# Application of Robots in Orthodontics: A Systematic Review

**Running title:** Application of robots in orthodontics

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**ABSTRACT**

Following the developments in industrial robot technology, robotics has found its way into the dental field, opening a new frontier with vast areas for expansion and exploration, more specifically in the field of orthodontics. The use of robots in orthodontic specialty can increase the precision, quality, and safety of various procedures and also reduce the treatment time. The aim of the study was to provide a current review of the applications of robots in orthodontics. Three database searches (PubMed, Scopus, and Web of Science) were conducted through January 2021 related to robots and orthodontics. A total of 188 articles were identified through an online database and an additional 5 hand-searched articles were added. In this study, only 10 articles were found to fit our inclusion criteria. Out of the 10 articles, two articles were on archwire bending robots. Three studies were on customized orthodontic appliances made by a robot. Further four articles were on the usefulness of robots in orthognathic surgery and one study was on the usefulness of patient robot in orthodontic bonding practice. Based on the systematic review of literature it can be concluded that the application of robots in orthodontics can provide improved accuracy, predictability, safety, quality of care with remarkably less treatment time compared to traditional methods. However, due to the heterogeneity of the studies, the generalization of the results may be difficult. Further, high-quality research is needed to prove the usefulness of robots in orthodontic practice.

**KEYWORDS**

Robotics, orthodontics, artificial intelligence, robotic surgical procedure, technology

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## INTRODUCTION

With the emergence of new technologies, the future of orthodontics is unpredictable. However, the main concern lies in the vision and feasibility of adopting these technologies in day-to-day orthodontic practice. Robotics has found its way into the dental field, opening a new frontier with vast areas for expansion and exploration, more specifically in the field of orthodontics. Robots are generally defined as machines that can be programmed to perform a specified set of simple or complex tasks, with or without human assistance.[1] Robots can carry out complex series of action with high speed and focus on precision and accuracy. Robots can also perform tasks that require the application of strength without becoming fatigued. However, high price, large space required to operate, need for frequent maintenance, and need for properly training the operators

presents a crucial disadvantage.[2-4] Despite these disadvantages, the positive impact of robotic systems can be observed in orthodontic specialty. Hence the aim of the study was to provide a current review of the applications of robots in orthodontics.

## METHODOLOGY

### Search strategy

The review was performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines.[5] A comprehensive review of the literature was conducted for peer-reviewed studies related to robotics in orthodontics published until January 2021. We searched the PubMed, Scopus, and Web of Science databases.

### Eligibility Criteria and Study Selection

All titles and abstracts of articles identified were first assessed against the inclusion criteria:

1. Examined the relevance of robotic use in orthodontics
2. Articles written in English
3. Original research
4. Randomized trials
5. Observational studies (case-control, cohort, and cross-sectional studies), including case series or reports.

A 3-stage screening strategy (title, abstract, and full-text study) for identified studies was performed independently and in duplicate by 2 authors (R.V.J and A.S.U). All titles and abstracts were reviewed by both reviewers who selected relevant articles based on the data collected from identified abstracts, which indicated that the inclusion criteria would be met. Disagreement about a study's eligibility was sorted by a third author (R.B) who served as a neutral arbiter. In the next stage, relevant full-text articles were obtained and evaluated independently for the eligibility criteria. Discrepancies between the 2 reviewers were sorted out by discussion and consensus. Studies in languages other than English that provided inadequate information or with no abstract available were excluded. review articles, editorial articles, letters to the editor, short communication, conference abstracts, animal-based studies; non-English articles; any studies deemed irrelevant to current orthodontics or robots were also excluded from the study.

### Data extraction

The first author (R.V.J) collected the relevant data from the included full-text articles into an evidence table (Table 1). The extracted data included the following: author and year of publication; country; robot/invention used and conclusion were considered. The second author (A.S.U) checked and verified the collected data independently. Discrepancies between the 2 reviewers were settled by discussion.

## RESULTS

A total of 188 articles were identified

through an online database and an additional 5 hand-searched articles were added. In this study, only 10 articles were found to fit our inclusion criteria. (Figure 1)

The overview of reviewed articles is summarized in table 1. Robotic studies included in the present review were carried out in 8 different countries, with 2 studies each from South Korea and the U.S, and 1 study each from the Netherlands, Germany, Mexico, England, Switzerland, and Japan. All the reviewed studies (n=10) were published from 2003 to 2021, and 6 of these studies were published in the past 5 years (since 2016).

There were significant variations in the use of robots in the reviewed studies. Out of the 10 articles, two articles were on archwire bending robots. Three studies were on customized orthodontic appliances made by a robot. Further four articles were on the usefulness of robots in orthognathic surgery and one study was on the usefulness of patient robots in orthodontic bonding practice.

**DISCUSSION**

The current review sought to assess the various application of robotics in the field of orthodontic specialty. Ten studies were found that met the criteria for inclusion in this review, and were dominated by uncontrolled descriptive studies, thus providing poor evidence. Randomized controlled trials are regarded as the most reliable method of evaluating the effectiveness of an intervention in health care.[6] However, conducting randomized controlled trials to evaluate the application and effectiveness of robots is often challenging, expensive, and not always practical, depending on local variations in administration and organization.

The results of the present study showed the use of a robotic arm to enhance orthognathic surgery. The study also found that robots provide proper improved accuracy in the repositioning of the maxilla and mandible providing accurate model surgery when compared to manual model surgery as reported by previous studies.[7,8] Robotic surgeries provide accurate results, dexterity, stability and fewer chances of infection, and less clinician exposure to contaminated blood and saliva.[9] Robot arm with image-guided navigation is helpful in identifying and removing bony interferences. Advanced technology such as CARLO® device could be a useful alternative to conventional burs, drills, and piezosurgery instruments for performing osteotomies.[10]

The results of the present study showed the use of archwire bending machines to form and bend the archwires to the desired shape as required for orthodontic fixed appliances. Virtual setups can be implemented in a clinically successful fashion with custom archwires fabricated by CAD/CAM.[11] Robots were helpful in lingual orthodontic as well, by forming lingual

archwires and brackets.[12] By using robots there will be no infection from models, patient chair time will reduce and a large number of patients can be seen in a short time. The mentioned studies proved that with the help of archwire bending apparatus the reproducibility, efficiency, and quality of the orthodontic treatment was improved when compared to conventional archwire manufacturing.

The study also found that customized orthodontic appliances formed by robots were more effective in treatment than in conventional bracket systems.[13,14] Bracket mounting position has a marked influence on the orthodontic treatment progress as it saves time, improves efficacy.

With the help of robots, the highest precision may be expected for all translational and rotational components of incisor movement. The studies also concluded that the appliance design can readily be optimized at any time while traditional optimization required huge resources which facilitates more timely care than conventional treatment.

Robots helped produce a multi-component dental appliance consisting of both a polymer baseplate and other parts, including clasps, springs, or screws with a fully digital workflow without the need of a physical model of the patient's dentition.[15] Previous studies have also found that the patient robot is useful in orthodontic bonding practice and has a positive educational impact.[16]

## CONCLUSION

Based on the systematic review of literature it can be concluded that the application of robots in orthodontics can provide improved accuracy, predictability, safety, quality of care with remarkably less treatment time compared to traditional methods. However, due to the heterogeneity of the studies, the generalization of the results may be difficult. Further, high-quality research is needed to prove the usefulness of robots in orthodontic practice.

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**Table**

Table 1: Summary of all included studies

| Sl. No. | Author and year | Country | Robot /Invention | Inference of the study |
|---|---|---|---|---|
| 1. | Jeong Joon Han *et al*., 2020 | South Korea | Robot arm and image-guided navigation | helpful to identify and remove bone interferences and reposition the bone segments with improved accuracy and safety |
| 2. | Sang-Yoon Woo *et al*., 2017 | South Korea | Robot system consisting of a robot arm with six degrees of freedom (Cybog-Lab, Suwon, Korea) . | The robotic system can enhance orthognathic surgery through improved accuracy, dexterity, and stability. |
| 3. | W. Joerd van der Meer *et al.*, 2016 | Netherlands | Wire-bending robotic machine (FMU 2.7, Wafios) | Can produce multi-component dental appliance without the need for a physical model of the patient's dentition |
| 4. | Ralf Mu¨ ller-Hartwich *et al*., 2016 | Germany | SureSmile process | The highest precision may be expected for all translational and rotational components of incisor movement. |
| 5. | Alfredo Gilbert, 2011 | Mexico | LAMDA (Lingual Archwire Manufacturing and Design Aid) | The third-generation wire bending robot formed more accurate bends than manually bent archwires |
| 6. | Theodossy T and Bamber | England | The robot arm (FaroArm) | Model surgery performed with the aid of a robot arm is significantly more accurate in anteroposterior and vertical |

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| | MA, 2003 | | | planes than is manual model surgery |
| 7. | Matthias Ureel *et al*., 2021 | Switzerland | CARLO® device | CARLO® device could be a useful alternative to conventional burs, drills, and piezosurgery instruments for performing osteotomies |
| 8. | Alana K. Saxe *et al*., 2010 | United States | Suresmile process | The SureSmile process results in a lower mean ABO OGS score and a reduced treatment time than conventional approaches. . |
| 9. | Rohit C.L. Sachdeva *et al.*, 2012 | United States | Suresmile process | SureSmile treatment facilitates more timely care than conventional treatment. |
| 10. | Katsuyoshi Futaki *et al.*, 2016 | Japan | Patient robot | Patient robot is useful in orthodontic bonding practice |

**FIGURE**

Figure 1: Flow diagram of data search