



## THE ROLE OF DIGITAL TECHNOLOGY IN OVERSEAS MAXILLOFACIAL PROSTHETIC COLLABORATION: A MODEL OF FUTURE COLLABORATION

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### ABSTRACT:

Digital technologies have a great role in revolutionized prosthodontics in general, and more specifically in maxillofacial prosthetics. Digitized prosthetic rehabilitation modalities are becoming an essential approach for the maxillofacial prosthetic field. This article reviews the role of digital technology in overseas maxillofacial prosthetic collaboration and introduces a model of prospective collaboration in the field of maxillofacial prosthetics using digital technology. Various intraoral and extraoral maxillofacial prostheses were briefly reviewed. Numerous digital technologies in prosthetics were also concisely reviewed in perspective of digitization and visualization, modeling and designing, and fabrication. Internet-based audiovisual synchronous and asynchronous technologies were also reviewed. In addition, a model of future collaboration in the field of maxillofacial prosthetics using digital technology was introduced.

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### الملخص العربي

#### دور التكنولوجيا الرقمية في التعاون الدولي في مجال استعاضة الوجه والفكين: نموذج للتعاون المستقبلي

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التكنولوجيات الرقمية لها دور كبير في ثورة التعويضات السنية بشكل عام، وبشكل أكثر تحديدا في مجال استعاضة الوجه والفكين. أصبحت طرق إعادة التأهيل الاصطناعي الرقمي نهجا أساسيا في مجال استعاضة الوجه والفكين. تستعرض هذه المقالة دور التكنولوجيا الرقمية في التعاون الدولي في مجال استعاضة الوجه والفكين، وتقدم نمودجا للتعاون المحتمل في مجال استعاضة الوجه والفكين باستخدام التكنولوجيا الرقمية. تم استعراض مختلف تعويضات الوجه والفكين الداخلية والخارجية بشكل موجز. كما تم استعراض العديد من التقنيات الرقمية المستعملة في استعاضة الوجه والفكين بشكل دقيق من منظور الرقمنة والتصوير، وإعداد النموذج والتصميم، والتصنيع. و تم أيضا استعراض التكنولوجيات السمعية البصرية المتزامنة وغير المتزامنة القائمة على الإنترنت. وبالإضافة إلى ذلك، تم تقديم نموذج للتعاون في المستقبل في مجال استعاضة الوجه والفكين باستخدام التكنولوجيا الرقمية.

## INTRODUCTION

Maxillofacial prosthetic rehabilitation aims to restore function and esthetics to patients with maxillofacial defects using removable and fixed prostheses.<sup>1</sup> Although the scope of maxillofacial prosthetics varies according to defect size and location, it can generally be divided into maxillofacial prosthodontics and facial prosthetics.<sup>2</sup> Maxillofacial prosthodontics involves the use of mandibular and maxillary prostheses, while facial prosthetic rehabilitation includes the use of auricular, nasal, facial, ocular, and orbital prostheses as well as craniofacial implant production. Conventional prosthetic rehabilitation techniques in maxillofacial prosthetics involve making an impression of the defect site, pouring a stone model and creating a wax pattern. The wax pattern is then invested and processed with a permanent prosthesis material such as metal, acrylic, and/or silicone. These procedures require considerable human involvement and manipulation of materials which may lead to the possibility of processing errors and inaccuracies of the definitive prostheses as well as being time consuming and incurring extra expenses.<sup>3</sup>

Digital technologies have revolutionized prosthodontics in general, and more specifically maxillofacial prosthetics.<sup>4</sup> Digitized prosthetic rehabilitation modalities are becoming an essential approach for the maxillofacial prosthetic field. In developing countries, because of the complexity of prosthesis construction and the limited expertise in specialized centers, maxillofacial defect patients seem to be deprived of appropriate prosthetic rehabilitation.<sup>5</sup> Therefore, an alternative process is needed for reducing the entire dependence on the human variables and for applying digitized visualization, modeling and design, and fabrication techniques, which would simplify and increase the productivity of maxillofacial prostheses. Furthermore, internet-based audiovisual synchronous and asynchronous technologies can play an important role in simplifying communication and improving overseas collaboration.<sup>6,7</sup> This article reviews the role of digital technology in overseas maxillofacial prosthetic collaboration and introduces a model of future collaboration in the field of maxillofacial prosthetics using various digital technologies.

## MAXILLOFACIAL PROSTHETICS

Maxillofacial prosthetics has been defined as the branch of prosthodontics concerned with the restoration and/or replacement of the stomatognathic and craniofacial

structures with prostheses that may or may not be removed on a regular or elective basis.<sup>8</sup> It is considered to be one of the most challenging and unique dental field as it deals with various head and neck congenital and acquired defects. The etiology of maxillofacial defects can be varied according to geographic region and the economic income of these regions. In high-income countries, the majority of defected cases are postoperative head and neck cancer patients, followed by trauma, clefts, burns, and infection.<sup>9</sup> In contrast, more traumatic maxillofacial defects that result from road traffic accidents and gunshots as well as cancer resections can be seen in low- and middle-income countries.<sup>10-12</sup> Maxillofacial prosthetics can be divided into two main categories in regard of treatment delivery; maxillofacial prosthetics for rehabilitation, and maxillofacial therapeutic appliances such as radiotherapy appliances, surgical appliances, and trismus prevention appliances.<sup>2</sup> The first category of maxillofacial prosthetics for rehabilitation is further divided into two main groups; maxillofacial prosthodontics which include rehabilitation of maxillary, mandibular, and other surrounding structures like tongue, soft palate, and floor of the mouth defects. The second category is facial prosthetics, this type includes any extraoral defect in the head and neck region which include but are not limited to orbital and ocular defects, nasal defects, auricular defects, and facial skin defects (Fig 1).

Maxillary defects can be functionally and esthetically rehabilitated using removable and/or fixed maxillofacial prostheses. In small defects, a one-piece maxillary obturator prosthesis can be used, whereas in large defects, a two-part prosthesis consisting of a hollow bulb obturator attached to a solid denture base can be used, especially if trismus makes it difficult to insert.<sup>13</sup> Other prostheses used in the maxillary region include the palatal augmentation prosthesis (PAP) and palatal lift prosthesis (PLP). The former is used mainly for tongue defects such as glossectomy or tongue immobility, while the latter is used to elevate and obturate a collapsed soft palate in cases of soft palate defects.<sup>14</sup> Partial loss of the mandible leads to a deviated path for opening and closing, and alteration of the occlusal position due to the effects of the anatomical structures on the unaffected side results in an unstable prosthesis.<sup>13</sup> The occlusal table or palatal ramp can be used in the maxilla to return a deviated mandible to an optimal maxillary-mandibular relationship.<sup>15</sup>

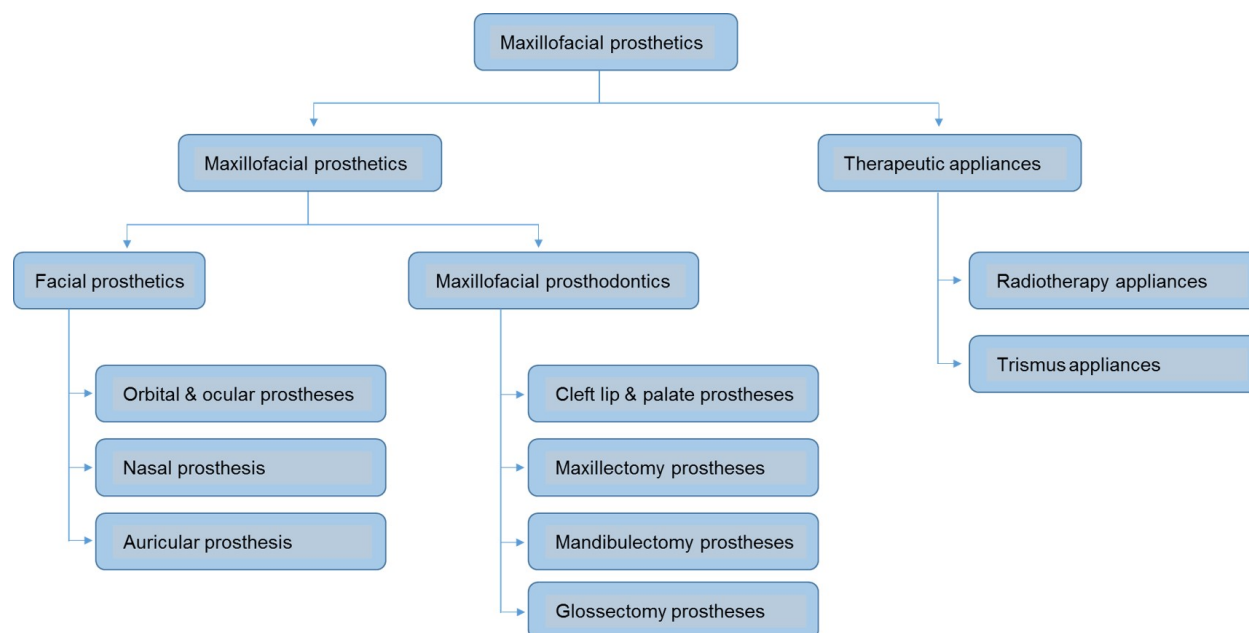


Fig 1: Flowchart shows the extent of maxillofacial prosthetics.

Facial prostheses are individually made prostheses that are used to rehabilitate extraoral maxillofacial defects. In cases of full exenteration of the orbital content, a silicone prosthesis is the only solution to restore the patient esthetics. The main structure of the orbital prosthesis is a silicone body that matches the patient skin's tone and texture, an acrylic eye unit, eyelashes and a sub-structure including retentive clips or magnets if required.<sup>16</sup> It is recommended that the patient wears glasses to camouflage the prosthetic eye and also to protect the natural eye. A nasal prosthesis is used to replace either partial or entire nasal defects. In some midfacial defect cases, they are even extended across the cheeks or combined with the upper lip. Since the nose is very prominent, located in the center of the face, providing the patient with a realistic prosthesis is of vital significance. An auricular prosthesis is used to replace an either partially or totally missing ear. It is the simplest facial prosthesis. Prosthetic replacement of the ear can provide excellent esthetic results.

Although the maxillofacial prosthetic rehabilitation procedures have been developed over time, they are labor intensive, time consuming and require highly specialized clinical and practical skills to achieve a satisfactory prosthesis. The techniques also require a lot of specialized training to become skilled. Multiple visits are needed for the patients, which often involve

long periods of sitting and waiting. The outcome is also largely dependent on the experience and skills of the individual practitioner.<sup>17</sup>

## DIGITAL TECHNOLOGY IN PROSTHETICS

The revolution of digital technologies has advanced prosthodontics, and more specifically maxillofacial prosthetics. Digitized prosthetic rehabilitation modalities are becoming an essential approach for the maxillofacial prosthetic field. Current maxillofacial prosthetic research focuses on the formation of prostheses through computer aided design and computer aided manufacturing (CAD/CAM) and computer supported rapid prototyping techniques (RP).<sup>18, 19</sup> In digitized maxillofacial prosthetics, three main treatment procedures are considered; digitization (visualization), modeling and designing, and manufacturing (RP) (Fig 2). In order to digitize the defect and surrounding area, computed tomography (CT), magnetic resonance imaging (MRI), laser surface scanners, intraoral scanners, optical scan systems, and three-dimensional (3D) photogrammetry systems are used.<sup>20-23</sup> These digitizing systems provide very clear topographic data of the patients. Therefore, the distortions that may be caused by the physical properties of the conventional impression materials are eliminated as the data are collected without touching the tissues. The created digital models are transferred to CAD/CAM and RP technologies in order to form successful prototypes for intraoral and extraoral maxillofacial prostheses with good contours and tissue adaptation.<sup>18, 19</sup>

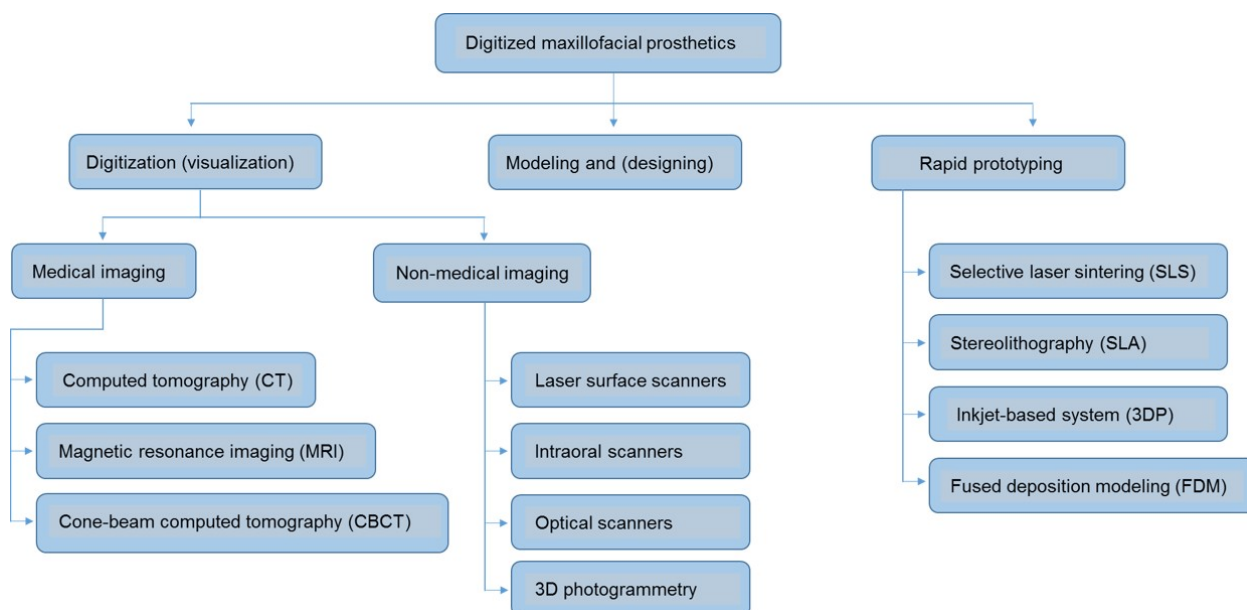


Fig 2: Flowchart shows the structure of digitized maxillofacial prosthetics.

Modeling and designing is the other element of digitized prosthetic rehabilitation. Modeling techniques are mainly dependent on the type of data acquisition, medical imaging data such as CT and MRI are usually acquired as digital imaging and communication in medicine (DICOM) data.<sup>24</sup> In order to create a 3D model, DICOM data need to be rendered and saved as a standard transformation language (STL) file format. For other digitizer systems, obtained data can be directly saved as STL file format. STL is an open-source surface-based format, which is easily accessible through most commercial software applications. These datasets allow for easy information exchange and communication among users. STL data can be saved in two different formats, American Standard Code for Information Interchange (ASCII) and binary.<sup>25</sup> The ASCII format is less commonly used due to the large size of the resultant file, but it can be easily modified for debugging purposes. The binary format is more complicated in its syntax, but generates smaller file sizes and is therefore used more often. For designing, there are many special softwares that are provided by the manufacturers for the design of various kinds of maxillofacial prosthetic restorations. Most of these softwares offer a comprehensive design and sculpting toolset allowing for sculpture of the prosthesis anatomical details and deformation of virtual clay models into any form required. The software of CAD/CAM systems presently available on the market is being continuously improved. The latest construction

possibilities are continuously available to the user by means of updates. The final designed prosthesis can be saved as STL file format, and can also be virtually matched to the defect model and evaluated for RP suitability before manufacturing process.

Rapid prototyping techniques have been used in digitized maxillofacial prosthetic production. The unique characteristic of RP is that, models and/or prostheses are produced by adding material from the main source layer by layer to form a 3D model in which all the layers are bound together. Through this technique, practitioners can easily manage the formation of inner details of complex structured substances and undercut areas.<sup>18</sup> RP techniques have been utilized effectively for fabrication of facial prosthesis over the past decade.<sup>18, 22</sup> Although the conventional processing was still essential to make some of the definitive prostheses, RP model production to aid prosthesis fabrication has been a feasible procedure. Using this mold would remove the conventional processing, and shorten overall procedures of making the prosthesis.<sup>22</sup> Furthermore, the produced mold can be kept for multiple reproduction of prostheses, since the mold is long-lasting and allows the pouring multiple times. Selective laser sintering (SLS), stereolithography (SLA), fused deposition modeling (FDM), and inkjet-based system (3DP) have been frequently used techniques of RP.<sup>26</sup> Various materials have commonly been used with these techniques such as wax, plastics, ceramics, and metals.



## INTERNET BASED MULTIMEDIA COLLABORATION

Internet based multimedia collaboration in the medical field is a digital technology based application that has been developed in relation to time significance. It aims to provide solutions to many health-related problems through the use of a collective approach. Overseas medical collaboration is a part of an international cooperation that bridges medical practitioners worldwide to work for the improvement of global health. Synchronous and asynchronous collaboration techniques should be utilized to achieve a suitable collaborative setting. For communications to be understandable, it is necessary to conduct real-time interactive multimedia conversations where high-quality patient's data can be shared over the internet between the institutions of two countries. As with any other technology, internet based multimedia collaboration is naturally associated with technical issues that affects its performance. Such issues include different scales of network heterogeneities, heterogeneities in computer performance, persistent traffic congestion due to changes in time zones, institutional logistics such as network security, and other infrastructural problems in developing countries.<sup>7</sup>

In medical collaboration, high-quality and real-time patient digital data conduction facilities are required.<sup>27</sup> It necessitates both synchronous and asynchronous collaboration framework with secure data and information sharing between the two sides of the collaboration. In the case of real-time discussions that are based on patients' digital data, a synchronous collaboration is necessary. The practitioners must be able to communicate with each other and discuss various aspects of a case, whilst observing the patient digital data in a real time manner. In addition, the collaborators need to perform the collaboration process asynchronously due to working schedule differences in the time space and inflexible time shifts in different time zones.

In the field of maxillofacial prosthetic rehabilitation, there are important features that need to be realized for effective internet based overseas collaboration. Real-time high quality digital data delivery is one of these features. In case of maxillofacial defect, it is highly important for the maxillofacial prosthodontist to see the patient defect with high quality digital data. Furthermore, different clinical information and other supporting digital data such as CT, MRI, and digital photos are required for observation. Interactivity of voice is also important to achieve effective collaboration, because it is the main

source of information between the collaborators. Interactive discussion of the patient details in a shared workspace is also required in order to reach collective decisions. Sharing patients' data requires an extremely secure database that protects patient information and details in both past and future collaboration. Considering the time differences due to geographical separation and working schedules mismatch, maxillofacial prosthetic overseas collaboration should support both synchronous and asynchronous collaboration.

Discussed here are two different examples of tools that have been used for collaboration purposes. Firstly, an internet-based audio/video conferencing tool. This type of tools facilitates a real time voice communication enhanced by real time video, which fulfills the basic functional requirements for collaboration. Skype (Skype Communications SARL, Luxembourg, Belgium) is an example of this category. It is a peer-to-peer free application that enable the collaborators to communicate using real time audio / video conferencing and other various features such as sharing screens, photos and files of any size. The second tool is synchronous/asynchronous mixed collaboration which is a more advanced technique; it requires the practitioners working on common tasks to remotely share computer display workspaces simultaneously, without leaving their workplaces. However, to support truly global cooperative work, asynchronous collaboration is equally important. This facilitates later reviewing of a project for the participants who may not be available for the synchronous session, due to conflicting working schedules as well as invariable time differences in different time zones.

## A MODEL OF FUTURE COLLABORATION

To extend overseas maxillofacial prosthetic collaboration activities carried out between developed countries and several developing countries, a model of future collaboration is proposed. This model includes synchronous and asynchronous collaboration patterns through network-effective persistent information sharing. The proposed model will facilitate synchronous collaborative work on maxillofacial prosthetic cases through real-time high-quality digital data delivery and by bringing the database objects to a shared workspace. The asynchronous activities will be supported through a web based collaborative environment that enables navigation of collaboration contents.

The primary focus of this model of future collaboration is to provide maxillofacial defect patients with required maxillofacial prostheses through remote overseas collaboration between the dental hospital at the faculty of dentistry of the University of Misurata-Libya and the department of maxillofacial prosthetics at Tokyo Medical and Dental University- Japan, by using various digital technologies. Patient data from CT, digital photography, and 3D photogrammetry could be synchronized and asynchronized through network-effective persistent data and information sharing.

The shared digital data would allow for 3D modeling and visualization, and the prosthesis could then be designed and partially fabricated using 3D RP technology. Finally, the produced prosthesis could be conventionally processed and finished. The definitive prosthesis would be shipped to the dental hospital of the University of Misurata and then fitted. It would be possible to provide synchronized instructions and consultation during the prosthesis fitting appointment. A free internet-based audiovisual synchronous program such as Skype (Skype Communications SARL, Luxembourg, Belgium) could be used for this purpose. Online lectures and training could also be provided to young Libyan prosthodontic practitioners about maxillofacial prosthetic rehabilitation techniques.

## CONCLUSION

This review has highlighted the role of various digital technologies in overseas maxillofacial prosthetic collaboration as an alternative to the conventional techniques. However, introduction of new technologies and techniques would require changes to current treatment protocols, workflow setting and training requirements. These challenges can be broadly considered as technological limitations and expenses.

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