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CASE REPORT
PRIKAZ SLUČAJA

Roko Bjelica[1], Joško Viskić[2], Goran Batinjan[3], Irina Filipović Zore[1]

Implantoprosthetic Rehabilitation by Computer-guided Implant Surgery (M-Guide): Case report

Implantoprotetičko zbrinjavanje kompjutorski navođenom implantologijom (M-guide): prikaz slučaja

[1] Department of Oral Surgery, School of Dental Medicine University of Zagreb
Zavod za oralnu kirurgiju Stomatološkog fakulteta Sveučilišta u Zagrebu
[2] Department of Fixed Prosthodontics, School of Dental Medicine University of Zagreb
Zavod za fiksnu protetiku Stomatološkog fakulteta Sveučilišta u Zagrebu
[3] Clinical Hospital "Dubrava", 10000 Zagreb, Croatia
Klinička bolnica Dubrava, 10 000 Zagreb

Abstract
Correct implant positioning poses a major challenge in modern dentistry and mismatch between the planned and final implant position is one of the most common treatment complications. A surgical guide or a template is a "transmission device" which enables the implant placement in the intended position as accurate as possible. **Case study:** A woman aged 60 came into dental office to resolve a single tooth loss in regions 15 and 24. Radiographic analysis and clinical examination showed a lack of transversal space in the regions of implantation. Considering the fact of having a narrow area available for implantation, a computer-guided implant therapy using the M-Guide system was selected. The treatment plan was a prosthetic restoration involving the placement of two implants in areas 15 and 24 and the fabrication of zirconium oxide crowns. After digital planning, a fully guided surgical protocol was performed. Immediately after implantation, a temporary suprastructure and temporary crowns were placed. After a period of osseointegration, a definitive prosthetic restoration was made.

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Address for correspondence
Roko Bjelica
University of Zagreb
School of Dental Medicine
Department of Oral Surgery
Gundulićeva 5, 10 000 Zagreb, Croatia
rbjelica@sfzg.hr

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Introduction

In modern dentistry, implant placement becomes an unavoidable procedure in rehabilitation of partially or completely edentulous patients. The rapid development of dental implant surgery and new achievements significantly contribute to clinical workflow (1). Modern trends include reduced duration of total rehabilitation process, minimally invasive surgical protocol and increased precision of dental implant placement. A correct implant positioning poses a major challenge in modern dentistry and mismatch between the planned and final implant position is one of the most common treatment complications (2). Unsatisfactory direction of the implant placement falls within the category of prosthetic complications which results in aesthetic and functional complications (3). A correct implant placement allows for a favorable force transfer to implants and future prosthetic suprastructure and, as a consequence, an appropriate aesthetic outcome. Such an approach is called prosthetically driven implantology (4). It is a precise surgical guide or a template that is a "transmission device" which enables the implant placement in the intended position as accurate

Uvod

U suvremenoj dentalnoj medicini ugradnja implantata postaje nezaobilazni postupak u rehabilitaciji djelomično ili potpuno bezubih pacijenata. Dentalna implantologija razvija se veoma brzo i neprestano se dolazi do novih spoznaja koje značajno pridonose kliničkom radu (1). Moderni trendovi uključuju skraćivanje vremena potrebnog za potpunu rehabilitaciju, minimalno invazivni kirurški protokol implantacije te povećanje preciznosti pri ugradnji dentalnih implantata. Njihovo pravilno pozicioniranje velik je izazov u suvremenoj dentalnoj medicini, a nesklad između planiranoga i konačnoga položaja implantata jedna je od najčešćih komplikacija tijekom terapije (2). Nezadovoljavajući smjer postavljanja implantata ubraja se u protetičku komplikaciju, što rezultira estetskim i funkcijskim nedostacima (3). Pravilnim postavljanjem implantata omogućen je povoljan prijenos sila na implantate i buduću protetičku suprastrukturu i posljedično odgovarajući estetski ishod terapije. Takav pristup zovemo *protetički vođenom implantacijom* (4). Upravo je kirurška vodilica ili šablona „prijenosno sredstvo" kojim se postiže što vjernije postavljanje implantata u planirani položaj (5). Ra-

as possible (5). The development of information technology (IT) has made an outstanding contribution to all branches of the medical profession, including dental implants. The introduction of the Cone Beam Computer tomography (CBCT) into practice has enabled a very high-quality three-dimensional representation of craniofacial structures. The development of appropriate software to plan the setting of dental implants, in addition to CBCT, gave a completely new guidance in implant therapy. Finally, surgical guides made by CAD/CAM (Computer Aided Design/Computer Aided Manufacturing) technology have been developed. They are produced by combining all data generated in the preparatory phases of implant therapy (4).

Case study

A woman aged 60 came into dental office to resolve a single tooth loss in regions 15 and 24. After a detailed medical and dental history had been taken, the patient was found to be healthy and there were no contraindications for implant therapy. Orthopantomograph analysis and clinical examination showed a lack of transversal space in the regions of implantation (Figure 1). In order to continue the planning and conduct of therapy, 3D scans and the interocclusal record were taken using Primescan (Dentsply Sirona, Charlotte, North Carolina, USA) and CBCT images of the upper jaw. According to CBCT data, the mesiodistal width in region 15 is 6.20 mm and in region 24 is 6.13 mm (Figure 2). Because of the narrow vestibulooral and mesiodistal area of implantation, a prosthetically driven implant therapy using the M-Guide system (MIS Implants Technologies Ltd., Bar-Lev Industrial Park, Israel) was selected.

zvoj informatičke tehnologije dao je izniman doprinos svim granama medicinske struke, pa tako i dentalnoj implantologiji. Uvođenjem u praksu CBCT-a (*Cone Beam Computer Tomography)* omogućen je vrlo kvalitetan trodimenzionalni prikaz kraniofacijalnih struktura. Razvoj odgovarajućih računalnih programa za planiranje postavljanja dentalnih implantata, uz CBCT, dao je potpuno nove smjernice u implantološkoj terapiji. Konačno, razvijene su kompjutorski izrađene kirurške vodilice CAD/CAM (*Computer Aided Design/Computer Aided Manufacturing)* tehnologijom koje se izrađuju kombiniranjem svih podataka dobivenih u pripremnim fazama implantoprotetičke terapije (4).

Prikaz slučaja

Žena u dobi od 60 godina došla je u ordinaciju zbog sanacije pojedinačne bezubosti u regijama 15 i 24. Nakon uzimanja detaljne medicinske i stomatološke anamneze ustanovljeno je da je pacijentica zdrava i nema kontraindikacija za implantoprotetičku terapiju. Analizom ortopantomogramske slike i kliničkim pregledom utvrđen je manjak transverzalnog prostora u regijama implantacije (slika 1.). Kako bi se nastavilo planiranje i provedba terapije, uzimaju se digitalni otisci i registrat međučeljusnih odnosa uređajem Primescan (Dentsply Sirona, Charlotte, Sjeverna Karolina, SAD) i CBCT snimka gornje čeljusti. Prema podatcima CBCT-a, meziodistalna širina u regiji 15 bila je 6,20 mm, a u regiji 24 iznosila je 6,13 mm (slika 2.). Zbog uskoga vestibulooralnoga i meziodistalnoga prostora za implantaciju, izabrana je protetički vođena implantoprotetička terapija s pomoću sustava M-Guide (MIS Implants Technologies Ltd., Bar-Lev Industrial Park, Izrael).

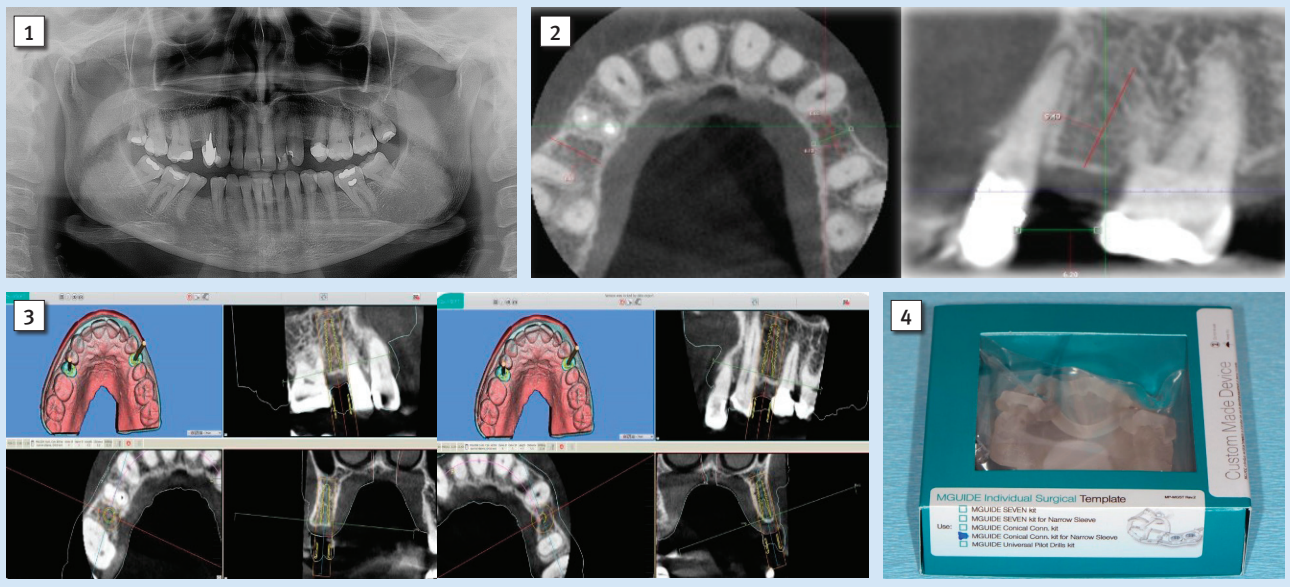


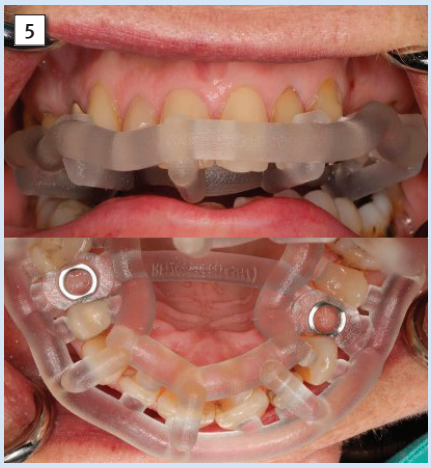
Figure 1 Panoramic radiograph at first visit - lack of transversal space in the regions of implantation
Slika 1. Ortopantomogram na prvom pregledu – manjak transverzalnoga prostora u regijama implantacije
Figure 2 CBCT image - mesiodistal width in region 15 is 6, 20 mm and in region 24 is 6, 13 mm
Slika 2. CBCT snimka – meziodistalna širina u regiji 15 iznosi 6,20 mm, a u regiji 24 iznosi 6,13 mm
Figure 3 M-soft digital planning - the ideal surgical and prosthetic position of the implant
Slika 3. Digitalno planiranje u M-soft programu – idealan kirurški i protetički položaj implantata
Figure 4 Surgical guide (M-guide)
Slika 4. Kirurška vodilica (M-guide)

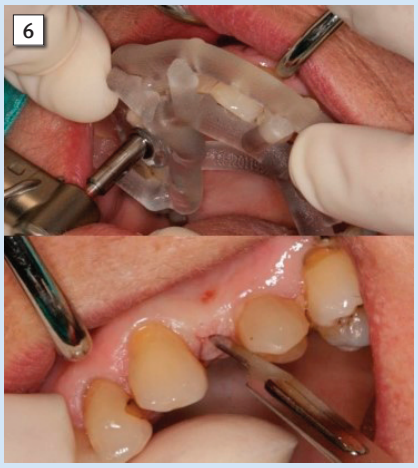
The treatment plan was the prosthetic restoration involving the placement of two MIS C1 implants (MIS Implants Technologies Ltd., Bar-Lev Industrial Park, Israel) of 3.30 mm diameter and 11.50 mm length in areas 15 and 24 and the fabrication of zirconium oxide crowns. The course of all the interventions was explained to the patient, and she accepted the recommended treatment and signed informed consent.

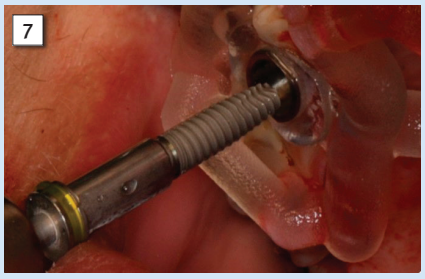
In the laboratory, digital wax-up of the future crowns was done and they were placed in an ideal aesthetic and functional position. The data were exported in stereolithographic (STL) format. Data files with wax-up; CBCT and patient data form were sent to the MIS M-guide center. In coordination with the surgeon and the prosthodontist, the ideal surgical and prosthetic position of the implant in MIS M-soft software was planned (Figure 3) and a surgical guide was de-

Plan terapije bio je izrada protetičkoga rada koji uključuje postavljanje dvaju implantata MIS C1 (MIS Implants Technologies Ltd., Bar-Lev Industrial Park, Izrael) promjera 3,30 mm i dužine 11,50 mm u područja 15 i 24 i postavljanje cirkonij-oksidnih krunica. Pacijentici je objašnjen tijek svih zahvata, prihvatila je preporučenu terapiju i potpisala informirani pristanak.

U laboratoriju su digitalno navoštane buduće krunice postavljene u idealan estetski i funkcijski položaj. Podatci su prikazani u stereolitografskom (STL) formatu. Datoteke sa situacijskim otiscima, navoštavanjem, CBCT-om i formularom s podatcima pacijentice poslani su u MIS M-guide centar. U koordinaciji s operaterom i protetičarem isplaniran je idealan kirurški i protetički položaj implantata u MIS M-softveru (slika 3.), te je tehnologijom 3D printanja izrađena kirur-







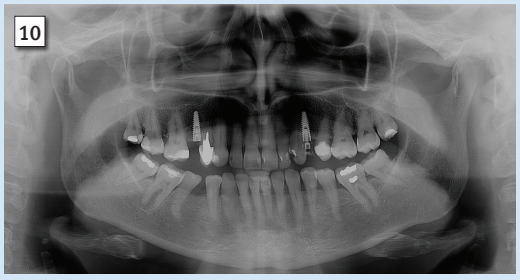


Figure 5 Surgical guide checked in mouth
Slika 5. Kontrola dosjeda kirurške vodilice u ustima
Figure 6 "Tissue punch incision" – flapless technique
Slika 6. „Tissue punch" rez – *flapless* tehnika
Figure 7 Implantation – fully guided protocol
Slika 7. Implantacija – potpuno navođeni protokol
Figure 8 Measuring the Implant Stability Quotient -ISQ
Slika 8. Izmjeren ISQ (Implant stability Quotient)
Figure 9 PEEK abutment and PMMA crown
Slika 9. PEEK *abutment* i PMMA privremena krunica
Figure 10 Control panoramic radiograph immediately after surgical treatment
Slika 10. Kontrolna ortopantomogramska snimka učinjena isti dan poslije završnoga kirurškoga dijela terapije

signed using 3D printing technology. The guide came to the office sterilized and ready for use (Figure 4). After checking whether the guide fitted (Figure 5), the surgery was initiated by a guided implant protocol. The ''Tissue punch" incision allows the implantation without raising a flap, so-called flapless technique (Figure 6). The preparation of the bone and implantation was carried out by a protocol which was partly different from a conventional technique without a guide. The difference is that longer drills corresponding to the dimensions of the guide were used in the guided implant protocol and the whole process was performed using only two drills. Bone preparation began with a ''bone mill" (MIS) drill to flatten the alveolar ridge, thus increasing the accuracy for the rest of the drilling sequence. Further preparation was performed using ''guided pilot drill" and ''guided conical drill" (MIS). The mere implantation of implants into the bone was also made through a guide, using a so-called fully guided protocol (Figure 7). After implantation, Implant stability Quotient (ISQ) was measured with Penguin RFA (Integration Diagnostics Sweden AB, Göteborg, Sweden) and a high primary stability value of 75 (Figure 8) was obtained. Immediately after implantation, a temporary suprastructure (polyether ether ketone [PEEK] abutment) and temporary crowns (milled polymethyl methacrylate [PMMA]) were placed (Figure 9). After a period of osseointegration, the definitive prosthetic restoration was made. The patient was referred to a control orthopantomograph image immediately after having undergone the surgical part of the treatment (Figure 10).

Discussion

Computer-guided implant surgery has numerous advantages for both the doctor and the patient. The procedure takes less time with consequently less post-operative problems such as pain, bleeding and edema. The implantation can be done without raising the mucoperiosteal flap (flapless technique), resulting in reduced resorption of the alveolar ridge, preservation of interdental papillae and gingival margins of adjacent teeth (6). Temporary or permanent prosthetic restoration can be designed and fabricated prior to surgery and, in cases of immediate loading, the total time of implantoprosthetic therapy is reduced (7).

Advantages that contribute to the dentist can be seen in immensely detailed diagnostics and precise planning of therapy. Thanks to computer technology, the virtually planned position of the implant is transferred to the surgical field, which reduces the possibility of errors and injuries of important anatomical structures. Such an approach enables a predictable and safe outcome of implantation (7).

Reports in the literature have noted some complications related to computer-guided implant therapy and it is of crucial importance to highlight possible deficiencies of such a therapy so that clinicians can determine the indications and contraindications for this therapy. Colombo et al. have claimed that the advantages of computer guided implant surgery do not have substantiated evidence recorded in the recognized scientific literature, but are mainly based on the clinical experience of certain doctors (2). No statistically

ška vodilica. Vodilica je u ordinaciju stigla sterilna i spremna za upotrebu (slika 4.).

Nakon kontrole dosjeda vodilice (slika 5.) kirurški zahvat počeo je prema protokolu za vođenu implantaciju. „Tissue punch" rezom omogućena je implantacija bez odizanja režnja, tzv. *flapless* tehnikom (slika 6.). Preparacija koštanoga ležišta i implantacija učinjene su prema protokolu koji se djelomično razlikuje od konvencionalne tehnike bez vodilice. Razlika je u tome što su u vođenoj implantaciji korištena duža svrdla koja odgovaraju dimenzijama vodilice i cijeli se postupak radi samo s dvama svrdlima. Preparacija kosti počinje svrdlom „Bone mill" (MIS) da bi se poravnao alveolarni greben, čime se povećava točnost za ostatak sekvencije bušenja. Preparacija ležišta implantata obavljena je s pomoću „Guided pilot drilla" i „Guided conical drilla" (MIS). Samo postavljanje implantata u koštano ležite također je učinjeno kroz vodilicu, prema tzv. potpuno navođenom protokolu (slika 7.). Poslije implantacije izmjeren je ISQ (*Implant stability quotient)* uređajem Penguin RFA (Integration Diagnostics Sweden AB, Göteborg, Švedska) i dobivena je visoka vrijednost primarne stabilnosti od 75 (slika 8.). Odmah poslije implantacije postavljena je privremena suprastruktura [poli(eter-eterketon) – PEEK suprastruktura) i privremeni protetički rad (glodani polimetilni metakrilat – PMMA) (slika 9.). Nakon oseointegracije pristupilo se izradi definitivnoga protetičkoga rada. Pacijentica je učinila kontrolnu ortopantomogramsku snimku odmah nakon obavljenoga kirurškoga dijela terapije (slika 10.).

Rasprava

Kompjutorski navođena implantacija ima mnogobrojne prednosti i za doktora i za pacijenta. Zahvat traje kraće s posljedično manjim postoperativnim tegobama kao što su bol, krvarenje i edem. Dentalni implantati mogu se ugraditi a da se pritom ne odiže mukoperiostalni režanj (*flapless* tehnikom), što rezultira smanjenom resorpcijom alveolarnoga grebena, očuvanjem interdentalnih papila i gingivnih rubova susjednih zuba (6). Protokol izrade privremenoga ili trajnoga protetičkoga rada moguće je učiniti prije kirurškoga zahvata, pa je, u slučaju imedijatnoga opterećenja implantata, skraćeno vrijeme cjelokupne implantoprotetičke terapije (7).

Prednosti za terapeuta vidljive su u iznimno detaljnoj dijagnostici i preciznom planiranju terapije. Zahvaljujući računalnoj tehnologiji virtualno planirana pozicija implantata prenosi se u kirurško polje čime je smanjena mogućnost pogreške i ozljeda važnih anatomskih struktura. Takav pristup omogućuje predvidiv i siguran ishod ugradnje implantata (7).

U literaturi su zabilježeni podatci o komplikacijama pri kompjutorski vođenoj implantološkoj terapiji i iznimno je važno istaknuti moguće nedostatke takve terapije kako bi kliničari mogli utvrditi koje su indikacije i kontraindikacije za navedenu terapiju. Colombo i suradnici tvrde da za prednosti kompjutorski navođene implantacije nema utemeljenih dokaza u priznatoj znanstvenoj literaturi, nego da su većinom bazirani na kliničkom iskustvu pojedinih doktora (2). U navedenom preglednom radu nije ustanovljena statistički

significant difference in implantation survival and frequency of complications between conventional and computer guided implant therapy was observed in this review. There was a difference in post-operative complications, such as pain and edema, which are more common in the conventional method without a surgical guide (2). Schneider et al. have observed that the type of computer guided technique, the number of missing teeth and the type of guide support in the patient's mouth could be main causes of the discrepancy in precision (8). Since surgical protocols consist of a large number of steps, the possibility of error increases in accordance with the number of steps and the resulting error is a sum of the following:

1. CT, layering and data storage,
2. Planning and printing of a guide
3. Inadequate stability and displacement of the guide during the rotation of the drill,
4. Inadequate fitting of a drill within a cylinder,
5. Mucosa thickness
6. Patient movement,
7. Software errors (9).

The error in implant positioning can be measured in two ways, directly and indirectly. The error is measured directly by comparing the CBCT image before and after the implantation. In indirect mode, an impression is taken or healing abutments mounted on the desired implants are scanned (4). Parameters taken into account in assessing the deviation of the planned and obtained implant position are: linear deviations at platform and apex level, vertical deviations in implantation depth, and angular deviations. Tahmaseb et al. showed the following average deviations: on an implant platform of 1.12 mm, at the implant apex level 1.39 mm, in the implant angulation 3.89 ° (10). D' haese et al. mentioned angular deviations of 2.71 ° – at the level of the implant apex 1.6 mm and at the level of the implant platform 1 mm (11). Due to these data and the fact that a large number of steps give a proportional error possibility, it is of paramount importance to assess whether there is and what is the indication for a computer-guided implant surgery. It is logical to conclude that such a therapy is recommended in cases of immediate proximity of important anatomical structures and in a demanding prosthetic aspect of the therapy. Further development of artificial intelligence and progress in computerization will make the planning and conducting of therapy even simpler and safer. For clinicians, as well as patients, an unavoidable reduction in the number of steps will bring computer-guided implant surgery closer to everyday dental practice (7).

Conclusions

Computer guided implantoprosthetic therapy was developed primarily in order for the clinician to reproduce the planned therapy as accurate as possible. It is precisely the accuracy of transferring the planned rehabilitation to the surgical field that is the main parameter taken into account in the evaluation of the therapy. An overview of modern literature has showed that there are no statistically significant differenc-

značajna razlika u preživljenju implantata i učestalosti komplikacija između konvencionalne i kompjutorski navođene implantološke terapije. Zabilježena je razlika u postoperativnim komplikacijama, kao što su bol i edem, no one su učestalije pri primjeni klasične metode (2). Schneider i suradnici kao glavni uzrok odstupanja u preciznosti spominju vrstu kompjutorski navođene tehnike, broj zuba koji nedostaje i vrstu sidrenja vodilice u ustima pacijenta (8). S obzirom na to da se kirurški protokol sastoji od velikoga broja koraka, mogućnost pogreške se, sukladno broju tih koraka, povećava i rezultantna pogreška je zbroj navedenih:

1. CT, slojevanje i pohrana podataka
2. planiranje i izrada šablone
3. neadekvatna stabilnosti i pomak šablone pri rotaciji svrdla
4. neadekvatno prilijeganje svrdla uz cilindar
5. debljina sluznice
6. pomak pacijenta
7. softverske pogreške (9).

Pogreška u pozicioniranju samih implantata može se mjeriti na dva načina – izravno i neizravno. Pri izravnom načinu uspoređuje se CBCT snimka prije i poslije implantacije. U neizravnom načinu uzima se otisak ili se skeniraju nadogradnje za cijeljenje (engl. *healing abutment*) koje su postavljene na željene implantate (4). Parametri koji se uzimaju u obzir u procjeni odstupanja planirane i dobivene pozicije implantata jesu linearna odstupanja na razini platforme i apeksa implantata, vertikalna odstupanja u dubini postave implantata te kutna odstupanja u angulaciji implantata. Tahmaseb i suradnici u svojem preglednom radu navode sljedeća prosječna odstupanja: na platformi implantata od 1,12 mm, na razini apeksa implantata 1,39 mm i u nagibu implantata 3,89° (10). D'haese i suradnici spominju odstupanja u nagibu od 2,71° – na razini apeksa implantata 1,6 mm i na razini platforme implantata 1 mm (11). Zbog navedenih podataka i činjenice da velik broj koraka daje proporcionalnu mogućnost pogreške, iznimno je važno procijeniti postoji li i koja je indikacija za kompjutorski vođenu implantaciju. Logično je zaključiti da se takva terapija preporučuje u slučajevima neposredne blizine važnih anatomskih struktura i zahtjevnoga protetičkoga aspekta terapije. Daljnji razvoj umjetne inteligencije i napredak u informatizaciji učinit će planiranje i provedbu terapije još jednostavnijima i sigurnijima. Za kliničare, ali i pacijente, nezaobilazno smanjenje broja koraka približit će kompjutorski navođenu implantologiju svakodnevnoj stomatološkoj praksi (7).

Zaključak

Kompjutorski navođena implantoprotetička terapija razvijena je primarno da bi kliničar što vjernije reproducirao planiranu terapiju. Upravo je preciznost prijenosa planirane rehabilitacije u kirurško polje glavni parametar koji se uzima u obzir u evaluaciji takve terapije. Pregledom suvremene literature zaključuje se da nema statistički značajne razlike koja bi dokazala da je kompjutorski vođena implantološka

es which would prove that computer-guided implant therapy is superior to conventional therapy. Nevertheless, there are advantages to be taken into account when planning and implementing therapy: minimal invasiveness of flapless technique, faster post-operative healing, optimal positioning of implants and the possibility of an immediate loading. However, the financial factor should not be omitted. Computer guided therapy is much more expensive than conventional therapy without surgical guide. Taking into account all of the above, it is concluded that the properly indicated and implemented computer-guided implant surgery is safe and it provides predictable results.

Conflict of interest

The authors deny any conflicts of interest.

Authors' contribution: **J.V., R.B.** and **I.F.Z.** made a research plan; **I.F.Z.** performed the implantation procedure; **J.V., G.B.** completed the prosthodontic treatment; **R.B., J.V.** wrote a manuscript; **I.F.Z., J.V.** revised it critically. All authors discussed the case and contributed to the final manuscript.

terapija superiorna u usporedbi s konvencionalnom. Unatoč tomu postoje prednosti koje valja uzeti u obzir pri planiranju i provedbi terapije – to su minimalna invazivnost *flapless* tehnikom, brže postoperativno cijeljenje, optimalno pozicioniranje implantata i mogućnost imedijatnoga opterećenja. Ne smije se izostaviti ni financijski čimbenik. Kompjutorski navođena terapija znatno je skuplja od konvencionalne terapije bez kirurške vodilice. Uzimajući u obzir sve navedeno, zaključuje se da je pravilno indicirana i provedena kompjutorski vođena implantološka terapija sigurna i njome se postižu predvidivi rezultati.

Sukob interesa

Autori negiraju bilo kakav sukob interesa.

Doprinos autora: **J. V., R. B.** i I. **F. Z.** – izradili plan istraživanja; **I. F. Z.** – obavila postupak implantacije; **J. V.** i **G. B.** – završili protetički tretman; **R. B.** i **J. V.** – napisali tekst; **I. F. Z.** i **J. V.** –kritički su revidirali tekst. Svi su autori raspravljali o slučaju i pridonijeli konačnom tekstu.

Sažetak
Uvod: Pravilno pozicioniranje implantata velik je izazov u suvremenoj dentalnoj medicini, a nesklad između njegova planiranoga i konačnoga položaja jedna je od najčešćih terapijskih komplikacija. Kirurška vodilica ili šablona „prijenosno je sredstvo" kojim se postiže što vjernije postavljanje implantata u planirani položaj. **Prikaz slučaja:** Žena u dobi od 60 godina došla je u ordinaciju radi sanacije pojedinačne bezubosti u regijama 15 i 24. Radiološkom analizom i kliničkim pregledom ustanovljen je manjak transverzalnoga prostora u regijama implantacije. Zbog manjka prostora za implantaciju izabrana je kompjutorski vođena implantoprotetička terapija s pomoću sustava M-Guide. Plan terapije bio je izraditi protetički rad koji uključuje postavljanje dvaju implantata u područja 15 i 24 i izradu cirkonij-oksidnih krunica. Nakon digitalnog planiranja pripremljen je potpuno navođeni kirurški protokol. Odmah poslije implantacije postavljena je privremena suprastruktura i privremeni protetički rad. Nakon oseointegracije pristupilo se izradi definitivnoga protetičkog rada.

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Adresa za dopisivanje
Roko Bjelica
Sveučilište u Zagrebu
Stomatološki fakultet
Zavod za oralnu kirurgiju
Gundulićeva 5, 10 000 Zagreb,
Hrvatska
rbjelica@sfzg.hr

MeSH pojmovi: zubni implantati; računalom vođena kirurgija
Autorske ključne riječi: dentalni implantati, kompjutorski navođena implantacija, kirurška vodilica

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