# Feasibility and accuracy of using intraoral scanners to digitize maxillectomy defects for prosthetic rehabilitation: A systematic review

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## ARTICLE INFO

## AUDIOABSTRACT

## ABSTRACT

**Purpose:** Few studies have focused on the feasibility and accuracy of intraoral digital impressions for maxillectomy defects, especially for extensive soft tissue defects. Using intraoral scanners alone might be feasible for producing maxillary obturator prostheses, albeit with some limitations. It seems logical to investigate this ambiguity. Therefore, this systematic review aimed to assessing the feasibility and accuracy of using intraoral scanners (IOSs) to digitize maxillectomy defects.

**Materials and Methods:** PubMed, the Cochrane Oral Health Group Trials Register, and the Cochrane Central Register of Controlled Trials were electronically searched, and five prosthodontics journals were manually searched for English-language articles published as of December 2020 that assessed the feasibility and accuracy of using intraoral scanners to acquire digital impressions for maxillectomy defects.

**Results:** Two in vitro studies, three clinical studies, six clinical reports, and three techniques were included (N=14). Aramany's and Brown's classifications were used to classify defects in twelve and one articles, respectively; the remaining article did not specify defect class. The 3M True definition IOS with Cone-beam computed tomography (CBCT), Computed tomography (CT), and/or optical scanners were used in both in vitro studies, mainly to evaluate accuracy. The Trios 3 scanner was used in nine studies as the main resource for data acquisition (75.0%), whereas the Trophy 3DI, Lava, and Cerec Omnicam scanners were used in three articles (25.0%). Four degrees of feasibility were identified: feasible (14.3%), feasible with limitations (28.6%), feasible with CBCT or CT (35.7%), and feasible with conventional impressions (21.4%). Accuracy was evaluated in four studies but was not mentioned in ten studies.

**Conclusion:** The results revealed a low level of evidence for the feasibility and accuracy of using intraoral scanners to digitize maxillectomy defects. Additional multicenter clinical studies are needed to evaluate the feasibility and accuracy of digital workflow compared with the conventional approach. (*Int J Maxillofac Prosthetics 2022;5:3-9*)

## INTRODUCTION

Maxillofacial prostheses are used for the rehabilitation of patients with defects or deformities in the maxillofacial region. Among these defects is maxillectomy, which is an acquired defect resulting from surgical resection of maxillary tumors. Maxillectomy defects can be classified into different types according to tumor size and location. The most commonly classification used in maxillofacial prosthetics is Aramany's classification.[1] Other classifications, such as Brown's and Okay's classifications, are also used.[2-4] Aramany's classification groups particular combinations of teeth and surgical defects relevant to the design of

maxillary obturator prostheses into six classes (I–VI). Among them, classes I, II, and IV are most common and interesting because they vary considerably in terms of shape and size.

Maxillectomy defects are complex due to the involvement of multiple anatomic structures and the presence of undercuts, perforations, and trismus following ablative surgery and/or radiation therapy. Making impressions of such complicated defects for obturator fabrication is quite challenging using conventional methods.[5] There is always an associated risk of aspiration or ingestion of material as well as foreign body impaction and difficulty inserting and removing the tray. Furthermore, trismus may limit the superolateral extension of the impression, which is important for the retention of the obturator. Since digital impressions don't require tray insertion or the use of impression material, intraoral scanning in maxillectomy patients could represent an easier and safer impression technique.[6] Numerous in vitro studies have reported that intraoral scanners can feasibly capture high-quality digital impressions. These studies ranged from simple digital impressions for fabrication of inlays, onlays, and single crowns to complex removable and fixed partial prostheses as well as more complicated digital impressions for implant-related restorations.[7-12] These findings were followed by a series of in vivo studies.[13-15] Although the use of intraoral scanners has usually been limited to the digitization of teeth, implants, and short-span edentulous areas for fabrication of fixed dental prostheses, recent studies have demonstrated the feasibility of digitally capturing edentulous jaws in both in vitro and in vivo conditions.[16,17]

To date, few studies have focused on the feasibility and accuracy of intraoral digital impressions for maxillectomy defects, especially for extensive soft tissue defects.[18-22] Elbashti et al.[18] evaluated the feasibility and accuracy of digitizing edentulous maxillectomy defects using an intraoral scanner. They reported, that digitizing edentulous maxillectomy defect models using a chairside intraoral scanner is feasible and accurate. Although in vitro studies show promising results, there are certain limitations in clinical studies. A recent clinical study by Zhang et al.[20] reported that completely scanning and fully digitizing the maxillary defect was relatively difficult to achieve, especially for deeper defect sites. Various approaches have been used to increase the feasibility of using intraoral scanners to digitize maxillectomy defects. CBCT and CT are methods that have been used with IO scanners.[21,23-26] Ye et al. reported that 3D digital casts of maxillary defects can be successfully generated from spiral CTs and intraoral scanners with a high level of accuracy consistent with that of conventional stone casts.[21] Combining conventional impressions with intraoral scanning has also been documented to overcome such limitations.[27-29] Few studies have reported that using intraoral scanners alone is feasible

for producing maxillary obturator prostheses, albeit with some limitations.[22,30,31] It seems logical to resolve this ambiguity. Therefore, this systematic review aimed to highlight the feasibility and accuracy of using intraoral scanners to digitize maxillectomy defects and identify potential intraoral scanning limitations, that may affect the digitization of maxillectomy defects.

## MATERIALS AND METHODS

### Study Protocol

This is a systematic review with an unpublished protocol. This systematic review followed the PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analyses) guidelines[32] and used the PICO (Population, Intervention, Comparison, and Outcome) framework to formulate the research question. The protocol was not registered in a database.

Patients: patients or patient models with maxillectomy defects.

Intervention: intraoral optical scanner data acquisition for maxillary obturator prostheses.

Comparison: conventional impressions or combination of conventional impression and optical scanning.

Outcome: feasibility and accuracy of optical scanner for the acquisition of maxillectomy defects

The resulting PICO question was: "In patients or patient models with maxillectomy defects, is optical scanning comparable to the conventional acquisition or a mix of analog and digital acquisition for fabricating maxillary obturator in terms of feasibility and accuracy?"

### Inclusion and Exclusion Criteria

This systematic review included published articles focusing on digital impression acquisition for maxillectomy defects (in patients or patient models) targeting feasibility and accuracy. The inclusion criteria were clinical studies, in vitro studies, case reports, or techniques with full texts published in English, reporting on intraoral scanners for acquiring the impression of maxillectomy defects. Exclusion criteria were articles with only English abstracts, insufficient information on the intraoral scanners used for impression acquisition, non-maxillectomy defects, and congenital maxillary cleft palate defects.

### Search Strategy for Identification of Studies

PubMed, the Cochrane Oral Health Group Trials Register, and the Cochrane Central Register of Controlled Trials were electronically searched for English-language articles published as of December 2020. The following MeSH terms and their combinations were used for the database searches: #1 maxillectomy, #2 hemimaxillectomy, #3 partial maxillectomy, #4 subtotal maxillectomy, #5 maxillary tumor resection, #6 maxillary defect*, #7 (#1)OR(#2)

OR(#3)OR(#4)OR(#5)OR(#6), #8 intraoral scan*, #9 optical impression*, #10 digitize*, #11 (#8)OR(#9)OR(#10), #12(#7) AND(#11). In addition, the references of all of the identified articles were manually searched for further relevant studies.

The electronic search was supplemented with a manual search of the issues of five prosthodontics journals, namely, the *Journal of Prosthodontic Research*, the *Journal of Prosthetic Dentistry*, the *Journal of Prosthodontics*, the *International Journal of Prosthodontics*, and the *Journal of Advanced Prosthodontics*, published between January 2010 and December 2020.

## Selection of Studies

Two of the review authors (M.E. and H.A.) independently screened the titles and abstracts from the electronic searches to identify potentially eligible studies, which required further evaluation to determine whether they followed the inclusion criteria for this review. Two other review authors (P.M.M. and A.A.) independently screened the titles and abstracts from the manual search of prosthodontics journals. Full-text copies of all eligible and potentially eligible studies were obtained. Two of the review authors (M.E. and P.M.M.) evaluated all identified studies to determine which ones satisfied all the inclusion criteria. Disagreements were resolved by discussion. When there was remaining disagreement, a third reviewer (H.A.) was consulted.

## Data Extraction and Management

Two of the review authors (M.E. and P.M.M.) independently extracted the data. The review authors were not blinded to the authors of the included studies. Disagreements were resolved by discussion, and when necessary, a third review author (H.A.) was consulted. Data were extracted using a customized data extraction form, which was pilot tested using a sample of the included studies. The following details were recorded: Publication details such as the authors' names and year of publication, type of study and sample size, inclusion and exclusion criteria, scanned objects, defect class and dentition status, digitization technique, details of the outcomes reported, results/outcomes.

## RESULTS

A total of 112 articles were identified in the PubMed database (n=67) and the manual search (n=45). A total of 36 potential articles were selected after screening the titles and abstracts, 16 of which were selected for full-text assessment after applying the inclusion criteria. Two articles were excluded during the full-text review, leaving 14 articles for the qualitative synthesis (Fig. 1).

All included articles were published in the past five years, with seven articles published in 2020 (50.0%) and the remaining seven articles between 2015 and 2019 (50.0%). There were two in vitro studies, three clinical studies, six clinical reports, and three techniques. The studies were performed in Japan, Germany, the Republic of Korea, Turkey, the People's Republic of China, the Kingdom of Saudi Arabia, the United States of America, Greece, and Italy. Table 1 presents a summary of the collected data. Among the two in vitro studies, there were 50 polyurethane maxillectomy defect models categorized as Aramany's class I, II, or IV. Twenty of the 50 models were edentulous (40%) and 30 (60%) were dentate. Among the clinical studies, reports, and techniques, there were 55 (93.2%) dentate maxillectomy defect patients and four (6.8%) edentulous maxillectomy defect patients. Aramany's classification was used to classify the defects in twelve articles (85.7%), including class I (36.3%), II (42.0%), and IV (20.3%); only 1.4% were class V. Brown's classification was also used in one clinical study with 28 maxillectomy patients; maxillectomy defects were class 2a in 17 patients (61%), class 2b in six patients (21%), class 2c in 3 patients (11%), and class 3a and 4b in 1 patient each. The classification was not mentioned in a clinical study of twelve maxillectomy patients.

For the digitization of maxillectomy defects, intraoral scanners were used in all studies. The 3M True definition intraoral scanner with CBCT, CT, and/or optical scanners were used in both in vitro studies, mainly for evaluating accuracy. The overall mean 3D deviation for edentulous maxillectomy defects was 168.3 ± 19.3 µm in the quarter-defect cases and 170.2 ± 24.0 µm in the half-defect cases.
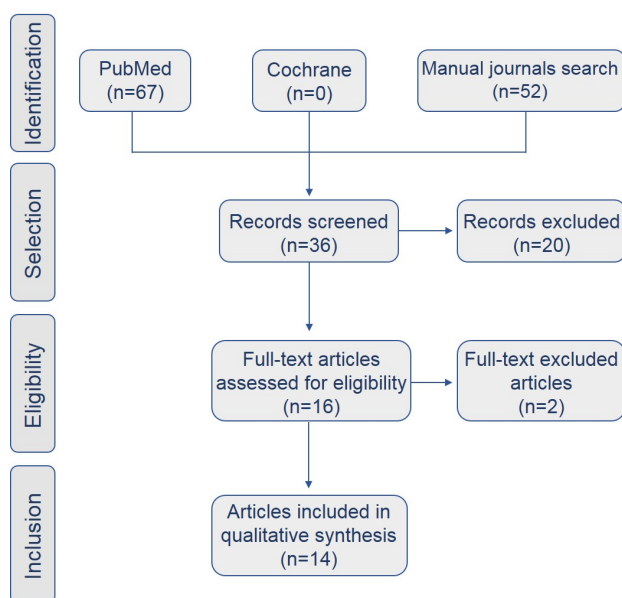


**Fig 1.** PRISMA flow diagram for study selection.

**Table 1.** Presents a summary of the major data extracted from the selected articles.

| Author, year | Article type | Scanned objects | Sample size | Defect class | De | Ed | IO | IO Type | CBCT | CT | OS | Surface treatment | Scanned pattern | Output format | Color | Prosthesis | feasibility | Accuracy |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Elbashti et al., 2017[18] | In vitro study | Polyurethane models | 20 | Class I & II | - | ✓ | ✓ | 3M True definition | ✓ | - | ✓ | Powder | Zigzag, non-defect to defect side | STL | - | NA | Feasible | Accurate |
| Elbashti et al., 2019[19] | In vitro study | Polyurethane models | 30 | Class I, II, & IV | ✓ | - | ✓ | 3M True definition | - | ✓ | - | Powder | Zigzag, non-defect to defect side | STL | - | NA | Feasible | Accurate |
| Zhang et al., 2020[20] | Clinical study | Maxillectomy patients | 10 | Class I, II, & IV | ✓ | ✓ | ✓ | Trophy 3DI | - | - | - | - | From non-defect to defect side | PLY | ✓ | NM | Feasible with limitations | NA |
| Ye et al., 2017[21] | Clinical study | Maxillectomy patients | 12 | NM | ✓ | - | ✓ | Trios 3 | - | ✓ | - | NM | NM | STL | ✓ | Maxillary obturator | Feasible with CT | Accurate |
| Park et al., 2017[22] | Clinical report | Maxillectomy patient | 1 | Class II | ✓ | - | ✓ | Trios 3 | - | - | ✓ | - | NM | NM | ✓ | Maxillary obturator | Feasible with limitations | Accurate |
| Murat & Batak, 2020[23] | Clinical report | Maxillectomy patient | 1 | Class II | - | ✓ | ✓ | Trios 3 | ✓ | - | - | - | NM | STL | ✓ | Maxillary obturator | Feasible with CBCT | NA |
| Murat et al., 2018[24] | Clinical report | Maxillectomy patient | 1 | Class II | ✓ | - | ✓ | Cerec Omnicam | ✓ | - | - | NM | From non-defect to defect side | STL | ✓ | Maxillary obturator | Feasible with CBCT | NA |
| Tasopoulos, 2020[25] | Clinical report | Maxillectomy patient | 1 | Class I | ✓ | - | ✓ | Trios 3 | ✓ | - | - | NM | NM | STL | ✓ | Maxillary obturator | Feasible with CBCT | NA |
| Ye et al., 2020[26] | Technique | Maxillectomy patient | 1 | Class I | ✓ | - | ✓ | Trios 3 | - | ✓ | - | NM | NM | NM | ✓ | Maxillary obturator | Feasible with CT | NA |
| Londono et al., 2015[27] | Clinical report | Maxillectomy patient | 1 | Class V | ✓ | - | ✓ | Lava | - | - | - | NM | NM | NM | - | Maxillary obturator | Feasible with conventional impression | NA |
| Brucoli et al., 2020[28] | Clinical study | Maxillectomy patients | 28 | Class 2a, 2b, 2c, 3a, & 4b | ✓ | - | ✓ | Trios 3 | - | - | - | NM | NM | STL | ✓ | Maxillary obturator | Feasible with conventional impression | NA |
| Alqarni et al., 2020[29] | Technique | Maxillectomy patient | 1 | Class I | - | ✓ | ✓ | Trios 3 | - | - | - | Composite resin | NM | STL | ✓ | Maxillary obturator | Feasible with conventional impression | NA |
| Michelinakis et al., 2018[30] | Clinical report | Maxillectomy patient | 1 | Class IV | ✓ | - | ✓ | Trios 3 | - | - | - | NM | From non-defect to defect side | STL | ✓ | Maxillary obturator | Feasible with limitations | NA |
| Fernandez et al., 2020[31] | Technique | Maxillectomy patient | 1 | Class II | ✓ | - | ✓ | Trios 3 | - | - | - | Powder | S movement, non-defect to defect side | STL | ✓ | Maxillary obturator | Feasible with limitations | NA |

De, dentate; Ed, edentulous; IO, intraoral scanner; CBCT, cone beam computed tomography; CT, computed tomography; OS, optical scanner; NM, not mentioned; NA not applicable; STL, stereolithography file format; PLY, polygon file format

For dentate maxillectomy defects, the range of 3D deviation was between 40.0 µm and 185.0 µm. A scanning powder was used in both studies as required by the manufacturer's instructions. For the clinical studies, reports, and techniques, the Trios 3 scanner was used in nine studies for data acquisition (75.0%), and the Trophy 3DI, Lava, and Cerec Omnicam scanners were used in 3 articles (25.0%). Twenty-five percent of those studies used only intraoral scanners: 41.6% used an intraoral scanner with either CBCT or CT; 8.4% used an IO scanner and an optical scanner, and 25.0% used an intraoral scanner and conventional impressions. The main difference within those studies was the possibility to fully digitize the maxillectomy defects. Intraoral scanners alone were limited to fully digitizing the defects while when they were used with CBCT, CT, or with conventional impressions, defects were fully digitized. Only 6 articles (42.9%) mentioned the scanning patterns used, including zigzag, circular, or S-shape movement starting from the non-defect side, including the teeth and palate, to the maxillectomy defect side. Although most of the IO scanners used were color scanners (78.5%), more than two-thirds (71.4%) of the articles reported stereolithography (STL) as file format output.

The most widely used prosthetic rehabilitation was the maxillary obturator, present in 49 of 59 patients (83.1%). There was no mention of prosthetic rehabilitation for the 10 patients (16.9%) in one of the clinical studies. Four degrees of feasibility were identified: feasible (14.3%), feasible with limitations (28.6%), feasible with CBCT or CT (35.7%), and feasible with conventional impressions (21.4%). Accuracy was evaluated in 4 studies (2 in vitro studies, 1 clinical study, and 1 clinical report) (28.6%) but was not mentioned in 10 studies (71.4%). For both clinical and report studies, they concluded that the scanning was clinically accepted and therefore maxillary obturator prostheses were fabricated and delivered to the patients.

## DISCUSSION

This systematic review investigated the feasibility and accuracy of intraoral scanners for digitizing maxillectomy defects. The 14 reviewed studies showed limited evidence for feasibility for maxillectomy defects digitalization, although the improved feasibility was found when intraoral scanners were used in combination with CT, CBCT, or conventional impressions. The accuracy evaluation of the described clinical workflow revealed inconsistent results and there was a lack of comparison with conventional techniques.

Making maxillectomy impressions for prosthetic rehabilitation to create accurate master models is a challenging procedure.[33] Each clinical case needs to

be considered in detail and most maxillectomy defect cases require an individualized treatment plan for prosthetic design and fabrication, especially in cases with a deep craniofacial defect.[34] Digital technology for maxillofacial prosthetics has spread[35,36] and become more reliable in the past ten years.[36] Although the optimal method for preparing maxillectomy models remains unclear, a conventional impression remains the most common approach for maxillary obturator fabrication.[6]

Considering the anatomical situation and limitations of maxillectomy patients, the reviewed literature suggests that 3D optical acquisition for maxillectomy defect is still in the developmental stage, given that the described techniques have heterogeneity when intraoral digitalization is performed. Most of the reviewed literature consists of articles based on clinical workflow scenarios. However, there were only two in vitro studies that evaluated accuracy, both demonstrating clinically acceptable deviations.[18,19] Given that most of the reviewed articles were clinical reports,[22-25,27,30] the obtained data should be carefully interpreted due to their methodological limitations. The data reviewed in this study showed that a vast majority of digitized maxillectomy defects are dentate with limited craniofacial affectation, which might indicate a preference toward dentate cases. The reason might be the presence of teeth, providing favorable anatomical landmarks for performing intraoral scans or subsequent matching to other STL or DICOM files. [21]

In this respect, all the reviewed studies described the use of intraoral scanners, which is consistent with the current literature regarding the feasibility of digital impressions with optical systems. However, due to the anatomical variations of the vertical and/or horizontal defects, the need to include tomographic systems was highlighted.[6] Indeed, five articles described the combination of systems for digital data acquisition.[21,23-26] Although this methodology is reliable for implementing the digital workflow, there is presently insufficient clinical data to evaluate the accuracy of digital planning when IO scanners are incorporated into a CBCT or CT scan for maxillectomy defects.[21] Moreover, considering the obtained data acquisition results related to CAD/CAM processing, a major challenge seems to be obtaining an accurate scan of the obturator hollow bulb and the border areas related to muscle movements around the defects before the design and fabrication of the prosthesis.[6] Therefore, some studies incorporated a conventional impression approach to overcome this challenge.[27-29] The addition of CBCT or CT has been revealed as a useful combination tool for the data acquisition necessary for the design and fabrication of prostheses.[21,23-26]

Although CBCT or CT data in combination with intraoral scanning enables the evaluation of the vertical and/or horizontal defect to obtain 3D models,

methods for evaluating the results and the reliability of this technology require further clinical development.[21] In addition, the lack of comparison with conventional techniques among the included studies is an important limitation in terms of evaluating the accuracy of the proposed protocols. A recent systematic review evaluating prosthetic rehabilitation for head and neck cancer highlighted the need for studies assessing novel digital techniques.[6]

The findings show reliable data for 3D optical acquisition based on clinical outcomes. However, limited results regarding the full digital workflow of prosthetic fabrication were reported, showing limited data on complete digital workflow processing.[30] Digital workflow for CAD/CAM fabrication processes might lead to reductions in treatment time and costs. However, this technology depends on the digital data processing, design, and assisted manufacturing capabilities of clinicians, technicians, and the involved dental laboratories. Considering the limitations of the reviewed literature, more high-quality studies are needed to evaluate the digital workflow for digitizing maxillectomy defects.

## CONCLUSION

Although the feasibility and accuracy of intraoral scanners to digitize maxillectomy defects were confirmed by in vitro studies, the results of our systematic review suggest that serious limitations in clinical workflows remain. However, by combining intraoral scanning with CBCT/ CT data, or conventional impressions, such limitations might be eliminated. The lack of clinical studies was the reason for the limited evaluation of accuracy in this review. Additional robust studies are needed to evaluate the accuracy of digital workflow compared with the conventional approach.

## ACKNOWLEDGEMENTS

## CONFLICT OF INTEREST

All authors declare that they have no conflicts of interest.

## REFERENCES

1. Aramany MA. Basic principles of obturator design for partially edentulous patients. Part I: classification. J Prosthet Dent 1978;40:554-7.

2. Brown JS, Rogers SN, McNally DN, Boyle M. A modified classification for the maxillectomy defect. Head Neck 2000;22:17-26.

3. Okay DJ, Genden E, Buchbinder D, Urken M. Prosthodontic guidelines for surgical reconstruction of the maxilla: A classification system of defects. J Prosthet Dent 2001;86:352-63.

4. Aggarwal H, Eachempati P, Kumar P,Nagaraj SK. Diverse classification systems for maxillectomy defects: Simplifying or complicating the treatment plan? Indian J Plast Surg 2015;48:98.

5. Dos Santos DM, de Caxias FP, Bitencourt SB, Turcio KH, Pesqueira AA, Goiato MC. Oral rehabilitation of patients after maxillectomy. A systematic review. Br J Oral Maxillofac Surg. 2018;56:256-66.

6. Soriano CM, Vega PC, Devesa AE, Salas EJ, López JL. Frequency and type of digital procedures used for the intraoral prosthetic rehabilitation of patients with head and neck cancer: A systematic review. J Prosthet Dent 2021;8:S0022-3913.

7. Özsürmeli H, Türker ŞB. In vitro evaluation of the marginal and internal accuracy of different types of dental ceramic restorations fabricated based on digital and conventional impressions. Int J Prosthodont 2021;34:61-9.

8. Ueda K, Beuer F, Stimmelmayr M, Erdelt K, Keul C, Guth JF. Fit of 4-unit FDPs from CoCr and zirconia after conventional and digital impressions. Clin Oral Investig 2016;20:283-9.

9. Jeon JH, In vitro precision evaluation of blue light scanning of abutment teeth made with impressions and dental stone casts according to different 3D superimposition methods. J Prosthet Dent 2020;64:368-72.

10. Diker B, Tak Ö. Accuracy of digital impressions obtained using six intraoral scanners in partially edentulous dentitions and the effect of scanning sequence. Int J Prosthodont 2021;34:101-8.

11. Rutkūnas V, Gečiauskaitė A, Jegelevičius D, Vaitiekūnas M. Accuracy of digital implant impressions with intraoral scanners. A systematic review. Eur J Oral Implantol 2017;10(Suppl 1):101-20.

12. Mangano FG, Admakin O, Bonacina M, Lerner H, Rutkunas V, Mangano C. Trueness of 12 intraoral scanners in the full-arch implant impression: A comparative in vitro study. BMC Oral Health. 2020;20:263.

13. Ender A, Attin T, Mehl A. In vivo precision of conventional and digital methods of obtaining complete-arch dental impressions. J Prosthet Dent 2016;115:313-20.

14. Gan N, Xiong Y, Jiao T. Accuracy of intraoral digital impressions for whole upper jaws, including full dentitions and palatal soft tissues. PLoS One 2016;11:e0158800.

15. Giachetti L, Sarti C, Cinelli F, Russo DS. Accuracy of digital impressions in fixed prosthodontics: A systematic review of clinical studies. Int J Prosthodont 2020;33:192-201.

16. Osnes CA, Wu JH, Venezia P, Ferrari M, Keeling AJ. Full arch precision of six intraoral scanners in vitro. J Prosthodont Res 2020;64:6-11.

17. Hack G, Liberman L, Vach K, Tchorz JP, Kohal RJ, Patzelt SBM. Computerized optical impression making of edentulous jaws - An in vivo feasibility study. J Prosthodont Res 2020;64:444-53.

18. Elbashti ME, Hattori M, Patzelt SB, Schulze D, Sumita YI, Taniguchi H. Feasibility and accuracy of digitizing edentulous maxillectomy defects: A comparative study. Int J Prosthodont 2017;30:147-9.

19. Elbashti ME, Hattori M, Patzelt SB, Aswehlee AM, Sumita YI, Taniguchi H. Precision and trueness of computerized optical impressions in maxillectomy defects: An in vitro 3D comparison. Int J Prosthodont 2019;32:289-92.

20. Zhang M, Hattori M, Elbashti ME, Sumita YI. Feasibility of intraoral scanning for data acquisition of maxillectomy defects. Int J Prosthodont 2020;33:452-6.

21. Ye H, Ma Q, Hou Y, Li M, Zhou Y. Generation and evaluation of 3D digital casts of maxillary defects based on multisource data registration: A pilot clinical study. J Prosthet Dent 2017;118:790-5.

22. Park JH, Lee KS, Lee JY, Shin SW. Fabricating a maxillary obturator using an intraoral digital impression: A case history report. Int J Prosthodont 2017;30:266-8.

23. Murat S, Batak B. Fabrication of a 3-dimensionally printed definitive cast for an obturator prosthesis by merging intraoral scan image with cone beam computed tomography data: A clinical report. J Prosthet Dent 2020:S0022-3913(20)30659-4.

24. Murat S, Gürbüz A, Kamburoğlu K. Fabrication of obturator prosthesis by fusing CBCT and digital impression data. Int J Comput Dent 2018;21:335-44.

25. Tasopoulos T, Chatziemmanouil D, Kouveliotis G, Karaiskou G, Wang J, Zoidis P. PEEK maxillary obturator prosthesis fabrication using intraoral scanning, 3D printing, and CAD/CAM. Int J Prosthodont 2020;33:333-40.

26. Ye H, Wang Z, Sun Y, Zhou Y. Fully digital workflow for the design and manufacture of prostheses for maxillectomy defects. J Prosthet Dent 2020:S0022-3913(20)30422-4.

27. Londono J, Abreu A, Baker PS, Furness AR. Fabrication of a definitive obturator from a 3D cast with a chairside digital scanner for a patient with severe gag reflex: A clinical report. J Prosthet Dent 2015;114:735-8.

28. Brucoli M, Boffano P, Pezzana A, Corio C, Benech A. The use of optical scanner for the fabrication of maxillary obturator prostheses. Oral Maxillofac Surg. 2020;24:157-61.

29. Alqarni H, Kattadiyil MT, Aponte-Wesson R, Alfaifi M, Alsayed H. Integration of intraoral scanning and conventional processing to fabricate a definitive obturator: A dental technique. J Prosthet Dent 2020:S0022-3913(20)30368-1.

30. Michelinakis G, Pavlakis M, Igoumenakis D. Rehabilitation of a maxillectomy patient using intraoral scanning impression technology and a computer-aided design/computer-aided manufacturing fabricated obturator prosthesis: A clinical report. J Indian Prosthodont Soc 2018;18:282-7.

31. Fernandez PK, Kuscu E, Weise H, Engel EM, Spintzyk S. Rapid additive manufacturing of an obturator prosthesis with the use of an intraoral scanner: A dental technique. J Prosthet Dent 2020:S0022-3913(20)30602-8.

32. Moher D, Liberati A, Tetzlaff J, Altman DG, PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. J Clin Epidemiol 2009;62:1006-12.

33. Sumita YI, Hattori M, Elbashti ME, Taniguchi H. Orientation of handle for successful prosthetic treatment in patients with an anatomic compromise after a maxillectomy. J Prosthet Dent 2017;117:694-6.

34. Vosselman N, Alberga J, Witjes MH, Raghoebar RM, Reintsema H, Vissink A, et al. Prosthodontic rehabilitation of head and neck cancer patients: Challenges and new developments. Oral Diseases 2021;27:64-72.

35. Naveau A, Bou C, Sharma A. Evolution of topics in maxillofacial prosthetics publications. Int J Prosthodont 2018;31:565-8.

36. Elbashti ME, Sumita YI, Kelimu S, Aswehlee AM, Awuti S, Hattori M, et al. Application of digital technologies in maxillofacial prosthetics literature: A 10-year observation of five selected prosthodontics journals. Int J Prosthodont 2019;32:45-50.