Future Dental Journal of Egypt

Volume 5 | Issue 2 Article 6

2019

Advent of computer assisted surgery and its Application in oral and maxillofacial surgery

Lobna Abdrlaziz
faculty of oral & dental mediciene- future university in egypt, laziz@fue.edu.eg

Ahmed Abozekry
faculty of oral and dental medicene- future university in egypt, ahmed.kamal@fue.edu.eg

Follow this and additional works at: https://digitalcommons.aaru.edu.jo/fdj

Part of the Oral and Maxillofacial Surgery Commons

Recommended Citation

Abdrlaziz, Lobna and Abozekry, Ahmed (2019) "Advent of computer assisted surgery and its Application in oral and maxillofacial surgery," *Future Dental Journal of Egypt*: Vol. 5 : Iss. 2 , Article 6.
Available at: https://digitalcommons.aaru.edu.jo/fdj/vol5/iss2/6

This Article is brought to you for free and open access by Arab Journals Platform. It has been accepted for inclusion in Future Dental Journal of Egypt by an authorized editor. The journal is hosted on Digital Commons, an Elsevier platform. For more information, please contact rakan@aaru.edu.jo, marah@aaru.edu.jo, dr_ahmad@aaru.edu.jo.

Advent of computer assisted surgery and its Application in oral and maxillofacial surgery

Lobna Abdel Aziz Aly

Abstract: Computer-assisted surgery (CAS) represents a surgical concept and set of methods, that use computer technology for surgical planning, and for guiding or performing surgical interventions.

Advances in imaging techniques can greatly improve the treatment outcome and enhance the success rate of surgical procedures. This review article updates the information on surgical navigation system and its application in maxillofacial surgery.

Keywords: computer assisted surgery, oral and maxillofacial applications

Introduction:

Advances in digital technologies have brought about profound changes throughout dentistry. Ever more powerful systems offer undisputed advantages, such as the economic use of resources, optimised quality management and the enhanced processability of innovative materials, resulting in computer-assisted procedures becoming firmly established to ensure safe and reliable surgery.(1-3)

Surgical navigation hypothetically resembles the global positioning system (GPS) used in automobiles and has three components: *A localizer*, which is similar to the satellite in space, *a surgical probe*, which represents the track waves emitted by the GPS in the vehicle and *a computerized tomography* (CT) scan data set, which is analogous to a road map (**Figure 1**). Apart from CT scan, the data set can also use magnetic resonance imaging and positron emission tomography (4). In conventional technique the surgeon uses the pointer to establish correlation with pre-operative image data and the surgical field , but it is difficult to orient the images, thus augmented reality system was developed, which projects the images directly on the surgical site and is based on monocular projection in the operating microscope, headup displays, projection on to purpose built semitranslucent screens placed between the operating scene and the surgeon, or by projection into the binocular optics of a tracked surgical microscope. There are several types of surgical navigation systems available today (3,4).

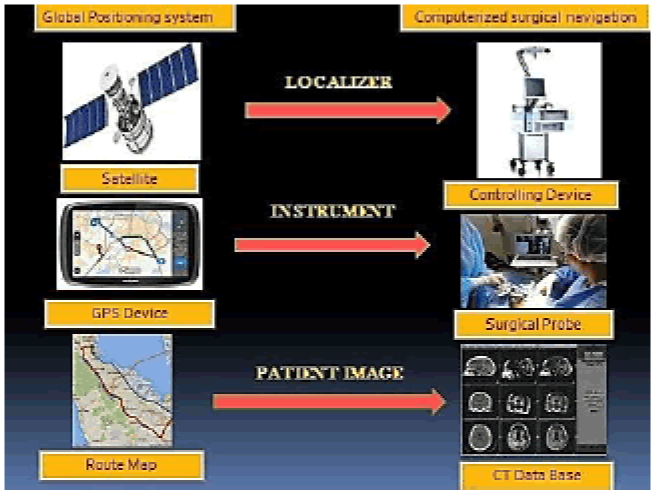

Figure 1: Hypothetical representation of surgical navigation surgery, emphasizing on its resemblance of each of its basic components with global positioning system, (1) The localizer (main controlling device for integration, replication and virtual reproduction of anatomical structures) works as a satellite. (2) A surgical probe which sends signals through infrared diodes or pointers and mimics the GPS system in the vehicle, as it emits track waves. (3) A computerized tomography database, for identification of abnormalities and confirming postoperative surgical results, is similar to the road map depicted in GPS system for route navigation.

Computer-assisted craniomaxillofacial surgery is based on four specific, well-described phases, which are all necessary in order to achieve predictable outcomes: planning, modeling, surgery, and evaluation.[5, 6]

With regard to the current economic climate in healthcare, potential limitation of widespread incorporation of virtual surgical planning VSP-CAD/CAM technology is its added cost and the resultant financial burdens that may be placed on the patient and medical system (7,8). Given the economic healthcare constraints, the improved patient outcomes seen with VSP-CAD/CAM have to be balanced against the cost of the technology (9,10).

Applications of computer assissted surgery in oral and maxillofacial surgery:

Computer-assisted surgery is the beginning of a revolution in surgery. It already makes a great difference in high-precision surgical domains, but it is also used in standard surgical procedures.

1. **Computer guided impalnt surgery:**

Digital implantology is one of the most imperative innovation drivers in dentistry. Computer guided implant surgery is dependent on comprehensive diagnostics and precise planning for the restorative outcome to be more predictable regarding function, biology and aesthetics. Therefore, the implant must be placed accurately according to the treatment plan. A radiographic template in conjunction with cone-beam computed tomography (CBCT) is considered a standard tool in dental implant diagnosis and treatment planning.(11) Once proper planning is accomplished, the radiographic template can be manually converted to a surgical template to be used during implant placement surgery.

Computer-guided surgery uses computer-aided design and computer-aided manufacturing (CAD/CAM) technology in conjunction with CBCT. With this technique, implant planning is done digitally, and the relationship between the implant position and radiographic template can be used to fabricate a stereolithographic surgical template. (12,13) The precision guide allows the clinician to place the implant in the planned position more accurately than when using a non-CAD/CAM surgical guide. (14)

Digital implant planning requires three-dimensional radiograph data (DICOM: digital imaging and communications in medicine) as well as STL data (STL: standard tesselation language) from an intraoral scan or the scan of a plaster cast (15,16) . This also means in effect that the procedure can be modified at any time to accommodate a specific implant system or the corresponding software.

Using cone beam computed tomography, the patient and the existing prosthesis are being scanned. Furthermore, the prosthesis alone is also scanned. Glass pearls of defined diameter are placed in the prosthesis and used as reference points for the upcoming planning. The resulting data is processed and the position of the implants determined. The surgeon, using special developed software, plans the implants based on prosthetic concepts considering the anatomic morphology. After the planning of the surgical part is completed, a CAD/CAM surgical guide for dental placement is constructed. The mucosal-supported surgical splint ensures the exact placement of the implants in the patient. Parallel to this step, the new implant supported prosthesis is constructed.

The dental technician, using the data resulting from the previous scans, manufactures a model representing the situation after the implant placement. The prosthetic compounds, abutments, are already prefabricated. The length and the inclination can be chosen. The abutments are connected to the model at a position in consideration of the prosthetic situation. The exact position of the abutments is registered. The dental technician can now manufacture the prosthesis (16). (fig. 2, 3)

Figure 2: a) Various surgical templates created by means of the polyjet technique (Smop; Swissmeda); b) the DLP technique (digital light processing; SHERAdigital); c) and SLS technique (selective laser sintering; EOS); d) as well as a subtractively manufactured (milled) surgical template. (Schubert et al.2019)

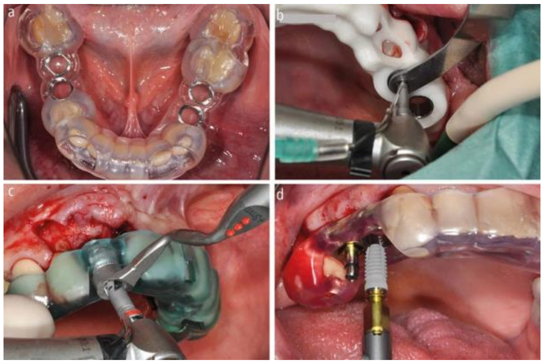

Figure 3: Surgical protocol for guided implantation (different patients): a) Optimal seating of the surgical template; b) guided pilot drilling (Zimmer Guided Surgery); c) guided implant site preparation (Straumann Guided Surgery); d) and guided implant placement (Camlog Guide System).(Schubert et al.2019)

Screen-Based Systems

Columbia scientific SIM/Plant software (Columbia scientific, USA)

This software helps the surgeon, in visualization of implants being inserted surgically, through CT scan images. It also provides a 3 dimensional picture of maxillofacial regions with accurate locations of vital structures and helps in the measurement of quality of bone (17,18).

VISIT surgical navigation software (Vienna, Austria)

This software aids in simulation of dental implant positions during treatment planning phase. Intraoperatively the drill is visualized by oblique reformatting beside the drill part and the images are changed according to the tracking system. VISIT is popularly used in placement of dental and extraoral implants in maxillofacial region (19,20).

2. Total joint reconstruction using computer-assisted surgery:

Ankylosis of the temporomandibular joint (TMJ) is a disabling condition in mastication, speech, facial expression, pain, and oral hygiene, resulting in compromise of patient’s quality of life [21, 22]. The objectives in the treatment of TMJ ankylosis are to restore the masticatory function, improve the facial esthetics and phonation, relieve the pain, and prevent the reankylosis [23]. There are a variety of surgical options to manage the TMJ ankylosis including gap arthroplasty, interpositional arthroplasty, and total joint reconstruction [24]. Incase of recurrent bony ankylosis, gap arthroplasty or interpositional arthroplasty has limitations to be applied due to low success rate and highre apserate [25–27]. Total joint reconstruction can be performed with autogenous graft or alloplastic prosthetic device.

Although costochondral Graft has been considered the ‘goldstandard’ for TMJ reconstruction of growing patients [28, 29], its outcome is reported to be unpredictable and of ten results in reankylosis of the TMJ [25, 27]. In this point of view, total joint reconstruction with alloplastic prosthetic device can be regarded as one of the reliable and effective surgical options for the end-stage TMJ ankylosis [30, 31].

On the other hand, the custom-made TMJ prosthesis system only requires as in gleoperation. Due to use of computer-aided design and computer-aided manufacturing (CAD/CAM) –fabricated surgical guide and custom made TMJ prosthesis, the precise operation can be performed with less time consuming due to accurate match of the custom made TMJ prosthesis with individual patient’s anatomy [32- 34]. Although it does not need as tereolithographic model, the custom-made TMJ prosthesis system has some disadvantages interms of high cost and difficulty in obtaining government approval in some countries. Therefore, it is necessary to combine the advantages of the two systems: low-cost and single operation with precise outcome.We combined three-dimensional (3D) virtual surgical planning, CAD/CAM-fabricated surgical guides, and stock TMJ prostheses for total joint reconstruction (34) (fig. 4,5).

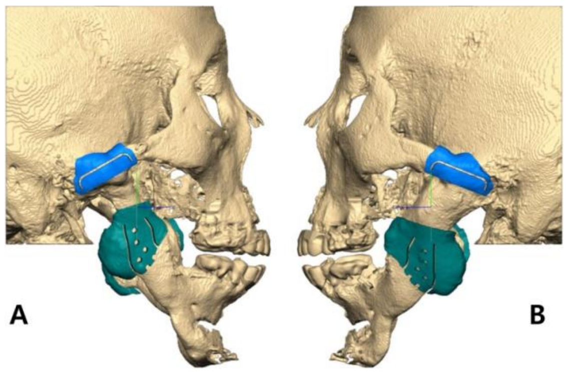

Figure 4: Right (a) and left (b) side of surgical guides using computer-aided design and computer-aided manufacturing. The upper part (blue) showed the location of upper margin for resection of the root of the zygoma and the location of the fossa component of stock TMJ prosthesis. The lower part (green) showed the location of lower margin for resection of the ankylosed condyle and several drill holes for screw fixation of the condyle component of stock TMJ prosthesis. (Rhee et al. 2019)

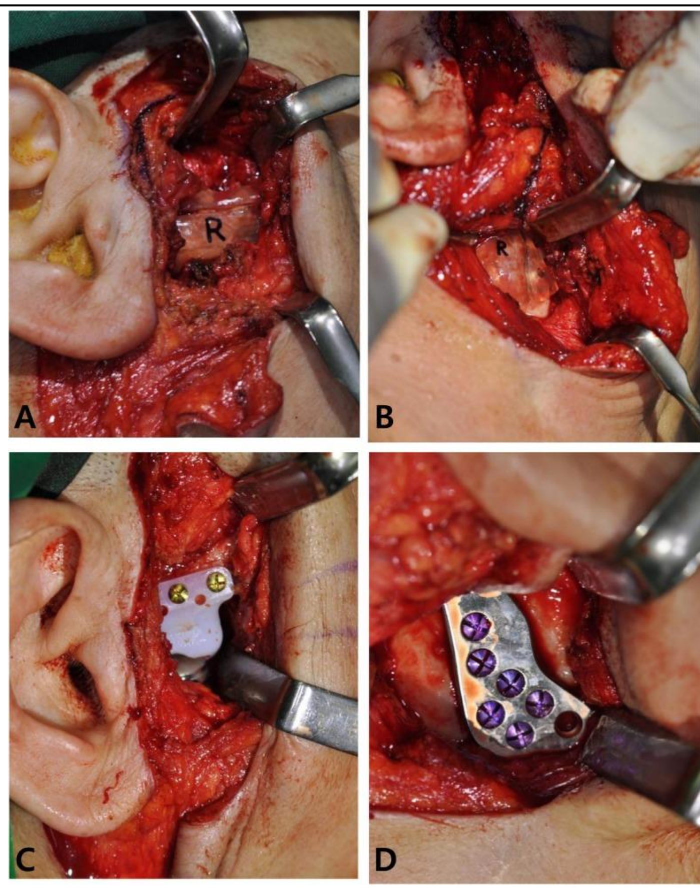

Figure 5: Intraoperative photographs taken at the right side. Placement of the surgical guide for the fossa component (the most left) and the condyle component (the second most left), and installation of the fossa component (the second most right) and the condyle component (the most right) (Rhee et al. 2019)

3. Accuracy of virtually 3D planned resection templates in mandibular reconstruction

Cutting guides have been widely used in mandibular reconstruction surgery. They are used to achieve resection at the preoperatively planned location (fig.6). Cutting guides plays a crucial role to bone, preventing possible recurrence.(35,36) The virtual planning aims to proper preoperative bending of the reconstruction plate through mirroring of the normal side to create a virtual model, which was printed to 3D model for preoperative plate bending. Mirror imaging has been successfully used for mandibular reconstruction by mirror the entire unaffected side to reconstruct a 3D model or plate bending. (37-39) Then the locating holes guide are made to accurately transfer the planned plate position from the model (during preoperative planning) to the mandible (during surgical procedures), using the screw holes as reference points. (40) The computer guided resection and titanium plate reconstruction using locating holes and cutting results regarding function and aesthetics.

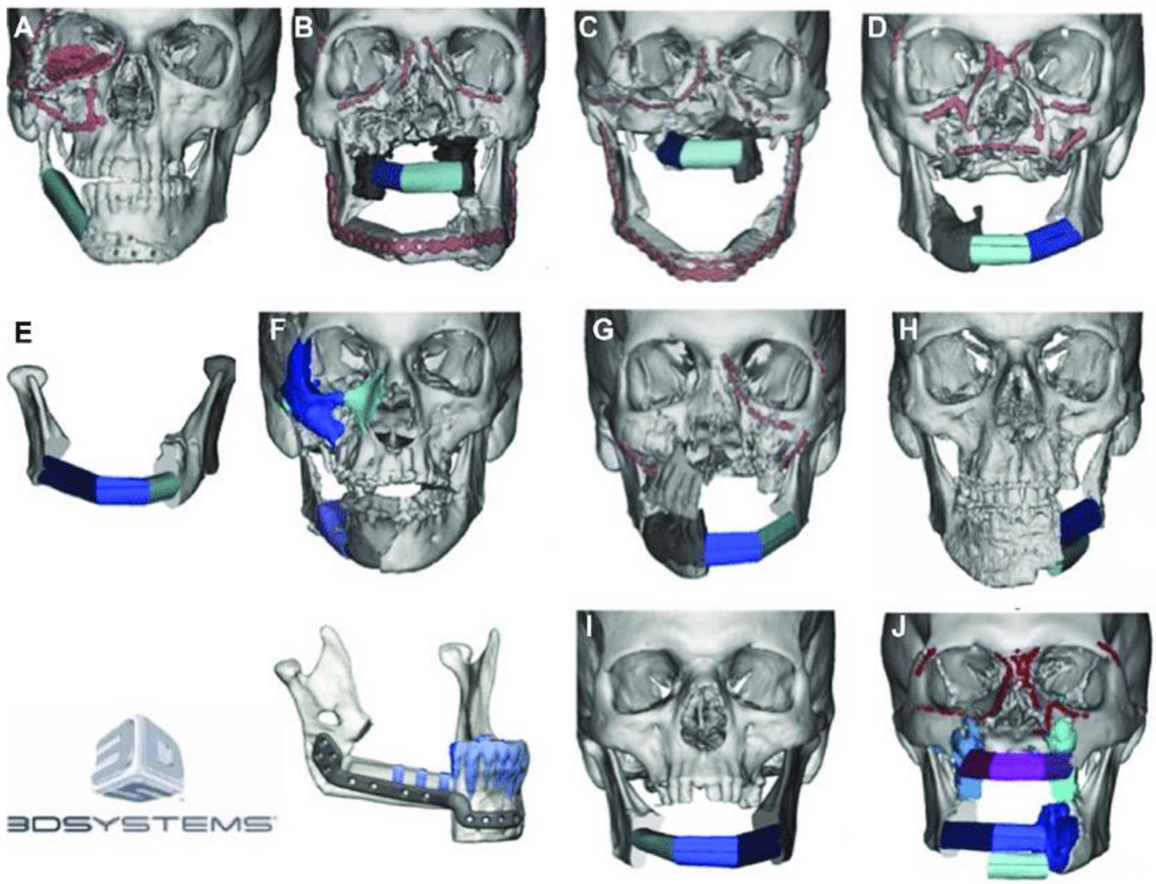

Figure 6 . Virtual surgical plan for computer-guided surgery: A, patient 1; B, patient 2; C, patient 3; D, patient 4; E, patient 5; F, patient 8; G, patient 7; H, patient 9; I, patient 6; and J, patient 10. Khatib et al. 2018.

4. Post traumatic reconstruction:

VSP-CAD/CAM has been utilized for reconstruction of traumatic facial injuries, including comminuted mandible and panfacial fracture reduction and repair. Three-dimensional modeling of craniomaxillofacial injuries facilitates precise intraoperative reduction of displaced bone fragments, while CAD/CAM produces occlusal splints that allow superior restoration of facial symmetry, appearance, and function to those fitted intraopertively (41).

Additionally, implementation of VSP-CAD/CAM offers use of pre-manufactured cutting guides for improved accuracy and reduced trial-and-error when harvesting and shaping autologous implants, thus helping to ensure optimal bone-to-bone contact and aesthetic outcome. Pre-bent fixation plates decrease intraoperative time and limit the extent of subperiosteal dissection, thus minimizing avascularization of bony fragments (42). Utilization of VSP-CAD/CAM starting at initial presentation of traumatic facial injury does not result in increased time to reconstruction and has been shown to better preserve facial height and width (41, 42).

Owing to the development of computer technology, there are many computer-assisted surgical techniques available to treat oral and maxillofacial trauma. Surgical planning software and computer generated stereolithographic (STL) models (43,44) (fig. 7) have already helped many surgeons perform accurate preoperative simulations that provide ideal 3-dimensional (3D) surgical simulation plans. However, before the use of intraoperative navigation systems, favorable results were difficult to achieve, because accurate translation of these computerbased surgical plans into real-world surgical outcomes is a major challenge. Intraoperative navigation systems (45) delivered an effective solution to the problem

For ZMC fractures, the traditional reduction method, based entirely on the surgeon's experience and skills without any assisted methods such as guide or preformed guide plates, cannot achieve a stable and accurate therapeutic effect, which can result in secondary deformity and might require repeat surgery (43,45); therefore, this method is rarely used. Use of preformed patient-specific guide plates for osteotomy and repositioning might achieve better accuracy than preoperative prediction alone, but might be relatively more expensive.

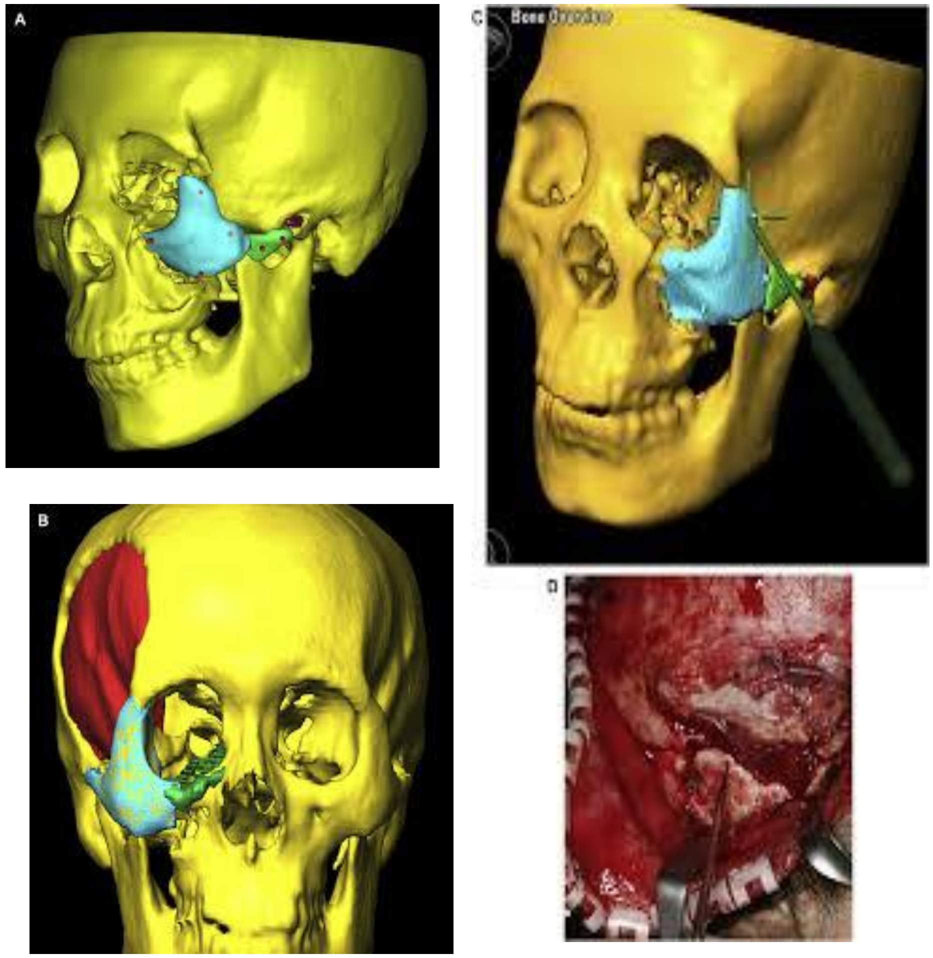

Figure 7: Design flow for the navigation group. A, A cylinder marker was placed for 3-dimensional maxillofacial reconstruction and zygomatic complex fracture segmentation (localization plan). B, Simulated surgery was conducted according to the mirrored data (non-fractured side); the bone segments with the markers were moved; and the bone segments were smoothly connected with the fixed bone segment to form the target position of bone fracture reduction (reduction plan). C, D, Real-time intraoperative navigation. The reduced zygomatic complex navigation verification position was designed according to the preoperative plan. Gong et al. 2017(44)

5. **Three-dimensional computer-assisted surgical simulation in orthognathic surgery:**

Orthognathic surgery emerged as a technical procedure to correct dento-skeletal deformities, correcting both esthetical and functional alterations, which includes occlusal, respiratory and articular abnormalities.

Originally, maxillofacial surgeons simply perform osteotomies and fix the bone segments into the desired position without any type of reference apparatus. With the advent of model surgery, first proposed by Angle (46).

Okumura., et al. (47) were the first authors to publish the possibility of use three-dimensional computed tomography in adjunct to scanned dental cast for pre-orthognathic surgery planning and simultaneously permit occlusal and morphological evaluation, specifically for bone interferences and anatomical landmarks

Evolving on that aspect, Xia JJ., et al, publish a scope for what was published after and consider the first step into the modern era of VSP creating the CASS (computer-assisted surgical simulation) protocol, particularized years later [48-50].

Conclusion:

Computer assissted surgery is a novel technology that holds potential to consistently and predictably advance reconstructive outcomes, both aesthetically and functionally. This technology is suited for use in spatially complex reconstructive cases due to its ability to visualize and virtually manipulate 3D configurations of the craniomaxillofacial skeleton. Its applications are expanding for cases of varying levels of complexity that require precise millimeter precision particularly in trauma, orthognathic procedures and oncology to obtain optimized function and aesthetic outcomes. VSP- CAD/CAM technology is attaining acceptance across the multiple surgical disciplines and innovative solution in the management of challenging head and neck reconstruction cases.

However the costs for the navigation systems are very high, and the time for preparation for the surgery is longer in comparison with conventional technique. However, the navigation procedure gives more security, particularly in complex cases and also may result in a better clinical outcome for the patient. Further development of software programs may reduce the preoperative planning time and time spent during the operation.

There are some aspects still under development, with promising results. More studies are necessary regarding different manufacturing techniques, materials and clinical randomized studies, specially related to mandibular positioning.

Conflict of Interest

We have no conflict of interest.

Ethics Statement

Ethics approval not required.

Referrences:

1. 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.

2. Miyazaki T, Hotta Y, Kunii J, Kuriyama S, Tamaki Y . A review of dental CAD/CAM: current status and future perspectives from 20 years of experience.*Dent Mater J* 2009; 28: 44–56.

3. van Noort R . The future of dental devices is digital. *Dent Mater* 2012; 28: 3–12.

4. Bell RB. Computer planning and intraoperative navigation in cranio-maxillofacial surgery. Oral Maxillofacial Surg Clin N Am 2010;22: 135-156.

5. Ciocca L, Mazzoni S, Fantini M et al. A CAD/CAM-prototyped anatomical condylar prosthesis connected to a custom-made bone plate to support a fibula free flap. Med Biol Eng Comput 2012;50(7);743-9.

6. Lethaus B, Poort L, Böckmann R, Smeets R, Tolba R, Kessler P. Additive manufacturing for microvascular reconstruction of the mandible in 20 patients. Journal of Cranio-Maxillofacial Surgery 2012;40;43-6.

7. Jepper O, Hirsch D, Levine J, Garfein E. The New Age of Three-Dimensional Virtual Surgical Planning in Reconstructive Plastic Surgery. Plast Reconstr Surg 2012;130(1);192-4.

8. Schultes G, Kärcher H, Gerzanic L. Prefabricated Iliac Crest Transplant. Journal of Oral and Maxillofacial Surgery 2013;71;428-32.

9. Xia J, Phillips C, Gateno J, Teighgraeber J, Christensen A, Gliddon M, Lemoine J, Liebschner M. Cost-Effectiveness Analysis for Computer-Aided Surgical Simulation in Complex Cranio-Maxillofacial Surgery. j.joms.2005.12.072

10. Rodby K, Turin S et al. Advances in Oncologic Head and Neck Reconstruction: Systemic Review and Future Considerations of Virtual Surgical Planning and Computer Aided Design / Computer Aided Modeling. J Plast Reconstr Aesthet Surg. 2014 Sep;67(9):1171-1185.

11. Kourtis S, Skondra E, Roussou I, Skondras EV. Presurgical planning in implant restorations: Correct interpretation of cone-beam computed tomography for improved imaging. J Esthet Restor Dent. 2012;24:321–332.

12. Sarment D, Al-Shammari K, Kazor C. Stereolithographic surgical templates for placement of dental implants in complex cases. Int J Periodontics Restorative Dent. 2003;23:287–295.

13. Marchack CB. An immediately loaded CAD/ CAM-guided definitive prosthesis: a clinical report. J Prosthet Dent. 2005;931:8–12.

14. Noharet R, Pettersson A, Bourgeois D. Accuracy of implant placement in the posterior maxilla as related to 2 types of surgical guides: A pilot study in the human cadaver. J Prosthet Dent. 2014;112:526–532.

15. Lanis A, Alvarez Del Canto O . The combination of digital surface scanners and cone beam computed tomography technology for guided

implant surgery using 3Shape implant studio software: a case history report. *Int J Prosthodont* .2015; 28: 169–178.
16. O. Schubert, J. Schweiger,M. Stimmelmayr,E. Nold & J.-F. Güth . Digital implant planning and guided implant surgery – workflow and reliability. *British Dental Journal* . 2019; 226:101–108.
17. Stockman CD . Using CT and SIM/ Plant to plan implant therapy. Alpha Omega .1996; 89: 35-38.
18. Hagiwara Y, Koizumi M, Igarashi T . Application of CT imaging for dental implant simulation. J Oral Sci . 1999; 41: 157-161.
19. Watzinger F . Evaluation of the intraoperative position of endosseous oral implants in the edentulous mandible. Clin Oral Implants Res.2002; 13: 59-64.
20. Wagner A, Wanschitz F, Birkfellner W, Zauza K, Klug C, et al. Computer-aided placement of endosseous oral implants in patients after ablative tumor surgery: Assessment of accuracy. Clin Oral Implants Res.2003; 14: 340-348.
21. Roychoudhury A,Parkash H,Trikha A.Functional restoration by gaparthroplasty in temporomandibular joint ankylosis: a report of 50 cases.Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 1999; 87:166–169.
22. Zhang X, Chen M, Wu Y, Wang B,Yang C. Management of temporomandibular joint ankylosis associated with mandibular asymmetry ininfancy. Jcraniofac Surg. 2002;22:1316–1319.
23. Movahed R, MercuriL G.Management of temporomandibular joint ankylosis. Oral Maxillofac Surg Clin North Am. 2005;27:27–35.
24. Wolford LM. Temporo mandibular joint devices: treatment factors and outcomes. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 1997;83:143–149.
25. Posnick JC, Goldstein JA. Surgical management of temporomandibular joint ankylosis in the pediatric population. Plast Reconstr Surg. 1993;91:791–798
26. Nitzan DW, Bar-Ziv J, Shteyer A.Surgical management of temporomandibular joint ankylosis type III by retaining the displaced condyle and disc. J oral Maxillofac Surg. 1998; 56:1133–1138

27. Lindqvist C, Pihakari A, Tasanen A, Hampf G. Autogenous costochondral grafts in temporomandibular joint arthroplasty: A survey of arthroplasties in 60 patients. J maxillofac Surg. 1986;14:143–149

28. Ware W,Taylor R. Cartilaginous growth centers transplanted to replace mandibular condyles in monkeys. J Oral Surg (American Dental Association:1966 ;24:33

29. MacIntosh RB. The use of autogenous tissues for temporomandibular joint reconstruction. J oral Maxillo fac Surg. 2000; 58:63–69

30. Burgess M, Bowler M, Jones R, Hase M, Murdoch B. Improved outcomes after alloplastic TMJ replacement: analysis of a multicenter study from Australia and New Zealand. J Oral Maxillofac Surg. 2014;72:1251–1257

31. Sanovich R, Mehta U, Abramowicz S,Widmer C, Dolwick M. Total alloplastic temporomandibular joint reconstruction using Biometstock prostheses: the University of Florida experience. Int J Oral Maxillofac Surg. 2014; 43:1091–1095

32. Gerbino G,Zavattero E, Bosco G, Berrone S, Ramieri G. Temporomandibular joint reconstruction with stock and custom-made devices: Indications and results of a 14-year experience. J Cranio maxillo fac Surg. 2017; 45:1710–1715

33. Aagaard E, Thygesen T. A prospective, single-centre study on patient outcomes following temporomandibular joint replacement using a custom-made Biomet TMJ prosthesis. Int J Oral Maxillofac Surg. 2014; 43:1229–1235.

34. Rhee S, Park S, Kim j, Jeong C, and Choi J. Total joint reconstruction using computer-assisted surgery with stock prostheses for a patient with bilateral TMJ ankylosis. Maxillofac Plast Reconstr Surg. 2019; 41(1): 41.

35. Weijs WL, Coppen C, Schreurs R, Vreeken RD, Verhulst AC, Merkx MA, Bergé SJ, Maal TJ. Accuracy of virtually 3D planned resection

templates in mandibular reconstruction. J Craniomaxillofac Surg. 2016 Nov;44(11):1828-1832.

36. Weitz J, Wolff KD, Kesting MR, Nobis CP. Development of a novel resection and cutting guide for mandibular reconstruction . J Craniomaxillofac Surg. 2018 Nov;46(11):1975-1978.

37. Lee JW, Fang JJ, Chang LR, Yu CK. Mandibular defect reconstruction with the help of mirror imaging coupled with laser stereolithographic modeling technique. J Formos Med Assoc. 2007 Mar; 106(3):244-50.

38. Cohen A, Laviv A, Berman P, Nashef R, Abu-Tair J. Mandibular reconstruction using stereolithographic 3-dimensional printing modeling technology. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2009 Nov;108(5):661-6.

39. Khalifa GA, Abd El Moniem NA, Elsayed SA, Qadry Y. Segmental Mirroring: Does It Eliminate the Need for Intra-operative Readjustment of the Virtually Pre-Bent Recon-struction Plates and Is It Economically Valuable? J Oral Maxillofac Surg. 2016 Mar;74(3):621-30.

40. Baber Khatib , Karl Cuddy , Allen Cheng , Ashish Patel , Felix Sim , Melissa Amundson , Savannah Gelesko , Tuan Bui , Eric J Dierks , R Bryan Bell Functional Anatomic Computer Engineered Surgery Protocol for the Management of Self-Inflicted Gunshot Wounds to the Maxillofacial Skeleton. J Oral Maxillofac Surg .2017; 76(3)

41. Foley BD, Thayer WP, Honeybrook A, McKenna S, Press S. Mandibular Reconstruction Using Computer-Aided Design and Computer-Aided Manufacturing: An Analysis of Surgical Results. J Oral Maxillofac Surg. 2013;71;e111-9.

42. Tepper OM, Sorice S, Hershman GN, Saadeh P, Levine JP, Hirsch D. Use of Virtual 3-Dimensional Surgery in Post-Traumatic Craniomaxillofacial Reconstruction. J Oral Maxillofac Surg. 2011;69;733-41.

43. Pham AM, Rafii AA, Metzger MC, et al: Computer modeling and intraoperative navigation in maxillofacial surgery. Otolaryngol Head Neck Surg.2007; 137:624.

44. Gong X, Yang He, Jingang An, Yao Yang, Xiuling Huang, Meng Liu, Yangyang Zhao, and Yi Zhang,. CANS for Delayed Zygomatic Fracture Treatment. J Oral Maxillofac Surg 2017; 75:1450-1463,.

45. Watzinger F, Wanschitz F, Wagner A, et al: Computer-aided navigation in secondary reconstruction of post-traumatic deformities of the zygoma. J Craniomaxillofac Surg 25:198, 1997

46. EH Angle. “Double Resection for the Treatment of Mandibular Protrusion”. Dental Cosmos 45.4 (1903): 268-274.

47. H Okumura , L H Chen, S Tsutsumi, M Oka. “Three-dimensional virtual imaging of facial skeleton and dental morphologic condition for treatment planning in orthognathic surgery”. American Journal of Orthodontics and Dentofacial Orthopedics 116.2 (1999): 126-131.

48. JJ Xia [1], Jaime Gateno, John F Teichgraeber, Andrew M Christensen, Robert E Lasky, Jeremy J Lemoine, Michael A K Liebschner “Accuracy of the Computer-Aided Surgical Simulation (CASS) System in the Treatment of Patients With Complex Craniomaxillofacial Deformity: A Pilot Study”. Journal of Oral and Maxillofacial Surgery 65.2 (2007): 248-254.

49. J. J. Xia , J. Gateno , J. F. Teichgraeber, P. Yuan , J. Li , K.-C. Chen , A. Jajoo , M. Nicol , D. M. Alf “Algorithm for planning a double-jaw orthognathic surgery using a computer-aided surgical simulation (CASS) protocol. Part 1: planning sequence”. International Journal of Oral and Maxillofacial Surgery 44.12 (2015): 1431-1440.

50. J. J. Xia , J. Gateno , J. F. Teichgraeber, P. Yuan , J. Li , K.-C. Chen , A. Jajoo , M. Nicol , D. M. Alf “Algorithm for planning a double-jaw orthognathic surgery using a computer-aided surgical simulation (CASS) protocol. Part 2: three-dimensional cephalometry”. International Journal of Oral and Maxillofacial Surgery 44.12 (2015): 1441-1450.