

## Robotic Surgery

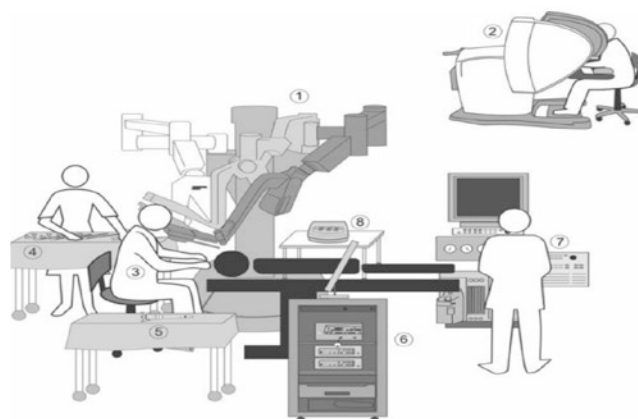
Robot-assisted surgery has attracted the attention of surgeons in different specialties during the past two decades. Although there is minimal evidence of its clinical success in oral and maxillofacial surgery, its increasing popularity in head and neck operations is undeniable [1]. It can be labeled as telesurgery, as this procedure can be performed without the surgeon's in-person presence.

The first clinical application of robots in head and neck surgery was introduced in 1999, while previous preclinical tests were conducted in 1994 by Kavanagh [2, 3]. Since 1999, many animals, cadaver, phantom, and clinical studies were conducted in various minor and major oral and maxillofacial surgeries (OMFS) [4].

Critical vital organs in the head and neck area with high neural and vascularized areas complicate the optimal accessibility to the surgical field [5]. Due to the need for a wide dissection area to approach the surgical site with routine transpharyngeal or transcervical approaches, minimally invasive techniques become highly important in OMFS surgeries [4, 6].

Transoral robotic surgery (TORS), which was first introduced and performed by McLeod et al. in 2005, provides suitable and deeper access to the surgical area in minor surgeries and overcome some of the limitations of conventional techniques [7, 8] (Fig. 52.1).

Many robotic systems have been introduced in recent years; one of the most effective robotic technologies is the Da Vinci surgical system. Its manipulators have the most similarity to the human wrist movements and provide a



**Fig. 52.1** Surgical setting. 1, Da Vinci robot; 2, first surgeon at the console; 3, second surgeon at the patient's head; 4, nurse at the instruments table; 5, second table for Da Vinci robot devices; 6, rack for imaging equipment; 7, anesthetist; 8, monopolar/bipolar cautery. (Reproduced with permission from Lawson et al. [8])

three-dimensional view of the surgical site [1, 9]. Based on a systematic review and meta-analysis, robotic surgery's most clinical application was transoral tumor resection, reconstructive surgeries, neck dissection, and flap harvesting consequently [1]. Still, it shows clinical success in flap harvesting, nerve transferring, reconstructive and cosmetic surgeries, thyroidectomy, and parathyroidectomy [7].

Reducing the operation time, enhancing visualization and precision, and eliminating some of the patients' post-surgical morbidity are among the most significant benefits of robotic surgery compared to conventional techniques, which need more well-designed controlled-trial studies to approve it [10, 11].

There is a lack of evidence regarding the usage of robot-assisted surgery in orthognathic operations, cosmetic surgeries, extensive trauma and fractures, and sleep apnea syndrome; future well-designed pre-clinical and clinical studies are required.

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## Head and Neck Cancer

Treating oral cancer is a long-term procedure requiring a combination of treatment modalities such as surgical excision, radiotherapy, and chemotherapy [12]. The oral side effects of these procedures may result in lifelong oral rehabilitation, which is challenging for both patients and physicians [12, 13].

Although the main goal of treating oral squamous cell carcinoma (OSCC) as a fatal cancer is the patients' survival, in recent years, surgeons emphasize minimally invasive procedures to reduce post-operative morbidities, maintain oral functions, and improve patients' quality of life (QOL).

One of TORS's principal aims in treating head and neck cancerous lesions is reducing the operation and in-patient time, eliminating invasive approaches, and reducing the side effects [13]. Maintaining speech and swallowing functions, which are usually compromised due to conventional surgical procedures, are crucial for preserving the patients' quality of life after tumor excision. This would be possible with robotic surgery [14, 15].

Moore et al. were pioneers of performing TORS in treating oral cancer in 45 patients with oropharyngeal squamous cell carcinoma followed by neck dissection [15]. In this study, similar to various clinical studies, the oropharyngeal functions were recovered rapidly, visualization and manipulation of the area were enhanced, in-patient time reduced, and transoral laser surgery limitations were resolved [11, 15, 16]. It reduces probable human errors in the head and neck's dense and crucial anatomical structures by tremor filtering and motion scaling technology [4].

Based on a comprehensive cohort study, robotic surgery in early-stage SCC (T1, T2) had superior clinical outcomes such as less positive margins, fewer complications, and long-term survival rates than non-robotic surgery [17]. TORS also resulted in successful oncological and postoperative outcomes in residual or recurrent SCC and can be considered as an alternative for conventional techniques in these patients [17].

Based on recent studies, it has been proposed that TORS can reduce postoperative complications of pharyngeal cancer and can be an alternative to adjuvant therapies such as chemoradiotherapy in some cases. According to a review of the evidence, it has satisfactory glottic and supraglottic pharyngeal cancer, but the clinical findings are controversial in several studies [16]. Although TORS's speed and effectiveness in supraglottic cancer treatment have priorities compared to the conventional techniques, it has its limitations. TORS require more working space in the surgical field. Airways compromises its optimal accessibility from the anatomical aspect; this fact resulted in less precision during the operation and remaining more positive margins after surgery in the robot-assisted surgery group in a pilot study [18, 19].

Therefore, in some patients with special conditions (e.g., trismus, inadequate transoral exposure for optimal manipulation, and vocal cord mobility impairment), TORS is completely contraindicated [18].

Postoperative hemorrhage and aspiration pneumonia are among the most commonly reported disadvantages of TORS in head and neck cancer surgery [13]. Future novel technologies of robots may resolve the limitations of the Da Vinci system. The novel systems should overcome some previous challenges such as providing proper hemostasis, precisely cutting the margins and providing less positive margins, and delivering optimal energy to the target area [20].

All in all, TORS's equal oncological success compared to conventional techniques in cancer patients has been reported in many clinical studies because TORS results in improving QOL with fewer complications [18, 20].

## Cleft Lip and Palate

According to the growing popularity of robot-assisted surgeries in the head and neck area, transoral robotic cleft surgery (TORCS) was performed in cadaver studies in the recent decade for approving further clinical applications [21–23]; based on these pilot studies, it is concluded that this technique provides excellent 3D visualization, convenient manipulation, and precise dissection. Subsequent clinical studies confirmed the clinical success of cleft lip and palate surgery with TORCS [23]. Nevertheless, the Da Vinci robotic system manipulators' size and the smaller size of the pediatric airway anatomy in the surgical field are important limitations of this surgical technique [24]. Besides, the duration of robot-assisted cleft surgery was longer compared to conventional surgery [23].

Novel surgical robot technologies with a more delicate design should be performed for enhancing their application in pediatric surgeries. Further comprehensive clinical studies should be conducted to certify the safety and efficacy of TORCS.

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## The Perspective of Minimally Invasive Surgery (MIS)

Minimally invasive surgery (MIS) can be referred to as endoscopic surgery, minimally invasive surgical arthroscopy, video-assisted surgery, telescopic surgery, and minimal-access surgery. Treatments that may involve an endoscope include laser therapy, which can be used for destroying cancer cells. Photodynamic therapy can destroy tumors by using a laser after injecting it with a light-sensitive substance. Endoscope can use in orthognathic surgery, sialoendoscopy,

and temporomandibular joint (TMJ) disorders in oral and maxillofacial surgery [25].

As we mentioned before, speech and swallowing functions usually compromise due to conventional surgery. New approaches like minimally invasive techniques can stop or reduce these results.

Endoscopy has been used for decades as a supportive technique for directing minimally invasive oral surgical procedures and, in recent years, has been used increasingly in endoscopically assisted operative techniques. In the future, we can use these methods in the field of dentistry because we can achieve the best results with a minimal postoperative problems. Three-dimensional planning and navigated surgery will also play a significant role in the future. Navigation allows surgeons to maneuver through the surgical field certainty and to put instruments and implants onto the ideal area with exactness and accuracy [26].

### Minimally Invasive Intraoral Approach (MIIA)

We can perform MIIA for treatment of abscess and neck phlegmon with odontogenic origin when the infections spread up to the inferior mandibular margin and no further, so it is better to evaluate the anatomical localization of abscess with CT or MRI, and then we can use the best surgical approach.

The results of one study in 2020 show the achievement of MIIA in comparison with conventional treatments.

Some of the advantages of this procedure are as follows: (1) excellent healing rates, (2) avoidance of injury to nerves and vessels in sensitive conditions, (3) patients not suffering from relapses during follow-up, (4) obtaining a shorter postoperative recovery, and (5) reduction in the length of hospitalization [27].

### Dental Implant and Endoscopic Approaches

Complications of dental implantation in the posterior maxilla still occur, including acute and chronic sinusitis, orofacial fistula (OAF), and implant dislocation and migration into the paranasal sinuses [28].

With the broad indications for dental implantation, complication rates have increased. Dental implant displacement into the maxillary sinus can occur during the restoration of posterior maxillary teeth, but it is rare.

Displacement of a dental implant to the maxillary sinus can happen preoperatively or postoperatively.

Some of the reasons for preoperative operations are as follows: placement of implants in sites with inadequate bone height and volume, surgical inexperience, improper surgical procedures such as over-preparation of the recipient site,

application of a heavy force during implant insertion, or sinus membrane perforation during the drilling procedure. Focal osteoporotic bone marrow defect (FOBMD) is commonly located in the mandibular edentulous posterior area of a middle-aged female. It is one reason for implant displacement in the mandible.

We can use endoscopic sinus surgery to remove the implant and restore sinus patency. If the implant is displaced to deeper areas (commonly anterior and inferior) of the maxillary sinus, a pre-lacrimal recess approach can provide a panoramic view of the maxillary sinus and is a good alternative Caldwell-Luc operation in terms of mucosal preservation and postoperative complications.

One of the reasons for the migration of dental implant is inadequate bone height. For patients with displacement dental implants, we suggest to remove the foreign body [29].

Endoscopic sinus surgery (ESS) can provide removal of foreign body, treatment of rhinosinusitis, and establishment of a patent maxillary ostium [27].

Endoscopic sinus surgery (ESS) has also been proposed as the preferred procedure for the removal of dislodged dental implants [28].

ESS is an effective and minimally invasive method to remove displaced dental implants and restore sinus health. Computed tomography can be used to localize a foreign body, but it may migrate before the operation. The PLR (pre-lacrimal recess) offers a direct and panoramic view of the maxillary sinus and can assist with the removal of difficult-to-reach foreign bodies. Multi-disciplinary cooperation between otolaryngologists and oral surgeons can improve treatment results [29, 30].

### Implant Surgery Using CAD/CAM (Guided Surgery or Static Navigation)

Implant surgery using CAD/CAM surgical templates has become widely used, and now, a new technology, dynamic navigation, is gaining popularity. Conventional free-handed implant placement has evolved into a guided approach, which has led the way into a navigated technique.

Computer-assisted dynamic navigation has been commonly employed in neurosurgery, orthopedics, and ear, nose, and throat surgery for many years. It has recently been implemented for dental implant surgery [33–35].

Dynamic navigation, in its present form, utilizes real-time, motion-tracking, optical technology to track the implant drill and patient during the preparation of the osteotomy and implant placement to match a virtually planned implant position. Two types of motion tracking are available: active tracking system and passive tracking system arrays, which use reflective spheres to reflect infrared light emitted from a light source back to a camera.

Advantage of dynamic navigation method: Implant placement accuracy is predictable with accuracy approximating 0.4 mm with angular deviation approximating 4°. But the rates of failure in dynamic navigation are similar to that in traditional methods [31, 32].

### Surgical Navigation for Oral and Maxillofacial Surgery

Navigation allows surgeons to maneuver through the surgical field with confidence and to place instruments and implants on to the desired location with accuracy and precision. The applications of navigation technology in oral and maxillofacial surgery continue to increase. Surgical navigation allows enhancement of both surgical precision and accuracy owing to real-time confirmation of position, without the need to obtain additional intraoperative images which can expose patients to additional radiation, navigation technology may also facilitate surgery when dealing with soft tissue lesions where access is limited by allowing for minimally invasive access compared with traditional open approaches, which may require extensive dissection for exposure. Indications for surgical navigation in OMFS have been described as complex unilateral orbital wall fractures comminuted unilateral fractures of the lateral midface, bony tumors, bony reconstruction of complex 3-dimensional anatomy, and for removal of foreign bodies [36].

### Temporomandibular Joint Arthroscopy

TMJ disorder is a multifactorial disease process caused by muscle hyperfunction or parafunction, traumatic injuries, hormonal influences, and articular changes. Physicians have used various types of splints since the eighteenth century for the treatment of TMJ disorders. Today, the use of splints has become one of the most common in-office initial treatments for TMD-associated pain [37].

Treatment of TMJ disorder can be divided into three procedures: noninvasive, minimally invasive, and invasive options. The future of TMJ-MIS may be through regenerative medicine approaches such as tissue engineering [38]. TMJ disorders encompass all age groups; it is generally considered to affect young- to middle-aged adults (20–40 years old) [37].

During the twentieth century, arthroscopic surgery was regarded as one of the three most significant improvements in the treatment of patients with conditions affecting the musculoskeletal system.

In addition to joint replacement and internal fixation of fractures, TMJ arthroscopy could be an effective and minimally invasive form of surgical intervention for treating

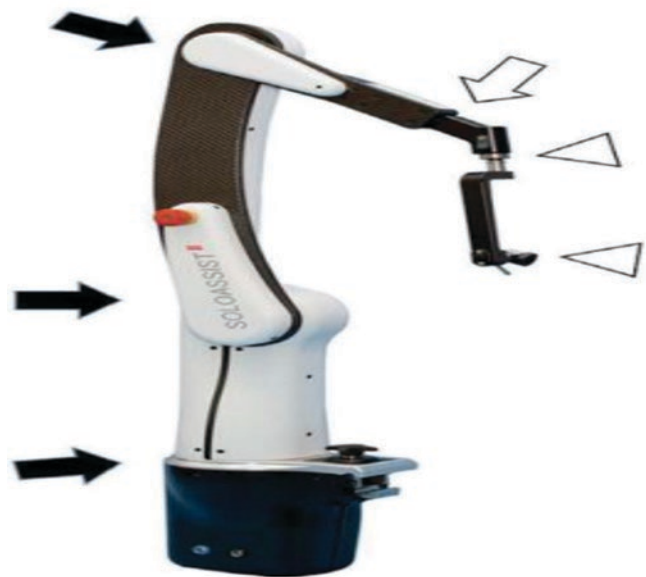
Wilkes II, III, and IV TMJ disorders in the pediatric population. It is an approach that has been used for more than 40 years to ameliorate pain and restore function. It might play a role in the early identification and treatment of disorders of the TMJ articular disc and synovium. These days, we have the plasma sprayer system for arthroscopy. Plasma is composed of highly ionized particles. These ionized particles can reduce tissue volume by separating molecules from each other. It only causes little damage to surrounding healthy tissues, not the whole tissues. And because of its benefit, it could be key for the next step required in arthroscopy – resection [39].

### Laparoscopic Surgery

The history of general laparoscopic surgery dates back to the introduction of appendectomy by Semm in 1980 [40].

In recent years, the da Vinci® system's robotic surgery has attracted attention and a limited number of institutions have reported various results.

The Soloassist® system is a joystick-guided robotic scope holder. Scope holders can reduce the number of participants in surgery and provide a stable surgical field without tremors. Initially, scope holders were only invented to fix the scope [41, 42] (Fig. 52.2).



**Fig. 52.2** Soloassist II has six joints: three are computer-controlled (black arrows), one can be adjusted manually (white arrow), and two act as a gimbal joint following the movement of the main body (white arrowheads). With minimally invasive procedures, surgeons work with both hands. As a consequence, the Soloassist is controlled by a joystick positioned on the instrument. (This figure is reproduced with permission from Ohmura et al. [42])

Shortly, the development of active scope holders might play an important role in laparoscopic surgery.

Advantages: Full functionality for general surgery, urology, and gynecology. No manual camera guidance is required. A stable and steady image enhances the quality of surgery. The assistant surgeon is now free to do more demanding tasks; it can reduce the trauma to the pitons. The Soloassist is compatible with all commercially available operating tables and endoscopes, thus protecting your investments. Setup and disassembly of the system can be performed in conjunction with your usual preparation procedures and do not add to operating time. The camera-holding system shows a very high velocity for head and neck surgery. This advantages shows that Solloassist has potential to use for surgery in the mandible fracture [43].

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### Paranasal Sinuses and Skull Base Robot Prototype

Endoscopic approaches to the nose, paranasal sinuses, and anterior skull base continue to expand with modern innovations and improved surgical strategies.

A new dedicated PSSB robot system is in development by a team of engineers and physicians at Vanderbilt University. This robotic system seeks to address the limitations in current instrumentation by utilizing a new concentric tube technology [44, 45].

The small footprint of the PSSB robot will facilitate less crowding at the surgical field, allowing both the scrub nurse/tech and assistants to more easily maneuver near the patient.

Robotic surgical systems for paranasal sinus and skull base surgery are achievable soon [46].

### Navigation for Oral and Maxillofacial Surgery

Navigation methods are classified into two types. In the first type, a stereo vision system is employed to conduct a 3D registration. This method is usually suitable for a subject with a clear texture like sinus, but failures can easily occur. In the second type, an endoscope is employed to conduct a 3D registration.

In innovative robotic surgery, surgeons do not create a direct impact on surgical results. But it can help reduce errors that occurs due to the fatigue of a surgeon. In this new technique, the patient lies down on the surgical bed and an oral and maxillofacial surgeon placed close to the patient's head. It can help focus on the teeth or other regions on which the surgeon wants to perform a surgery. With this new technique, surgeons would not be tired during osteotomy as they do not hold the device for a long time to drill or cut in the target bone area. In this new technique, the surgeon starts the operation

and allows the navigation system to guide the robot precisely to complete the operation. Two screens display the VR image and output data in real time. An autonomous OMS robot that can detect a skull's pose and automatically finish an operation under the surveillance of a surgeon was proposed.

But the navigation systems' costs are very high, and the time for preparation for the surgery is longer compared to the conventional technique. The navigation procedure gives more security, particularly in complex cases, and 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 [47].

### Yomi (New Robot in Maxillofacial Surgery)

Yomi is the first and the only FDA-cleared robot-assisted dental surgery system since 2018; the first country to use this system is China. Surgical robotic technology helps dentists to successfully place dental implants. Yomi provides computerized navigation to aid in arranging pre-operative and intra-operative phases of dental implantation surgery. The system offers physical guidance through haptic robotic innovation, which constrains the drill in position, depth, and direction to reduce errors from human sources. The assistive innovation gives the specialist full oversight, which allows for clear visualization of the surgical site. Yomi is intended to empower a minimally invasive flapless methodology, which has been demonstrated to prompt quicker medical procedures, faster recovery, and less pain for the patient. It manages a specialist's hand to the exact point and area for an arranged osteotomy [48].

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### Conclusion

The purpose of this chapter is to determine some new technologies that may become valuable in maxillofacial surgery or other kinds of treatments in dentistry in the future.

Medical robots are one of the greatest scientific achievements of modern surgery. They can be used in different types of surgery like paranasal sinus surgery or implant surgery. It can also help surgeons become safe from infections like Covid-19, one of the most important diseases these days.

The development of robotic technology is also necessary for the future development of maxillofacial surgery, but it is necessary to consider the most desirable cost-benefit for patients struggling with diseases under limited medical expenses. Naturally, as a surgeon, robotic surgery is very interesting. There is a desire to perform it as a surgeon, but making it universally applicable to various diseases would require immense financial resources, manpower, and a new educational system.

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