Migration Letters

Volume: 20, No: S1 (2023), pp. 1800-1810

ISSN: 1741-8984 (Print) ISSN: 1741-8992 (Online)

www.migrationletters.com

The Effectiveness Of A 3D Printed Tooth-Supported Drilling Template In Biopsy Removal For Intra-Bony Lesions

Saleh Muawwadhah Mohammed Alqahtani[1], Mohamed Fawzi Almghamsi[2], Eman Mohammad Khalid Marghalani[3], Eyad Mohammad Khalid Marghalani[4], Rayan Abdullah Yousef Aljawi[5], Abdullah Jumaan Al Gharamah[6], Nouf Naef Alsharef[7], Maha Salem Baaboud[8], Hanadi Ateeq Alansari[9], Sarah Faihan Ghazi Al-Otaibi[10], Thourayah Gazi Alotabi[11]

Abstract

Digitalization in medicine and dentistry offers new treatment options and increased safety and predictability. The challenge is to integrate these technologies into clinical practice and use existing methods to address new problems. Guided implantology has developed into a reliable and accurate method, benefiting other a[1]pplications like jawbone biopsies. Irregularities in the jawbone are often found accidentally on radiological scans, but a histopathological examination is required for a reliable diagnosis. Lesion classifications are a controversial topic, with the 2017 World Health Organization Classification being the most relevant guideline. Therapies may include radiological recall, aesthetic surgical revision, systemic management with medications, surgical exploration, or full resection. However, radiologically exact diagnoses are sometimes not made, and some lesions are not biopsied after risk assessment. Today's 3-dimensional (3D) imaging, such as cone beam computed tomography (CBCT) and dental scans, can be combined with modern guided implantology to integrate safe and minimally invasive guided bone biopsies into the clinical routine. However, anatomical conditions may restrict its use, and computer-assisted interventions may reduce operating time and improve patient outcomes.

Keywords: *3D printed tooth-supported drilling template in biopsy removal for intra-bony lesions.*

Introduction

Technological advancements are driving the evolution of oral and cranio-maxillofacial surgery, with additive manufacturing (AM) processes such as 3D printing playing a growing role. 3D printing involves fabricating objects through the deposition of material using a print head,

[1]General dentist, Alnadwah primary health care center, Saudi Arabia.
[2]General dentist, Phc barahrah (albaha), Saudi Arabia.
[3]Resident Dentist, East Jeddah General Hospital, Saudi Arabia.
[4]Resident Dentist, Kelakh Primary health care center, Saudi Arabia.
[5]Resident dentist, Alwash'ha primary health care center, Saudi Arabia.
[6]General Dentist, Um Al Jarm primary health care, Saudi Arabia.
[7]A Dentist Doctor, Al Faisalih North PHC, Saudi Arabia.
[8]General Dentist, Ghran health center, Saudi Arabia.
[9]Dental assistant, Dental Department, King abdulaziz hospital, Saudi Arabia.
[10]Dental Resident , Al-Dawadmi General Hospital, Saudi Arabia.
[11]Dental Assistant, Dwadmi General Hospital, Saudi Arabia.

nozzle, or other printing technology. It allows creating objects layer-by-layer through computer-aided design/computer-aided manufacturing (CAD/CAM). 8 Originally developed in the 1980s to accelerate the production of small and custom-designed objects, 3D printing revolutionized prototyping concepts and embraced many applications in manufacturing industries. It has been integrated into various medical techniques and procedures, providing important inputs to various domains such as dentistry, maxillofacial surgery, orthopedics, and neurosurgery. (**Lin et al; 2018 and D'Haese et al; 2000**).

Frequent clinical applications of 3D printing include the fabrication of surgical templates to improve surgery accuracy and reduce the duration and morbidity of interventions. It is now applied in routine oral and craniofacial surgery. Recent progress in 3D-printing of implantable biomaterials has been applied to the fabrication of custom implants based on patients' radiological data. (**Charles et al; 2019; Park et al; 2016**).

Three-dimensional printing techniques involve creating accurate physical 3D models from patient radiological data. Techniques such as vat photopolymerization, material extrusion, and binder jetting can be used for surgical model fabrication. The obtained surgical models can fulfill three purposes: training, planning, and simulating. **(Charles et al; 2019 and Meglioli et al; 2020).**

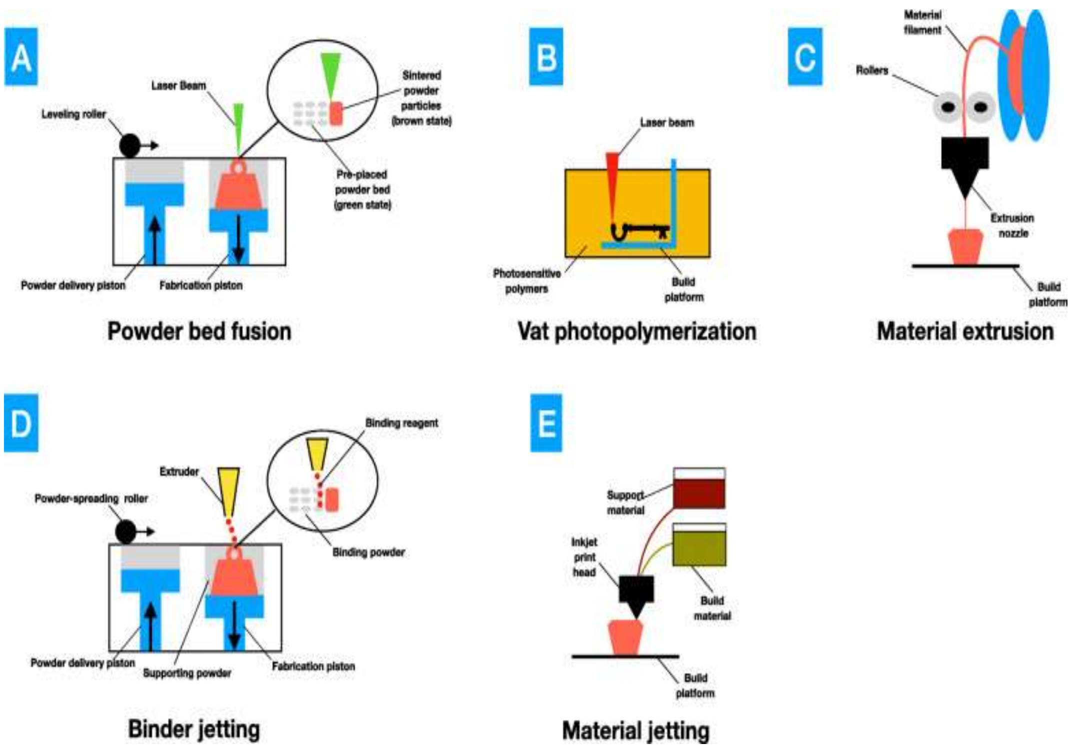

Fig 1: Rapid prototyping techniques for surgical applications are represented schematically as follows: (a) Powder bed fusion (b) Vat photopolymerisation (c) Material extrusion (d) Binder jetting (e) Material jetting (Meglioli et al; 2020).

Oral and perioral tissues are susceptible to various diseases, including developmental, neoplastic, infectious, inflammatory, and reactive pathologies. Diagnosing these pathologies can be challenging due to their diverse nature and nonspecific features. The oral and maxillofacial area is exposed to harmful factors and carcinogenic chemicals, leading to a variety of diseases. Some can only be identified based on clinical signs and symptoms, while others require incisional or excisional biopsy for soft tissue diseases and bony structures. The distribution of oral and maxillofacial lesions is assessed to estimate prevalence, identify high-risk subpopulations, and optimize healthcare resources. (**Hassona et al; 2020 and Alhindi et al; 2019**).

The occurrence of these lesions varies globally due to environmental differences and lifestyles. Most studies on oral conditions in children have focused on caries, periodontal disease, malocclusion, and dental trauma. Oral mucosal lesions occur in approximately 30% of the general population, and clinical characteristics can lead to definitive diagnoses. However, biopsy and microscopic examination are often necessary to confirm or refine a preliminary diagnosis. Discords between clinical impressions and histopathological diagnoses often occur due to methodological differences in diagnosis criteria and evaluation professionals. (**Mahmoudi et al; 2018 and Melrose et al; 2019**).

Dental schools often lack sufficient training in oral pathology and medicine, leading to incomplete referral letters or forms accompanying specimens submitted for histopathological examination. This lack of knowledge makes it difficult to achieve accurate histopathological diagnoses. Incisional biopsy is used when removal of the whole lesion is not possible or indicated, and clinician performance is crucial. However, the impact of biopsy size on histopathologic diagnosis remains an under-evaluated issue. Small samples may lack representative areas of the lesion and exhibit more histological tissue artifacts, compromising interpretation and impeding pathologists' ability to reach definitive diagnoses. (**Sardella et al; 2017 and Ghoreishi et al; 2020**).

Empirical suggestions vary concerning the dimensions of incisional biopsy, with some suggesting a length of three times its width and a depth of 2 to 5 mm. Depth should include the basement membrane and underlying connective tissue, especially in cases of thickened epithelial lining and hyperkeratosis. Adequate tissue depth can reveal important diagnostic features in mucosal dysplastic and malignant lesions, influencing diagnosis and prognosis. (**Avon & Klieb; 2022 and Poh et al; 2018**).

Biopsy size affects the possibility of reaching a histopathological diagnosis, but larger sampling allows for more accurate diagnosis. Mucosal biopsy examination showed a satisfactory accuracy rate of 87.5%, but 13.3% of misdiagnoses were attributed to insufficient tissue. Most discordance was imputed to sampling error, which is when submitted specimens are not representative of the lesion. Multiple-site biopsy examination is advocated to allow for more representative specimens, and it seems to be powerful to decrease under diagnosis rates compared to single-site examination. (**Ji et al; 2020**).

Franklin and Jones emphasize the importance of adequate tissue collection for accurate examination, diagnosis, and treatment. Dentists who perform biopsy procedures must understand the appropriate amount of tissue for the lesion. This depends on the selection of the biopsy site, the type of biopsy, and the specimen's submission to the laboratory. Small or superficial biopsies can be insufficient and not diagnostically useful, as they can be lost or distorted during processing. The amount of tissue submitted is crucial for assessment, and an accurate clinical description of the lesion can aid the pathologist in diagnosis. (**Poh et al; 2018 and Melrose et al; 2017**).

Selection of biopsy site

In large lesions, there may be discrepancies in histological features between sites within the lesion. The site chosen for a biopsy must be representative of the overall pathology present in the lesion. Multiple smaller biopsies may be appropriate to provide representative tissue for examination. A recent study by Lee et al. showed that when histological diagnoses from single-site biopsies of oral leukoplakia's were compared with histological diagnoses after resection, the "agreement rate" was only 56%. However, 29.5% of patients were underdiagnosed. The rate of underdiagnosis was reduced to 11.9% when multiple biopsies were taken initially. For smaller, discrete lesions, an excisional biopsy may be appropriate. Clinical factors such as surrounding anatomical factors and the clinical nature of the lesion may also influence the type of biopsy or tissue selection.29,30**(Mehrotra et al; 2019 and Da Silveira et al; 2017**).

Surgical biopsy

The traditional method for collecting tissue for histological examination is scalpel biopsy, which can be done by taking a sample of the lesion or removing the entire lesion. The choice between incisional or excisional biopsy depends on factors such as the lesion's anatomical site, proximity to other structures, and the size and nature of the lesion. Excisional biopsy is suitable for small, clinically benign lesions, while punch biopsies are another method commonly used. Disposable punch biopsies are available in different sizes and can be provided on request from pathology laboratories. These biopsies are useful and easy to perform, depending on the type of lesion and clinical access, and produce few artefacts within the tissue. (**Diamanti et al; 2022**).

Exfoliative cytology/brush biopsies

The use of digital guided biopsies is a non-invasive method that can be useful in evaluating mucosal pathology, particularly in assessing superficial cellular features of lesions for signs of malignancy. However, the accuracy of cytological analysis has improved with the advent of computer-assisted analysis, but diagnosis based on examination of cytological features alone is not recommended for definitive diagnosis of malignant lesions. In cases of clinically suspicious lesions, surgical biopsy techniques should be considered due to the limited sensitivity and specificity of cytological examination. (**Seone et al; 2019**).

Despite the importance of submission of tissue for histological examination, there may be difficulties in the interpretation of the histology or a lack of correlation between clinical signs and symptoms and the histological features observed. Digital guided biopsies can be combined with modern guided implantology knowledge to integrate safe and minimally invasive guided bone biopsies into the clinical routine. This method enables challenging bone biopsies to be performed under local anesthesia in a predictable manner, reducing both risks and invasiveness. However, anatomical conditions such as the locations of the lesion, mouth opening, and existing soft tissue may restrict its use.35 (**Pellegrino et al; 2020**).

Bypassing a biopsy provides a wider tolerance to obtain a representative specimen, but it also requires deviations from the planned position due to the necessary sliding fit of the printed sleeve. Studies have shown that the accuracy of surgical guides with distal extension is lower in comparison to the accuracy of surgical guides without extension. Further research is needed to investigate the dependence of accuracy on the angulation of the biopsy relative to the orthograde tooth axis.36,37 (**Martin et al; 2021**).

Depth deviations may be caused by cylinders not fractured at the lowest point before removal and variations in the hardness of osseous lesions. In the future, samples should be planned deeper depending on the density of the lesion. Increased temperature during drilling is expected due to friction on the large surface of the trephine bur, which can lead to inaccuracies due to thermoplastic manipulation and thermal damage of soft and hard tissue. To avoid contamination and increase precision, metal sleeves can be used, but studies have shown that due to the current accuracy of 3D printing and the necessary tolerances of two metal-guided surfaces, even lower accuracy would be expected. (**Tallarico et al; 2019**).

Computer guided 3D printing

Three-dimensional (3D) printing, also known as additive manufacturing (AM), has evolved over the past three decades and has the potential to revolutionize various fields, including reconstructive medicine. Initially described by Hideo Kodama in 1981, 3D technology has evolved into more sophisticated printers, allowing for applications in aerospace, engineering, consumer products, arts, food industry, education, manufacturing, and medicine. AM uses metals, ceramics, and plastic materials to produce 3D objects for various disciplines, including medical applications. The process, defined by ISO and ASTM, involves joining materials to create parts from 3D model data layer by layer, unlike subtractive and formative manufacturing methodologies. (**Steven et al; 2023**).

Additive manufacturing (AM) has various definitions over the last 30 years, including direct digital manufacturing, additive layer manufacturing, additive fabrication, additive processes, free-formed fabrication, solid free-formed fabrication, rapid manufacturing, and rapid prototyping. Unlike conventional manufacturing processes, AM technology can create complex geometric products with high functionality and low manufacturing costs, making it an ideal technology for producing unique 3D objects in low volumes, commonly used for medical and dental applications. (**Anand & Prasad, 2021**).

Three-Dimensional (3D) Printing Techniques

In the medical field, there are various variants of additive manufacturing (AM) processes and printers available today. These processes share a common workflow: capturing anatomical scans using imaging techniques like MRI and CT scans, processing and optimizing CAD models, and transforming them into a standard triangulation or tessellation language (STL) file and imported into an AM setup. Each model is formatted in the STL to a geometric shape, sliced into thin layers, and the movement of the depositing or fusing unit, substrate, and other parameters is programmed by specialized software. (**Ghantous et al; 2020**).

Stereolithography

Stereolithography (SLA) is a 3D printing process that generates 3D models in layers based on CT scan axial image slices. This method uses a vat photopolymerization AM process in which UV light is directed onto a photopolymerize resin solution. The layers are polymerized to a thickness of 0.05-0.15 mm, and the process repeats until each CT image slice is reproduced in the resin model. SLA models are utilized in medicine, notably in OMF surgery, for surgical guides, templates, training, designing soft tissue incisions, resection margins, assessing bone defects, adapting and pre-bending reconstructive plates, and fabricating custom prostheses. Numerous reports have shown the accuracy with which these printed items resemble human anatomy and their utility in perioperative management. (**Mehra et al; 2011**).

Laser Sintering

Laser sintering (LS) is a powder bed fusion process in additive manufacturing (AM) that is widely used in medical fields. It is based on layer-by-layer AM and includes a laser, an automatic powder layering equipment, a computer system for process control, and additional mechanisms such as gas protection and powder bed preheating systems. The procedure entails concentrating a high-powered energy laser onto a powdered substrate, inducing fusion into the desired shape. After one layer of substrate has been sintered, a second layer is added, and energy is injected once more. Different types of lasers are utilized, depending on the material's laser absorptivity and the metallurgical process of powder densification. (**Gu et al; 2012**).

The procedure consists of levelling and stabilizing the substrate, deposition of a thin layer of loose powder, and scanning the powder bed surface to create a layer based on CAD data. The technique is repeated layer by layer until a complete, extremely accurate, virtually full density functional part is created. LS technologies have transformed the workflow for a variety of surgical procedures, enabling the creation of a diverse range of objects such as surgical osteotomy guides, custom-made titanium orbital floors, grids, sub-periosteal dental implants, and cranial plates. (**Mangano et al; 2014**).

Extrusion Printing

Extrusion printing is a popular 3D printing technique for biological and non-biological materials, particularly polymers and thermoplastic composites. It entails loading and liquefaction of a printed material, which is forced through a nozzle or aperture using pneumatic pressure. The liquid material is then plotted along a predetermined course, with layer-by-layer bonding to create a coherent solid structure. The technology allows for multi-material deposition and can be used to several thermoplastics in the same product. Material extrusion additive manufacturing is grouped into three types: plunger-based, filament-based, and screw-based. Stratasys first patented the method, which was later commercialized as fused deposition modelling (FDM). FDM is popular in the medical profession because of its safe and simple construction method, low equipment costs, and wide range of filaments. Previously, FDM was employed for OMF reconstructive surgery, primarily to create surgical guidelines for difficult surgical procedures. However, it has lately been effectively utilized to print alloplastic materials such as polyetheretherketone (PEEK), which possesses high-temperature performance, chemical resistance, fatigue resistance, lightweightness, high yield strength, stiffness, and longevity. (**Honigmann et al; 2018 and Turner et al; 2014**).

Surgical stent fabrication

Surgical stent fabrication software makes possible the direct link between anatomic interpretation, surgical and prosthetic treatment planning, and precise surgical execution. Bone preparation is guided through computerized digital procedures, and patient-specific surgical guides are developed to obtain the optimum result of implant insertion in predetermined, prosthetically acceptable positions. Clinicians may face challenges when performing osseous biopsies on the lower jaw due to its individual anatomy and the presence of anatomical structures such as nerves and tooth roots. Computer-assisted methods may be helpful in avoiding damage to these structures. (**Manfredini et al; 2023**).

Navigation systems are used for surgical procedures in the head area, but they often require registration to locate the position of anatomical structures, such as the lower jaw. Markers are often used to track the position of these structures as the patient moves, such as the mandible's bone or teeth. A surgical template is a common auxiliary tool used for implant positioning in dentistry and does not require registration. In dental implantology, conventional methods are used to produce surgical guides, which usually include surface information from a plaster model and information about the location of the bony lesion. (**Postl et al; 2022**).

Computer-aided design (CAD) technology is used to combine these two data to plan a precise surgical guide. CAD provides a complex 3D body of the surgical guide, which can be realized using computer-aided manufacturing (CAM) technology. CAD/CAM technology has gained attention in recent years, and many systems allow computer-assisted implementation using data from CT scans. Although computer-assisted surgeries are gaining popularity for implant positioning, they are not yet established as standard procedures for osseous biopsies of the jaw. (**Gulati et al; 2015**).

Comparison of guided surgery with freehand surgery

Free-hand surgery involves using panoramic and periapical radiographs to assess the width and alveolar bone profile for implant placement, examining surrounding anatomy, and relying on CBCT imaging. Periodontal probes, gauges, or calipers are used to make sounds in the bone, providing a logical view of the height and thickness of the ridge. The surrounding teeth can also be used as a guide for determining the correct position of the implant. (**Choi et al; 2017**).

Implants placed too close to the root of an adjacent tooth can result from poor surgical technique, treatment planning, insufficient space, and incorrect angle, leading to bone displacement in the periodontal ligament (PDL) space, changes in blood supply to adjacent teeth, loss of tooth freshness, apical periodontitis, and internal or external resorption. Implants very close to nearby teeth are more likely to be lost due to infection or bone resorption. If the distance between the implant and the adjacent tooth is more than 1.5mm, any bone defect around the implant remains a vertical defect, which does not occur in adjacent natural teeth. (**Yogui et al; 2021**).

Free-hand surgery has many benefits for the dentist, such as visualization and relation of diagnostic data to the actual clinical condition, easy performance of additional treatments like bone grafts, PRF, and GBR, and the use of diagnostic wax for planning the surgical procedure. Guided implant surgery differs from free-hand surgery in that after completing CBCT imaging, a DICOM file is created, accompanied by a digital intraoral impression or precise putty light body impression to prepare the model. The DICOM file is passed to the implant scheduling software along with the patient data, which presents data in two dimensions and three dimensions. (**Todescan et al; 2021**).

Digital planning

A 3D radiograph (CBCT) is uploaded into SMOP planning software as a DICOM file, followed by superimposition using an intraoral surface scan or a surface scan of a cast model. Tooth crowns are used as landmarks for facilitated matching, resulting in alignment of the 3D image and intraoral scan. The software was originally designed for guided implant surgery but can now insert a cylinder equivalent to the inner dimension of a trephine bur virtually into the lesion in the desired position. The new tooth-supported drill guide STL file can be exported and sent to a 3D printer, allowing for design according to individual surgical situations and providing enough space for water cooling. A visual overview for the surgeon can be achieved using a skeletal design. (**Franchina et al; 2020**)

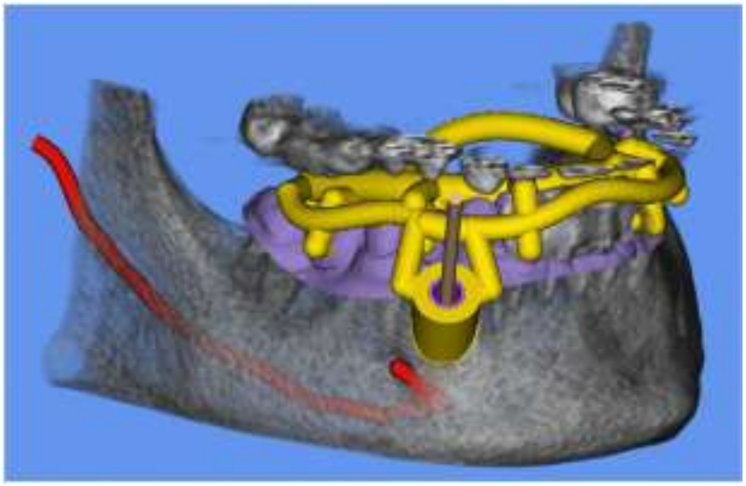

Figure (2): Planning software created for guided implant surgery (Martin et al; 2021)

Conclusion

Digitalization in medicine and dentistry opens new therapeutic possibilities while improving safety and predictability. The issue is to integrate these technologies into clinical practice while utilizing existing ways to solve new difficulties. Guided implantology has evolved into a dependable and accurate procedure, which benefits additional applications such as jawbone biopsies. Irregularities in the jawbone are frequently discovered incidentally on radiological scans, but a histological study is required for a definitive diagnosis. Lesion classifications are a contentious issue, with the 2017 World Health Organization Classification serving as the most appropriate guideline. Radiological recall, aesthetic surgical revision, medication-based systemic therapy, surgical exploration, or complete resection are all possible treatments. However, radiologically precise diagnoses are not always obtained, and some lesions are not biopsied following risk assessment. Today's 3D imaging technologies, including cone beam computed tomography (CBCT) and dental scans, can be integrated with current guided implantology to include safe and minimally invasive guided bone biopsies into clinical practice. However, anatomical factors may limit its utilization, and computer-assisted therapies may save operating time while improving patient outcomes.

Declarations

Consent for publication

Not applicable.

Availability of data and materials

Available

Competing interests

No competing interests.

Funding

No fund

Author contributions

Acknowledgements
We would like to acknowledge staff members of the ------ University.

References

Alhindi NA, Sindi AM, Binmadi NO, Elias WY. A retrospective study of oral and maxillofacial pathology lesions diagnosed at the Faculty of Dentistry, King Abdulaziz University. Clin Cosmet Investig Dent. 2019;11:45–52.

Avon SL, Klieb HB. Oral soft-tissue biopsy: an overview. J Can Dent Assoc 2022;78: c75

Charles Champeaux, Sebastien Froelich and Caudron Y. Titanium Three-Dimensional Printed Cranioplasty for Fronto-Nasal Bone Defect 2019;30(6):1802–1805.

Charles Champeaux, Sebastien Froelich and Caudron Y. Titanium Three-Dimensional Printed Cranioplasty for Fronto-Nasal Bone Defect 2019;30(6):1802–1805.

D'Haese J, Ackhurst J, Wismejier D, et al. Current state of the art of computer-guided implant surgery. Periodontology 2000. 2017;73(25):121–133.

Da Silveira EJ, Godoy GP, Lins RDA, et al. Correlation of clinical, histological and cytokeratin profiles of squamous cell carcinoma of the oral tongue with prognosis. Int J Surg Pathol 2017; 15: 376– 383.

Diamanti N, Duxbury AJ, Ariyaratnam S, Macfarlane TV. Attitudes to biopsy procedures in general dental practice. Br Dent J 2022; 192: 588– 592.

F. C. Yogui, F. R. Verri, J. M. de Luna Gomes, C. A. A. Lemos, R. S. Cruz, and E. P. Pellizzer, "Comparison between computer-guided and freehand dental implant placement surgery: a systematic review and meta-analysis," International Journal of Oral and Maxillofacial Surgery, vol. 50, no. 2, pp. 242–250, 2021.

F. F. Todescan, M. M. Hayashi, L. R. Giugni, M. A. Bottino, and J. P. M. Tribst, "From denture to the final implant-supported prosthesis using a full-digital protocol: a dental technique," Oral, vol. 1, no. 4, pp. 332–339, 2021.

Franchina A, Stefanelli LV, Maltese F, Mandelaris GA, Vantaggiato A, Pagliarulo M, Pranno N, Brauner E, Angelis F, Carlo SD. Validation of an Intra-Oral Scan Method Versus Cone Beam Computed Tomography Superimposition to Assess the Accuracy between Planned and Achieved Dental Implants: A Randomized In Vitro Study. Int J Environ Res Public Health. 2020 Dec 14;17(24):9358. doi: 10.3390/ijerph17249358. PMID: 33542168; PMCID: PMC7765074.

Ghantous Y, Nashef A, Mohanna A, Abu-El-Naaj I. Three-Dimensional Technology Applications in Maxillofacial Reconstructive Surgery: Current Surgical Implications. Nanomaterials (Basel). 2020 Dec 16;10(12):2523. doi: 10.3390/nano10122523. PMID: 33339115; PMCID: PMC7765477.

Ghoreishi S, Zargaran M, Baghaei F. Survey of pathology reports with no definitive diagnosis in oral lesions: the necessary skills for the clinicians. Heliyon 2020 Apr;6(4):e03848

Gu D.D., Meiners W., Wissenbach K., Poprawe R. Laser additive manufacturing of metallic components: Materials, processes and mechanisms. Int. Mater. Rev. 2012;57:133–164. doi: 10.1179/1743280411Y.0000000014.

Gulati M, Anand V, Salaria SK, Jain N, Gupta S. Computerized implant-dentistry: Advances toward automation. J Indian Soc Periodontol. 2015 Jan-Feb;19(1):5-10. doi: 10.4103/0972-124X.145781. PMID: 25810585; PMCID: PMC4365158.

Hassona Y, Al Boosh D, Al Saed A, Al Mousa M, Barghout N, Al Kayed A, Sawair F. The range of pathological diagnoses of oral diseases in Jordan: an 11-year-retrospective study. Saudi J Oral Sci. 2020;7(3):151

Honigmann P., Sharma N., Okolo B., Popp U., Msallem B., Thieringer F.M. Patient-specific surgical implants made of 3D printed PEEK: Material, technology, and scope of surgical application. Biomed. Res. Int. 2018;2018 doi: 10.1155/2018/4520636.

Ji YD, Peacock ZS, Resnick CM. Characteristics of national malpractice claims in oral and maxillofacial surgery. J Oral Maxillofac Surg 2020;78:1314–8

Lin HH, Lonic D, Lo LJ, et al. 3D printing in orthognathic surgery − a literature review. J Formos Med Assoc. 2018;117(7):547–558.

M. Tallarico, M. Martinolli, Y. Kim, F. Cocchi, S.M. Meloni, A. Alushi, E. Xhanari. Accuracy of computer-assisted template-based implant placement using two different surgical templates designed with or without metallic sleeves: a randomized controlled trial Dent J (Basel), 7 (2019)

Mahmoudi P, Razavi SM, Tahani B. Orofacial pathological lesions in children and adolescents: a 25-year survey in Iran. J Dent. 2018;19(4):265–272.

Manfredini, M.; Poli, P.P.; Maiorana, C.; Salina, F.E.; Tandurella, M.; Beretta, M. Computer Aided Full Arch Restoration by Means of One-Piece Implants and Stackable Guide: A Technical Note. Dent. J. 2023, 11, 256. https://doi.org/10.3390/dj11110256

Mangano F.G., De Franco M., Caprioglio A., MacChi A., Piattelli A., Mangano C. Immediate, non-submerged, root-analogue direct laser metal sintering (DLMS) implants: A 1-year prospective study on 15 patients. Lasers Med. Sci. 2014;29:1321–1328. doi: 10.1007/s10103-013-1299-0.

Martin Lotz, Caterina Schumacher, Bernd Stadlinger, Kristian Ikenberg, Martin Rücker, Silvio Valdec, Accuracy of guided biopsy of the jawbone in a clinical setting: A retrospective analysis, Journal of Cranio-Maxillofacial Surgery, Volume 49, Issue 7, 2021, Pages 556-561, ISSN 1010-5182, https://doi.org/10.1016/j.jcms.2021.02.025.

Martin Lotz, Caterina Schumacher, Bernd Stadlinger, Kristian Ikenberg, Martin Rücker, Silvio Valdec, Accuracy of guided biopsy of the jawbone in a clinical setting: A retrospective analysis, Journal of Cranio-Maxillofacial Surgery, Volume 49, Issue 7, 2021, Pages 556-561, ISSN 1010-5182, https://doi.org/10.1016/j.jcms.2021.02.025.

Meglioli, M., Naveau, A., Macaluso, G.M. et al. 3D printed bone models in oral and cranio-maxillofacial surgery: a systematic review. 3D Print Med 6, 30 (2020). https://doi.org/10.1186/s41205-020-00082-5

Mehra P., Miner J., D'Innocenzo R., Nadershah M. Use of 3-D Stereolithographic Models in Oral and Maxillofacial Surgery. J. Maxillofac. Oral Surg. 2011;10:6–13. doi: 10.1007/s12663-011-0183-3.

Mehrotra R, Hullmann M, Smeets R, Reichert TE, Driemel O. Oral cytology revisited. J Oral Pathol Med 2019; 38: 161– 166.

Melrose RJ, Handlers JP, Kerpel S, Summerlin DJ, Tomich CJ. The use of biopsy in dental practice. The position of the American Academy of Oral and Maxillofacial Pathology. Gen Dent. 2017;55(5):457-61

Melrose RJ, Handlers JP, Kerpel S, Summerlin D-J, Tomich CJ. The use of biopsy in dental practice: the position of the American Academy of Oral and Maxillofacial Pathology. Gen Dent 2017; 55: 457– 461.

Park JY, Gao G, Jang J, Cho D. 3D printed structures for delivery of biomolecules and cells: tissue repair and regeneration. J Mater Chem B. 2016.

Pellegrino, G., Mangano, C., Mangano, R., Ferri, A., Taraschi, V., Marchetti, C. Augmented reality for dental implantology: a pilot clinical report of two cases. BMC oral health; 2020: 19, 158.

Poh CF, Ng S, Berean KW, Williams PM, Rosin MP, Zhang L. Biopsy and histopathologic diagnosis of oral premalignant and malignant lesions. J Can Dent Assoc 2018 Apr;74(3):283–8.

Poh CF, Ng S, Berean KW, Williams PM, Rosin MP, Zhang L. Biopsy and histopathologic diagnosis of oral premalignant and malignant lesions. J Can Dent Assoc 2018; 74: 283– 288.

Postl, L., Mücke, T., Hunger, S. et al. Biopsies of osseous jaw lesions using 3D-printed surgical guides: a clinical study. Eur J Med Res 27, 104 (2022). https://doi.org/10.1186/s40001-022-00726-8

S. Anand Kumar, R.V.S. Prasad, Chapter 2 - Basic principles of additive manufacturing: different additive manufacturing technologies, Editor(s): M. Manjaiah, K. Raghavendra, N. Balashanmugam, J. Paulo Davim, In Woodhead Publishing Reviews: Mechanical Engineering Series, Additive Manufacturing, Woodhead Publishing, 2021, Pages 17-35, ISBN 9780128220566, https://doi.org/10.1016/B978-0-12-822056-6.00012-6.

Sardella A, Demarosi F, Lodi G, Canegallo L, Rimondini L, Carrassi A. Accuracy of referrals to a specialist oral medicine unit by general medical and dental practitioners and the educational implications. J Dent Educ. 2017;71(4):487-91.

Seone J, Varela-Centelles PI, Ramirez JR, Cameselle-Teijeiro J, Romero MA. Artefacts in oral incisional biopsies in general dental practice: a pathology audit. Oral Dis 2019; 10: 113– 117.

Steven Gernandt, Olivia Tomasella, Paolo Scolozzi, Mathilde Fenelon, Contribution of 3D printing for the surgical management of jaws cysts and benign tumors: A systematic review of the literature, Journal of Stomatology, Oral and Maxillofacial Surgery, Volume 124, Issue 4, 2023, 101433, ISSN 2468-7855, https://doi.org/10.1016/j.jormas.2023.101433.

Turner B.N., Strong R., Gold S.A. A review of melt extrusion additive manufacturing processes: I. Process design and modeling. Rapid Prototyp. J. 2014;20:192–204. doi: 10.1108/RPJ-01-2013-0012.

W. Choi, B. C Nguyen, A Doan, S Girod, B Gaudilliere, and D Gaudilliere, "Freehand versus guided surgery: factors influencing accuracy of dental implant placement," Implant Dentistry, vol. 26, no. 4, pp. 500–509, 2017.