakuumske folije identične onima koje se primenjuju za radiološke vodiče. Takav vodič daje uvid u položaj buduće krunice, pa hirurg, na osnovu toga, može da mapira mesto implantacije. Dalji tok implantacije je vođen rukom terapeuta i zavisi od njegovog iskustva i spretnosti.

Kada govorimo o savremenim statičkim vodičima, implantacija virtualno isplaniranog postupka ugradnje implantata može se realizovati kroz delimično (*eng. half guided*) ili potpuno vođenu ugradnju (*eng. full guided*) u zavisnosti od dizajna vođica (cilindara) koje su integrisane u vodiču [15, 23, 24]. Potpuno vođena ugradnja podrazumeva primenu hirurškog vodiča čiji dizajn obezbeđuje precizno isplaniranu poziciju, angulaciju, dijametar i dubinu implantata. Vodič je pozicioniran u ustima pacijenta tokom cele procedure implantacije, ne ostavljajući mogućnost terapeutu da intraoperativno vodi instrument u bilo koji drugi položaj osim onog koji je definisan cilindrima integrisanim unutar vodiča. Zahvaljujući osobinama materijala od kojih su izrađeni vodiči (polimetil-metakrilat ili legure metala) i vođicama, koje mogu biti od legure metala ili cirkonije, osigurana je rigidnost stenta, a samim tim i veća sigurnost za terapeuta [15]. Da bi se dodatno obezbedila sigurnost u radu, vodič bi trebalo da bude dobro retiniran na bezubom grebenu. Ovo je ujedno i razlog zbog kojeg nije opravdano koristiti loše retinirane, stare totalne proteze kao hirurške vodiče.

Termin delimično vođene implantacije odnosi se na vodiče koji koriste terapeutu samo tokom početnih faza implantacije. Ovi vodiči koriste cilindrične vođice koje mogu prihvatiti prvo, i eventualno drugo hirurško svrdlo. Kada ne postoji dovoljno prostora u meziodistalnom pravcu, prednost treba dati vodičima za poluvođenu ugradnju s obzirom na to da cilindi imaju uži promer u odnosu na cilindre za potpuno vođenu hirurgiju [15]. Potpuno vođeni pristup ima prednost u slučajevima sa slabim kvalitetom kosti, s obzirom na to da lagani pokreti ruke tokom plasiranja implantata mogu rezultirati većim odstupanjem za poluvođenu ugradnju [24]. Kako oba sistema imaju svoje prednosti i nedostatke, autori [24] koji su analizirali razliku u preciznosti ugradnje implantata prilikom korišćenja delimično i potpuno vođene hirurgije, zaključili su da je statistički značajna razlika u preciznosti bila evidentna samo u poziciji apikalne trećine implantata. Prednosti potpuno vođene hirurgije su: smanjen rizik od povrede anatomskih struktura, izvođenje hirurškog postupka bez odizanja režnja (*eng. flapless surgery*) i time skraćenje perioda postoperativnog oporavka, mogućnost individualizacije dizajna abatmenta prema poziciji hirurškog vodiča itd. [15].

Međutim, iako koncept primene hirurških vodiča podrazumeva jednostavan protokol za ugradnju, ovakva rešenja nose sa sobom određene nedostatke. Kao glavni, navode se nedovoljna preglednost operativnog polja, nemogućnost primene hirurškog vodiča u slučaju malog interokluzalnog prostora, opasnost od oštećenja ili kontaminacije svrdla prilikom prolaska kroz cilindar vođice [23]. Da bi se nadomestili pomenuti nedostaci, danas se uveliko razvija metoda ugradnje implantata primenom otvorenog vodiča (TWIN-Guide®, 2Ingis, Brussels, Belgium) [23, 25]. Otvoren dizajn kompenzuje navedene nedostatke zatvorenog sistema vodiča i kompatibilan je sa svim implantološkim sistemima. Takođe, sama implantacija sprovodi se uz kontinuiranu irigaciju operativnog polja. Vodič koristi obrazac otvorenog okvira, dajući kliničaru smernice za implantaciju u vidu dve referentne cilindrične vodilice postavljene sa vestibularne i oralne strane rama hirurškog vodiča.

ZAKLJUČAK

Idealna pozicija implantata podrazumeva prostornu orijentaciju u odnosu na susedne anatomske strukture i/ili susedni implantat. Pogrešno pozicioniranje može imati za posledicu funkcionalne, tehničke, biološke ili estetske posledice. Upotrebom kompjuterski planirane i vođene implantologije može se obezbediti predvidljivost terapijskih rezultata. Iako posledice loše pozicije implantata mogu dovesti do klinički manifestnih komplikacija tek kroz nekoliko meseci, odnosno godina, prve poteškoće mogu nastati već u fazi realizacije otiska za zubnu nadoknadu kada odstupanja u angulaciji implantata sprečavaju pravilno plasiranje prenosnika. Veliki izbor hirurških vodiča, koji se međusobno razlikuju prema dizajnu i svojoj nameni, omogućio je kliničarima da indikuju njihovu primenu i u kompleksnim slučajevima. Ipak, ograničenja koncepta popuno vođene implantologije su u vezi sa njegovom primenom samo kod krezubih pacijenata. Implantatno-protetska rehabilitacija bezubih pacijenata se realizuje konvencionalnim metodama delimično ili potpuno vođenim rukom hirurga.