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Robotic surgery in oral and maxillofacial, craniofacial and head and neck surgery: A systematic review of the literature

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Abstract. A systematic review of the literature concerning robotic surgery in oral and maxillofacial (OMF), craniofacial and head and neck surgery was performed. The objective was to give a clear overview of the different anatomical areas of research in the field of OMF, craniofacial and head and neck surgery, in all its fields (pre-clinical and clinical). The present indications are outlined and the critical reader is invited to assess the value of this new technology by highlighting different relevant parameters. A PubMed and Cochrane library search yielded 838 papers published between 1994 and 2011. After screening the abstracts, 202 articles were considered clinically or technically relevant and were included. These full papers were screened in detail and classified as articles on synopsis ($n = 41$), educational aspects ($n = 3$), technical/practical aspects ($n = 11$) and clinical papers ($n = 147$). Regarding clinical feasibility this systematic review revealed the following main indications: transoral robotic surgery (TORS) for upper digestive and respiratory tract lesions; TORS for skull base surgery; and TORS for trans-axillary thyroid and endocrine surgery. Regarding functional outcome, this systematic review revealed a promising reduction of morbidity in patients with cancer of the upper digastric and respiratory tract.

Key words: robotic surgery; robotics; robot; oral and maxillofacial; head and neck; craniofacial; systematic review.

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In 1921, the Czech science fiction author Karel Čapek used the word '*robot*' in his stage play *R.U.R.* (*Rossum's Universal Robots*). The etymological origins of the word 'robot' can be found in the Czech '*robota*' meaning 'compulsory labour' derived from the Old Church Slavonic '*rabota*' or 'servitude'.[1] Current robotic technology has its origin in the 1980s when researchers at the National Aeronautics and Space Administration (NASA) conceived the idea of a surgeon-controlled robotic handpiece as an extension of NASA-developed virtual reality. The US Department of Defense became interested and envisioned

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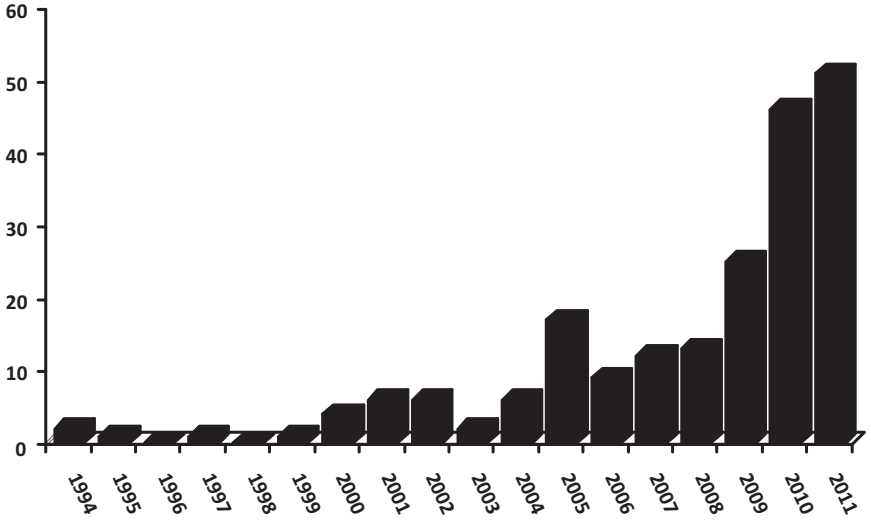

Fig. 1. Distribution of published articles in this SR on robotic surgery in oral and maxillofacial, craniofacial and head and neck surgery.

a marriage between telecommunication and robotic technology that would allow a surgeon to operate on a wounded soldier from a remote location. That initial vision has been realized, but not on the battlefield.[2]

Experience with minimal invasive laparoscopic procedures helped surgeons to understand the limitations of rigid equipment and two-dimensional (2D) views. This resulted in the development of semi-rigid robotic equipment with three-dimensional (3D) views for the operative setting. Combining these tools with telenavigation surgery led to the development of the Automated Endoscopic System for Optimal Positioning (AESOP), a robotic arm (controlled by a surgeon's voice command) that manipulated an endoscopic camera. Shortly thereafter, Intuitive Systems (Sunnyvale, CA, USA) released the SRI Telepresence Surgery System that was recently updated to the current da Vinci Surgical System (dVSS) (Intuitive Surgery, Inc., Sunnyvale, CA, USA), the most common robotic system in clinical use today.[3]

Since the introduction of robotic surgery in the medical field in 1985, when a robotic stereotactic brain biopsy was performed, it has become a state-of the art technique in many surgical disciplines such as orthopaedics, urology, radiosurgery, interventional radiotherapy, endoscopic abdominal surgery, cardiac surgery and neurosurgery.[4] The first preclinical tests with robots in the oral and maxillofacial (OMF)/head and neck field were performed by Kavanagh with the use of a Robodoc system in 1994.[5] The first recorded medical application of a robot occurred in 1985 where the robot was a simple positioning device to orient a needle for brain biopsy.[6] The first clinically approved robotic system in OMF surgery was 'Otto', in September 1999.[7]

The number of publications related to robotic surgery in OMF, craniofacial and head and neck surgery has increased exponentially, especially over the last 3 years (Fig. 1). Although 41 synopsis articles were found in the literature, only one systematic review (SR) has been published, but it was limited to the field of otolaryngology-head and neck surgery.[8]

Materials and methods

The objective of this study was to provide an overview of the different anatomical areas of research on robotic surgery in the field of OMF, craniofacial and head and neck surgery, in all its fields (pre-clinical and clinical). An attempt was made to outline the present indications and to assess critically the value of this new technology by highlighting different relevant parameters (accuracy, feasibility, functional outcome, safety and learning curve).

An SR of the literature concerning robotic surgery in OMF, craniofacial and head and neck surgery was performed in the bibliographic databases PubMed (National Library of Medicine, NCBI) and Cochrane Library was performed and updated on 9 August 2011. 3 primary keywords related to robotic surgery were used in combination with 37 secondary keywords to restrict the search to robotic surgery in OMF, craniofacial and head and neck surgery (Table 1). All possible combinations between one primary keyword and each secondary keyword were explored (Table 2).

The initial search yielded 838 references after removal of the duplicates (Table 3 and Fig. 2). The abstracts of all these references were analysed thoroughly and a subsequent categorization produced the following clusters (Table 3): 618 references had no relevant relationship to robotic surgery in OMF, craniofacial and head and neck surgery; 3 papers were excluded because they were in a language other than English, French or German; and

Table 1. Primary and secondary keywords used for the SR (PubMed, National Library of Medicine, NCBI, 9 August 2011).

Primary keywords ($n = 3$)	Secondary keywords ($n = 37$)
Robotic surgery, Robotics, Robot	Maxillo-facial, Head and Neck, Oral, Transoral, Mandible, Mandibular, Transmandibular, Maxilla, Maxillary, Pharynx, Pharyngeal, Oropharynx, Oropharyngeal, Nasopharynx, Nasopharyngeal, Hypopharynx, Hypopharyngeal, Larynx, Laryngeal, Sinus, Sinusal, Nose, Nasal, Transnasal, Tongue, Supraglottic, Face, Facial, Transfacial, Cranium, Cranial, Transcranial, Tonsil, Tonsillar, Transsphenoidal, Thyroid, Skull