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PRIKAZ SLUČAJA
CASE REPORT

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Izrada modela za planiranje kirurškog liječenja prijeloma donje čeljusti

Additive Manufacturing for Surgical Planning of Mandibular Fracture

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Sažetak
Trenutačno se u zdravstvu tehnologije poput kompjutorske tomografije (CT) s trodimenzionalnom rekonstrukcijom (3D) i magnetska rezonancija rutinski koriste u pretkirurškom planiranju. Danas se virtualne trodimenzionalne slike, obično na dvodimenzionalnim površinama poput kompjutorskih zaslona, upotrebljavaju za brzu izradu prototipova zbog velike točnosti kad je riječ o dimenzijama te detaljne reprodukcije anatomskih struktura. To omogućuje specijalistima da se koriste biomodelima u planiranju i simuliranju medicinskih i dentalno-medicinskih postupaka (oralna i maksilofacijalna kirurgija, izrada individualiziranih implantata i proteza te mjerenja i priprema fiksacijskih pločica), što pridonosi znatno kraćim kirurškim zahvatima, te posljedično i trajanju anestezije, smanjenju rizika od infekcije te manjim bolničkim troškovima. U ovom izvještaju opisali smo slučaj kirurškog planiranja terapije obostrane atrofične frakture mandibule za koju su autori, kao dodatno sredstvo, odabrali izradu prototipa nakon što su uzeli u obzir sve navedene prednosti.

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Uvod

U medicini i stomatologiji dogodila se prava evolucija – tradicionalne radiograme zamijenila je suvremenija tehnologija poput kompjutorizirane tomografije i magnetske rezonancije. Istaknimo da obje omogućuju trodimenzionalni pregled anatomskih struktura koje zanimaju kirurga te liječnicima u svakom slučaju pružaju informacije važne za dijagnozu i odgovarajuću terapiju (1, 2, 3).

Ipak, 3D slike prikazane na dvodimenzionalnim zaslonima nisu dovoljno jasne za temeljito razumijevanje pacijentove anatomije jer si specijalist mora zamisliti rekonstrukciju 3D geometrije koju vidi na računalu (2).

No nedavno su se pojavile nove tehnologije, kao što je brza izrada prototipova (RP), koje pomažu specijalistima u medicinskom i dentalnom području u planiranju i obavljanju kirurških zahvata. Tako se u dentalnoj medicini sve češ-

Introduction

the field of dentistry is constantly evolving and changing to best suit patient needs. The progress in medical and dental technology has been made, particularly in imaging technologies. The incorporation of new technology in dentistry has improved the way we serve our patients, and we have just begun to see the impact of advanced modalities such as computed tomography and MRI that have replaced conventional radiographs. These technologies enable to obtain a three-dimensional (3D) view of anatomical regions of surgical interest, as well as provide physicians with important information needed for diagnosis and appropriate therapy of each patient (1, 2, 3).

However, 3D images exhibited on 2D displays are not clear enough to provide a thorough understanding of the patient's anatomy, requiring the professional to mentally reconstruct the 3D geometry generated in the computer (2).

će primjenjuje RP tehnologija. U tom području stvaraju se do u mikrone točni humani 3D modeli, a sve se to postiže kombinacijom sustava medicinskog i zubnog prikazivanja (CAD-CAM). Izrada RP modela neobično je važna u oralnoj i maksilofacijalnoj kirurgiji i implantologiji jer omogućuje kirurzima bolje planiranje i skraćenje zahvata (4).

Prikazi dobiveni kompjutorskom tomografijom (CT) ili magnetskom rezonancijom (MRI) u obliku DICOM-a (engl. Digital Imaging and Communications in Medicine) obrađuju se u specijaliziranim programima, stvara se trodimenzionalni (3D) komplet podataka u STL obliku (Stereolithography) i šalje u stanicu za izradu brzih prototipova (RP) gdje se oni pripremaju u CAM sustavu (engl. Computer Aided Manufacturing) (5).

Biomodeli se koriste za mjerenje anatomskih struktura, osteotomiju i simulaciju resekcijskih tehnika te za temeljito planiranje oralnih i maksilofacijalnih kirurških zahvata (6). Prototipovi su potrebni ako zahvati zahtijevaju potanko planiranje, kao u slučaju teških trauma ili pacijenata s gubitkom struktura zbog patoloških lezija (7), ortodontske kirurgije (8) i postavljanja implantata (9). Time se skraćuje postupak, trajanje anestezije i rizik od infekcije.

Terapija frakture bezube mandibule izazov je za svakog maksilofacijalnog kirurga. U većini slučajeva lomovi se događaju starijim pacijentima kojima je regeneracija kosti fiziološki smanjena, lokalna prokrvljenost je slabija, a loša kvaliteta kosti često otežava odgovarajuću fiksaciju. Kako je starija populacija iz godina u godinu sve brojnija, potrebno je posvetiti pozornost osiguravanju odgovarajućih terapijskih zahvata te smanjenju broja fraktura s atrofičnim rubovima koje karakterizira niska koštana masa, pa kirurg često mora posegnuti za krutim materijalima za fiksiranje (2). Mora se uzeti u obzir da starija populacija zahtijeva strukturne i funkcionalne promjene jer je, uz sustavne bolesti, podložna različitim vrstama fraktura. Osim toga dulji životni vijek i aktivniji način života dodatno rezultiraju češćim traumama glave, što zahtijeva specijaliziranu i skuplju zdravstvenu zaštitu u usporedbi s mlađim pacijentima (1, 6).

Povećanje broja bezubih pacijenata s atrofijom alveolarnih grebena postalo je velik problem u rehabilitacijskoj dentalnoj medicini.

Zato se u maksilofacijalnoj kirurgiji i traumatologiji predlažu različite terapijske mogućnosti – od konzervativnih zahvata poput *beskrvnog* pristupa uz korištenje vodilica, do invazivnijih postupaka kao što su redukcija, krvava fiksacija te nasađivanje kosti (*bone grafting*) (10).

Ako je terapijski izbor otvorena redukcija, fiksiranje toga oblika frakture obično se obavlja s pomoću sustava 2,4 milimetarskih pločica zbog debljine jer imaju zadovoljavajuću mehaničku čvrstoću te su zato otpornije na postupak oblikovanja (11).

Ovome je članku svrha predstaviti slučaj obostrane frakture mandibule kod gerijatrijskog pacijenta koja je nastala zbog prometne nesreće, a liječena je metodom otvorene redukcije i funkcionalno-stabilne fiksacije temeljene na kriterijima za redukciju i fiksaciju frakture atrofične bezube mandibule, a pritom se u obzir uzelo i načelo opterećenje. Kirurzi su se odlučili koristiti modelom dobivenim stereolitograf-

Recently, new technologies such as Rapid Prototyping (RP) have emerged, thus helping professionals in medical-dental field to both plan and perform surgical procedures. RP is a technology increasingly present in dentistry. In this field, 3D human anatomy biomodels are created, in micron-accuracy, from the combination of medical and dental imaging with computers (CAD - CAM) systems. The RP-based biomodels fabrication assumes great importance in Oral and Maxillofacial Surgery and Implantology, by allowing better surgical planning, and shortening surgery time interval (4).

The images captured from computed tomography (CT) or magnetic resonance imaging (MRI) in DICOM format (Digital Imaging and Communications in Medicine) are processed in specific programs, creating a three-dimensional (3D) data set in STL format (Stereolithography) sent to the Rapid Prototyping stations, where the prototypes are built through the CAM system (Computer Aided Manufacturing) (5).

The biomodels are used in measurement of anatomical structures, osteotomies and resection techniques simulation as well as in a thorough planning of oral and maxillofacial surgery (6). Prototyping is frequently used in interventions that require a detailed planning, as in case of severe trauma patients, loss of structure by pathological lesions (7), orthognathic surgery (8) and implantology (9). Its use reduces the procedure time interval, the period of anesthesia and the risk of infection.

The treatment of atrophic edentulous mandible fractures in individuals is a challenge to maxillofacial surgeons. In most cases, these fractures occur to the elderly, in whom the bone regeneration process is physiologically decreased, local vascularization is reduced and poor quality of the jaw bone is often insufficient for proper fixation. Since elderly populations are growing faster than any other age group year by year the professionals' attention is being required to provide appropriate treatment and reduction of fractures associated with atrophic jaw edges, characterized by low bone mass, in cases that often require surgeons to make use of more rigid mounting material (2).

These facts should be considered: an aging population undergoes structural and functional changes; due to the coexistence of systemic diseases the elderly are predisposed to various types of trauma. In addition, longer longevity and more active lifestyles lead to an increase in head trauma in these individuals, therefore, specialized and more expensive health is required care when compared to younger patients (1, 6).

The increase in the number of edentulous patients with atrophy of the alveolar ridge has become a serious problem for the rehabilitative dentistry.

This particularly relates to the fields of maxillofacial surgery and traumatology so that various therapeutic possibilities are suggested, ranging from the most conservative treatment, such as bloodless approach with the use of gutters, to more invasive procedures such as reduction and bloody fixing, along with bone grafting (10).

When treatment option is open reduction, fixing this kind of fracture is commonly performed with 2.4 mm plate system, since these plates exhibit satisfactory mechanical

skim procesom za kirurško planiranje i tako olakšati preoblikovanje pločice za sustav rekonstrukcije.

Prikaz slučaja

Pacijent u dobi od 71. godine, žrtva prometne nesreće na motoru, liječen je u državnoj bolnici Campina Grande u Paraíbi, u Brazilu. Kliničkim pregledom otkrivene su oteklina i ogrebotine u području brade, bezubost, pomak s mandibularnom asimetrijom i pucketanje kostiju. Pronađena je i obostrana fraktura mandibule u području parasinfize (slike 1. a i 1. b).

Pacijent je poslan na 3D CT skeniranje, a pritom su se koristile sljedeće postavke: 120 KVp, 150 mA, matriks 512 × 512, field of view (FOV) 14 cm × 18 cm, Pitch 1 : 1, debljina rezova 1,0 mm, povećanje rekonstrukcijskog reza od 1,0 mm i rekonstrukcijski algoritam (kost). Svi podatci dobiveni kompjutorskom tomografijom snimljeni su u DICOM formatu i poslani u 3D tehnološki laboratorij Centra za strateške tehnologije i zdravlje Državnoga sveučilišta Paraiba (Technologies Laboratory of the Center for Strategic Technologies in Health at the State University of Paraíba). Serija DICOM podataka uvedena je u softver InVesalius (12) u kojemu je provedeno odvajanje regije interesa. 3D model pretvoren je u STL format i proslijeđen na 3D sustav tiskanja (Objet Connex 350/ Stratasys Ltd.) koji je za izradu biomodela koristio smolu Objet Verowhite Plus. Rezolucija tiskanja bila je 600 dpi u obje koordinate – **x** i **y** te 1600 dpi u **z** koordinati. Točnost stroja je do 0,1 mm. Za izradu je bilo potrebno oko 9 sati.

Prethodno modeliranje rekonstrukcijske ploče debljine 2,4 mm omogućilo je mnogo bolje uvjete za prilagodbu anatomskim obrisima regije te je skratilo zahvat i poboljšalo funkcionalan oporavak pacijenta (slike 2.a,b).

Frakture su sanirane kirurški u općoj anesteziji s orotrahealnom intubacijom. Liječnici su ozljedama pristupili obostrano ekstraoralno, submandibularno kirurškom redukcijom i fiksacijom loma (slika 3.a).

Uočeno je da je model s velikom točnošću reproducirao anatomiju operiranog područja, jer je pločica prilagođena pacijentu bila iznimno točna i glatka (slika 3.b).

Postoperativne slike tijekom tomografske analize pokazale su redukciju i fiksaciju sa zadovoljavajućim poravnanjem koštanih fragmenata i dobrom adaptacijom redukcijske ploče (slika 4.).

strength due to their thickness, which makes them more resistant during the modeling process (11).

This article aimed to present a case report of a bilateral mandibular fracture in a geriatric patient due to motorcycle accident, treated by the open reduction and functionally stable fixation method, based on criteria for reduction and fixation of atrophic edentulous mandible fracture, considering the principle of load-bearing. Surgeons decided to use a biomodel for surgical planning, obtained from stereolithographic process, facilitating the pre-modeling of a reconstruction plate system.

Case report

a seventy-one year-old male patient, motorcycle crash victim, was treated in a public hospital in Campina Grande, Paraíba, Brazil. Physical examination revealed swelling and bruising in the chin region and edentulism along with mandibular asymmetry and bone crackling. A bilateral mandibular fracture in parasymphysis region was observed during imaging analysis (Figures 1a/1b).

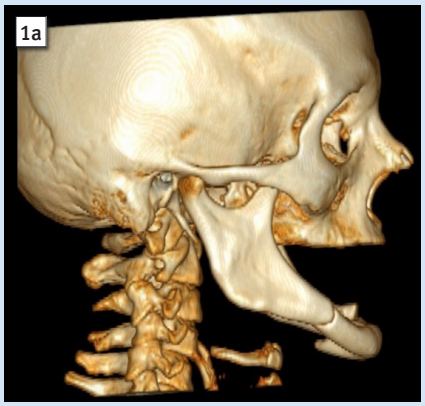
Three dimensional CT scanning was performed on the patient, using the following parameters: 120KVp, 150mA, matrix 512×512, field of view (FOV) 14 cm × 18 cm, Pitch 1:1, 1.0 mm slice thickness, reconstructed slice increment of 1.0mm, reconstruction algorithm (Bone). All computer tomography images were saved in DICOM format and then, sent to 3D Technologies Laboratory of the Center for Strategic Technologies in Health at the State University of Paraíba. The DICOM series were imported into In Vesalius software (12) where the segmentation of the region of interest was performed. The 3D model was converted into STL format and sent to the 3D Printing System (Objet Connex 350 / Stratasys Ltd.), which used the Objet Verowhite Plus resin to fabricate the biomodel. The machine's printing resolutions were 600 dots per inch (dpi) in both the x and y axes and 1600 dpi in the z axis. The accuracy of the machine is up to 0.1 mm. The construction took about 9 hours to complete.

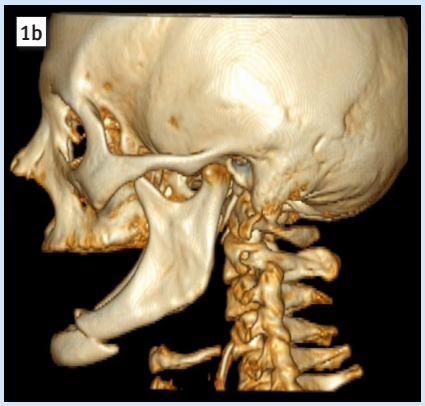
The previous modeling of the 2.4 mm reconstruction plate allowed far better circumstances for its improved adaptation to the anatomical contours of the region, enabling the reduction of surgical time and a better patient functional recovery (Figures 2a,b).

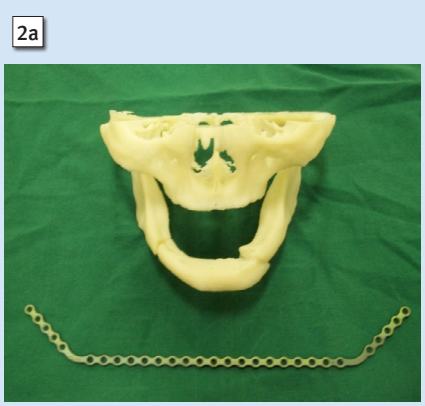
The treatment of fractures was performed through surgery under general anesthesia with orotracheal intubation. Surgeons performed the procedure through extra-oral access, bilateral submandibular, surgical reduction and fixation of the fracture (Figure 3a).

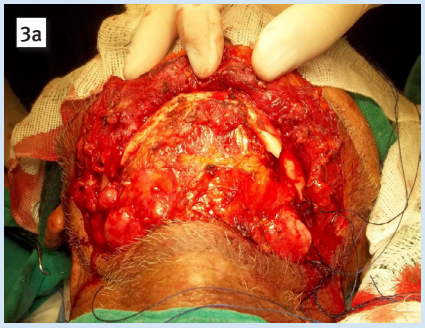
It was observed that the prototype reproduced the anatomy of the area to be operated with high precision, since the adaptation of the plate to the patient was extremely accurate and smooth (Figure 3b).

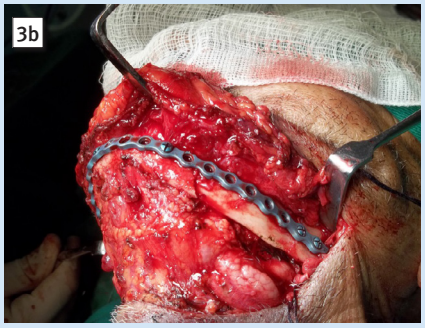
In the course of tomographic analysis, the postoperative images showed a reduction and fixation with satisfactory alignment of bone fragments and a good adaptation of the reconstruction plate (Figure 4).

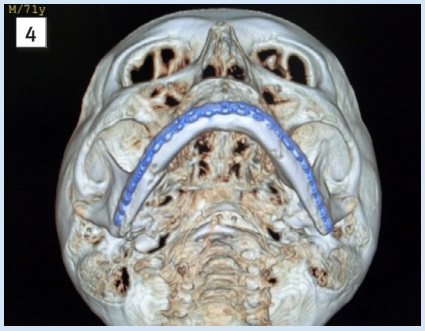












Slika 1. a/1. b. Obostrana fraktura mandibule snimljena CT-om
Figure 1a/1b CT scan showing a bilateral mandibular fracture
Slike 2.a/2.b. Pacijentov biomodel kojim se reproducira obostrana fraktura mandibule i predmodelira titanijeva pločica od 2,4 mm
Figures 2a/2b Patient biomodel reproducing the bilateral mandibular fracture and premodeling of a 2.4 mm titanium plate
Slika 3. a/3. b. Mandibularne frakture i njihova fiksacija titanijevom pločicom od 2,4 mm te devet kortikalnih vijaka
Figure 3a/3b Exposure of mandibular fractures and fixation using a 2.4 mm titanium plate and nine cortical screws
Slika 4. Postoperativno stanje snimljeno CT-om
Figure 4 CT scan showing postoperative appearance

Rasprava

Kad je riječ o pacijentima s terapijom atrofične bezube mandibule, uz ekstraoralni pristup (otvorena redukcija) s unutarnjom fiksacijom, nakon analize rezultata uočeno je da taj pristup omogućuje trenutačnu rehabilitaciju žvakanja i ima nizak postotak komplikacija (13, 14, 15).

U opisanom slučaju kirurzi su se odlučili za otvorenu redukciju s unutarnjom fiksacijom pod općom anestezijom kako bi poboljšali funkcionalne mogućnosti pacijenta i osigurali što bolji rezultat.

Ako se uzmu u obzir troškovi za funkcioniranje, estetiku i socijalnu rehabilitaciju pacijenta s deformitetima lica, poput dugog boravka u bolnici, potrebnog broja operativnih zahvata nužnih za rekonstrukciju i troškove za kirurški tim (16) te sve rizike vezane za opću anesteziju, kirurzi su odabrali postupak koji bi ublažio te čimbenike.

Uporaba mandibularnog modela, na osnovi kojeg je oblikovana rekonstrukcijska pločica, skratila je kirurški zahvat za jedan sat.

Izrada brzog prototipa biomodela (RP) nova je i vrlo važna tehnologija u maksilofacijalnoj kirurgiji. No taj je proces

Discussion

During the research in which the results of the patients who underwent atrophic edentulous mandible fractures treatment, conducted through an extra-oral approach (open reduction) with internal fixation were analyzed, it was observed that this approach enabled immediate masticatory rehabilitation, reaching good results and a low percentage of complications (13,14,15)

In the present case report, surgeons decided to perform open reduction with internal fixation under general anesthesia with the purpose to improve patient functional capacity and promote better outcomes

Considering the costs related to functional, aesthetic and social rehabilitation of patients with facial deformities, due to factors such as long hospital stay, number of required reconstructive surgery and time of surgical teams (16) as well as considering the risks regarding general anesthesia, the surgeons chose a procedure that could mitigate these factors. The use of a mandibular biomodel, upon which the reconstruction plate was modeled, has shortened surgical time for about an hour.

i složen te uglavnom zahtijeva intenzivnu suradnju biomedicinskih stručnjaka i inženjera (4, 17).

Dobra kvaliteta tomografskih slika i njihova odgovarajuća primjena u softveru InVesalius omogućila je pouzdano tiskanje prototipova, a u ovom slučaju osigurala je točniju dijagnostiku i posljedično bolji kirurški plan. Nadalje, u ovom slučaju korištena je tehnologija tiskanja *polyjet*. U istraživanju je ciljano analizirana točnost selektivnog laserskog sinteriranja, 3D tiskanja i tehnologije *polyjet* u izradi biomodela. Pokazalo se da je točnost *polyjeta* veća u usporedbi s drugim tehnikama i omogućuje detaljniju i precizniju reprodukciju anatomskih struktura (18).

U jednom novijem preglednom tekstu analizirano je 158 članaka objavljenih između 2005. i 2015. godine o primjeni 3D tiskanja u kirurgiji te je potvrđeno da je glavna prednost ove tehnologije mogućnost prijeoperacijskog planiranja (48,7 %), točnost korištenog procesa (33,5 %) i kraća operacija (32,9 %). Sve te prednosti potvrdili su kirurzi u opisanom slučaju (19). Na kraju – autori znaju da je korištenje RP-a u nekim dijelovima svijeta, poput Brazila, još uvijek ograničeno zbog skupe dijagnostike koja zahtijeva složen i sofisticiran tehnološki slijed – od stvaranja prikaza do konačnog oblika biomodela. No taj terapijski pristup može poboljšati kirurško planiranje i povećati kvalitetu liječenja, ugoditi pacijentu i povećati profesionalnu sigurnost, ali i smanjiti bolničke troškove tijekom kirurškog zahvata i nakon njega.

Rapid prototyping biomodels manufacturing is a recent technology, with great importance in oral and maxillofacial surgery. However, some complexity is involved in this process, mainly because it requires intense interaction between biomedical and engineering sciences (4, 17).

The good quality of the tomographic image and its appropriate handling by the In Vesalius software facilitated printing a prototype reliably in this case, allowing a more accurate diagnosis and, consequently, a better surgical planning. Furthermore, the printing technology used in this case was PolyJet. Data from a survey aimed at analyzing the accuracy of selective laser sintering, three-dimensional printing and PolyJet technologies in the production of biomodels, showed that the accuracy of the PolyJet was higher when compared to the others, providing greater detail of anatomical structures and precision (18).

A recent systematic review analyzed 158 articles published between 2005 and 2015, focused on 3D printing applications in surgery and they confirmed the fact that the main advantages of this technology are the possibilities of preoperative planning (48.7%), the accuracy of the process used (33.5%), and the saving operating time (32.9%). The surgeons who performed surgery described in this paper were familiar with these advantages (19). Finally, the authors understand that the use of rapid prototyping is still restricted in some parts of the world, such as Brazil, because it is a costly diagnostic tool which requires the use of a sophisticated and complex technology chain, from image acquisition up to the final shape of biomodel itself. However, the use of this therapeutic approach can improve surgical planning in order to improve treatment quality, patient comfort and professional safety by reducing hospital costs and risks during and after surgery.

Sukob interesa

Autori nisu ni u kakvom sukobu interesa.

Conflict of interest

The authors deny any conflicts of interest.

Abstract
Currently, imaging techniques such as Computed Tomography with three-dimensional reconstruction (3D) and Magnetic Resonances are being routinely used in pre-surgical planning in all fields of medicine. Nowadays, virtual three-dimensional images, commonly displayed on two-dimensional surfaces, such as the computer screen, can be used to produce rapidly prototyped models, with excellent dimensional accuracy and fine reproduction of anatomical structures, providing professionals with the ability to use the biomodel in planning and simulating medical and dental procedures (oral and maxillofacial surgery, making individualized facial implants and prostheses, measurements and previous adaptations of prefabricated fixation plates), thus contributing to considerable reductions in surgical time and consequently the duration of anesthesia, minimizing infection risks and reducing hospital costs. In this report, we describe a case of surgical planning and treatment of bilateral atrophic mandibular fracture, in which, for surgical planning, authors used Rapid Prototyping as an adjunct tool, considering the advantages already outlined.

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Key words
Mandibular Fractures, Maxillofacial Surgery, Three-Dimensional Printing

References

1. Marciani R. Critical systemic and psychosocial considerations in management of trauma in the elderly. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 1999 Mar;87(3):272-80.
2. Liu Q, Leu MC, Schmitt SM. Rapid prototyping in dentistry: technology and application. Int. J. Adv Manuf Technol. 2006;29:317-335.
3. Rosa ELS, Oleskovictz CF, Aragão BN. Rapid prototyping in maxillofacial surgery and traumatology: case report. Braz Dent J. 2004;15(3):243-7.
4. Safira LC, Costa Bastos L, Beal VB, de Azevedo RA, Francischone CE, Sarmento VA, et al. Accuracy of rapid prototyping biomodels plotted by three dimensional printing technique: ex vivo study. ACT. 2010;2:41-45.
5. Sugar A, Bibb R, Morris C, Parkhouse J. The development of a collaborative medical modeling service: organizational and technical considerations. Br J Oral Maxillofac Surg. 2004 Aug;42(4):323-30.
6. Mainenti P, Oliveira GS, Valério JB, Daroda LS, Daroda RF, Brandão G, et al. Amelobrastic fibro-odontosarcoma: a case report. Int J Oral Maxillofac Surg. 2009 Mar;38(3):289-92.

7. Gong X, Yu Q. Correction of mallary deformity in infants with bilateral cleft lip and palat using computer-assisted desing. Oral Surg Oral Med Oral Pathol Oral Radiol. 2012 Nov;114(5 Suppl):S74-8.
8. Bai S, Bo B, Bi Y, Wang B, Zhao J, Liu Y, et al. CAD/CAM surface templates as an alternative to the intermediate wafer in orthognathic surgery. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2010 Nov;110(5):e1-7.
9. Zhou L, Shang H, Feng Z, Ding Y, Liu W, Li D, et al. Prototyped flexible grafting tray for reconstrucion of mandibular defects. Br J Oral Maxillofac Surg. 2012 Jul;50(5):435-9.
10. Zide MF, Ducic Y. Fibula free microvascular reconstruction of the severely cominuted atrophic mandible fracture – case report. J Craniomaxillofac Surg. 2003 Oct;31(5):296-8.
11. Mardones MM. Tratamiento de fracturas em mandíbulas atroficas: presentación de dos casos clinicos. Int J Odontostomat. 2011;5:126-132.
12. Renato Archer Information Technology Center—CTI. In Vesalius 3. Open source software for reconstruction of computed tomography and magnetic ressonance images, 2013.
13. Torriani MA, Oliveira MG. O cirurgião dentista, sua formação e sua prática no atendimento ao idoso portador de traumatismo bucomaxilofacial. Rev odonto ciênc. 2000;3:31.
14. Edward E, Price C. Treatment protocol for fractures of the atrophic mandible. J Oral Maxillofac Surg. 2008 Mar;66(3):421-35.
15. Hachleitner J, Enzinger S, Brandtner C, Gaggl A. The role of the titanium functionally dynamic bridging plate for the treatment of the atrophic mandible fractures. J Craniomaxillofac Surg. 2014 Jul;42(5):438-42.
16. Yamauchi K, et al. Open reduction with internal fixation for mandibular fracture of 98-year-old female with severe atrophic mandible: report of a case. Asian J Oral Maxillofac Surg. 2010;22:102-104.
17. Meurer MI. Aquisição e manipulação de imagens por tomografia computadorizada da região maxilofacial visando à obtenção de protótipos biomédicos. Radiol Bras. 2008;41:49-54.
18. Salmi M, Paloheimo KS, Tuomi J, Wolff J, Mäkitie A, et al. Accuracy of medical models made by additive manufacturing (rapid manufacturing). J Craniomaxillofac Surg. 2013 Oct;41(7):603-9.
19. Martelli N, Serrano C, van den Brink H, Pineau J, Prognon P, Borget I, et al. Advantages and disadvantages of 3-dimensional printing in surgery: A systematic review. Surgery. 2016 Jun;159(6):1485-500.