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FUTURE TECHNOLOGICAL ADVANCEMENT IN MAXILLOFACIAL REHABILITATION: A LEAP TOWARDS REALITY

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Abstract

Digitalised prosthetic rehabilitation modalities are becoming an essential approach for maxillofacial prosthetic field in present era. As technologies like nanotechnology, biotechnology, informatics, and cognitivism improve, maxillofacial amplification prostheses can now operate instinctively rather than passively. Through hybridization and the establishment of a genuine neurophysiological link with the environment, these can make maxillofacial amplification prostheses a reality. This narrative review emphasizes numerous technological advances in the field of maxillofacial rehabilitation, which, by resolving graft rejection and minimizing donor site morbidity, may pave the way for new avenues in reconstructive surgery.

Keywords: Maxillofacial rehabilitation, 3D printing, trends, technologies

Introduction

Maxillofacial deformity can result from malignancy, developmental trauma, or genetic flaws that impair function and appearance, making it difficult to lead a regular social life. Rehabilitating patients with craniofacial deformities has historically been a difficult task due to the extended procedures and multiple clinical visits needed for the fabrication of maxillofacial prostheses. People have been able to get beyond these restrictions to some extent because to the usage of cutting-edge materials and technology[1-3]. The industry has undergone a revolution in digital technology, which have made the process of designing, producing, assessing, and visualizing prostheses more efficient. The convergence of technologies such as nanotechnology, biotechnology, informatics, and cognitivism (NBIC) has made it possible for prostheses to introduce new extrasensory capabilities and facilitate authentic neurophysiological interactions with their users. The biotechnological future of maxillofacial rehabilitation incorporating augmented reality with bioprinting along with 3D scanning can make a patient experience new level of reality and comfort.

Literature Review

Maxillofacial prosthetics (MP) has long been driven primarily by its strong association with maxillofacial surgery. The field of maxillofacial rehabilitation has historically been directed by surgical considerations, and maxillofacial prosthesis is a dependable and complementing option that fills in the gaps and resolves the shortcomings that surgery alone cannot1. However, the field of maxillofacial rehabilitation is changing as a result of the rapid development of new technologies. This evolution is progressing from simple repair to more advanced methods that prioritize regeneration. As these technologies advance, they have the potential to improve treatment outcomes and better satisfy patients demands for all-encompassing, conclusive solutions to their maxillofacial problems[2].

Maxillofacial cyborgology

Combining the terms cybernetic and organism, neurophysiologist Manfred Clynes coined the term "cyborg" in 1960 to denote a person who enhances or benefits from artificial means in their biological functioning and was reintroduced into the scientific literature following the work of Donna Harway in its cyborg manifesto[4]. These techniques modifies the body biochemically or electronically. Jean Claude Heudin proposed an extensive classification of cybernetic phenotypes from robots to avatars[5]. Robotic and biological cybornetic organisms are the two subcategories of cyborgs. Robotic Cybornetic organisms are groups of organic molecules (e.g., the Terminator) on artificial structures that eventually become humanoids which exist in science fiction only. Conversely, those with sophisticated prostheses (robocops) are considered biological cyborgs and are already a part of our environment.

Augmented Vision

AR finds application in managing visual impairments like low vision, color vision deficiencies, blindness, and visual field defects (Amblyopia, Nyctalopia, and Metamorphopsia) HMD-based AR systems and smartphone-based AR systems are the two main types of AR prototypes. HMD-based augmented reality systems comprise both home-built and commercially produced AR systems, such as those made by Google and Microsoft. Google Glass is a wearable computing device with an optical head-mounted projection which works by combining both augmented and virtual reality. Google introduced it in April 2012, and the Google X lab developed to work based on the Android operating system6.

Working Principle & Components

Google Glass is built in with tiny chips that house a speaker, battery, video display, and camera. It has an Android-powered hands-free display and can establish Wi-Fi and Bluetooth connections with a phone. To record pictures and scenes that are within the wearer's field of vision, tiny camera chips are used. On the video display, information is provided in a pop-up manner for hands-free viewing.

A. Video Display

Its options with the tiny video display screen that's display the crop up hands free data.

B. Camera

It has the front facing video camera with that photo and video can be taken in it.

C. Speaker:

Google glasses are designed to be hands free wearable device which will be build or receive calls too. Therefore, a speaker is additionally designed by the ear.

D. Microphone

A mike is additionally place in, which will take the voice commands of the user.

One of the major concerns of Google Glasses is the possibility of privacy violations regarding the user. Being expensive, only surgeons, military, astronauts, and elite athletes can use it. A British start up, Place Ltd® unveiled the MindRDR® device in 2014, merging a control system with Google glasses®. This technology detected brain waves and converted them into commands for augmented reality using a Neurosky® electro encephalography biosensor placed on the user's forehead[7]. A patent application for electronic contact lenses that display augmented reality was also made by Google® in 2016. Although this new device uses nanotechnology to fit inside the polyethylene terephthalate lens,it can be used for medical application by examining the fluids on the cornea's surface[7-8].

Augmented Olfaction and Taste

The human nose is far more complex than the ear or the sight, especially when it comes to the systems that initiate the initial reaction to an external stimuli. On the other hand, hundreds of different types of biological receptors are involved in the sense of smell. Electronic noses have made many interesting advances, but they still don't perform as well as our sense of smell does. Artificial olfaction, utilizing "electronic noses" consisting of three major components: a sample handler, multiple gas sensors, and a signal processing technique.

An electronic nose is a machine that is designed to detect and discriminate among complex odoursusing a sensor array.

A) Sample Handling System

To introduce the volatile compounds present in the headspace (HS) of the sample into the e-noses detection system, several samplingtechniques have been used

1) The Static Headspace (Shs) Technique

2) Purge And Trap (P&T) And Dynamic Headspace (Dhs)

3) Solid-Phase Micro-Extraction (Spme)

4) Stir Bar Sorptive Extraction (Sbse)

5) Inside-Needle Dynamic Extraction (Index)

B) Detection System: Sensors

1) Metal-Oxide Sensors

2) Conducting Polymer Sensors

3) Optical Sensors

4) Gravimetric/Acoustic Sensors

5) Quartz Crystal Microbalance Sensors

6) Saw Sensors

7) Love-Wave Sensors

C) Pattern Recognition Methods

The sensor array gathers intricate information that is able to be viewed and understood by humans. It is also possible to send the data which represents the particular molecule measured to a computer for automated analysis that simulates human smell.

In 2012, a French start-up called Aryballe Technologie® created an artificial nose that could identify and assess smells. It's more of a peripheral technical device, slightly larger than a smartphone, that can identify up to fifty distinct scents than a true facial prosthetic9. Apart from its usefulness in the food sector, the apparatus has the ability to identify scents that are imperceptible to human sense organs. A 2016 invention by Japanese scientists at the University of Tokyo's Rekimoto Lab is an electronic fork that stimulates taste buds to replicate the flavor of salt.[10]

Augmented Hearing

By making the sound audible, hearing aids serve to treat hearing loss. The American Society Sonitus Medical® researchers came up with the idea to use a detachable experimental prosthetic device called Soundbite®[11], mounted at the level of the dental organs, to transmit sounds through bone conduction in cases where the patient has a healthy inner ear but abnormalities of the external auditory duct and/or tympanic membrane. The receiver is placed on the ear, on a pair of glasses, or on a jacket pin in order to record ambient noises.

Soundbite Technology

The SoundBite hearing system is an intraoral device created by Sonitus Medical[12]. The SoundBite hearing system works on bone conduction, it may produce sound without the need for a working middle or outer ear. Bypassing the middle and outer ears completely, the SoundBite hearing device is made to enable sound to pass via the teeth, bones, and cochleae. The SoundBite is designed to help people with SSD, conductive, or mixed hearing loss regain normal hearing without the need for surgery by employing bone conduction via the teeth.

Components of Soundbite

The SoundBite hearing system consists of a discrete, detachable in-the-mouth (ITM) device and a behind-the-ear (BTE) microphone unit that houses the receiver, wireless transmitter, and attached microphone. The tiny microphone is put in the affected ear canal, where it is fitted with an open dome to pick up noises. The SoundBite hearing device is designed to take advantage of the patient's own pinna, or outer ear, which naturally possesses the ability to capture and guide sound by placing the microphone in the ear canal. Following microphone capture, sound is processed by the BTE digital audio device and wirelessly sent to the detachable ITM hearing aid. Through the use of cutting-edge technology, the ITM gadget produces subtle sound vibrations that go through the teeth, bone and cochlea.

An innovative low-frequency gadget known as an audio implant[12] was created in 2002, but it was not removable,the process involved implanting a sensor to detect noises in the inner ear through bone conduction in a prosthetic tooth. One advantage was that voices seemed crystallike due to the ability to detect vibrations below the average apparent frequency.

3D Bioprinting

3D bioprinting is the process of printing biomaterials, bioactive factors, and even cells with precise placement and spatial control to recreate human tissues and organs that closely resemble their natural counterparts in terms of both structure and function. The technique is based on the additive manufacturing which is combination of tissue engineering and 3D printing[15]. One area of regenerative medicine called tissue engineering uses patient cells to make autologous grafts. Murphy and Atala described 3D bioprinting as, "layerby-layer precise positioning of biological materials, biochemicals and living cells, with spatial control of the placement of functional components (extracellular matrix, cells and pre-organized microvessels) to fabricate 3D structures."[16]

Phases of Bioprinting

1. Pre-Bioprinting Phase: During this stage, materials for bioprinting are selected and models are made. Upon organ biopsy, cells are combined with a specific liquefied medium.

2. Phase of bio printing: In this stage, patients' scans are analysed to determine the extent of the defect and bio inks are inserted into particular cartridges. Bioinks are applied in accordance with the defect to produce the proper "printed tissue."

3. Post-processing phase: Printed constructs are placed in bioreactors during this step, which can be either a basic incubator or a culture environment that has been specially created to allow for the management of environmental factors that impact biological processes. The tissue has access to the nutrients and maturogens.

Bioink

A bioink is an integration of either differentiated cells or stem cells and fluidic biomaterial[17]. It is comparable to the cell-containing extracellular matrix, which forms the scaffold when correctly deposited and polymerizes or cross-links. As the technology has advanced, it is now possible to deposit many components of bioinks with exceptional accuracy, simulating the intricate architecture of human tissues, when previously only a single bioink could be deposited. The specific application, the kind of cells, and the bioprinter to be utilized all influence the choice of bioink.

Types of Bioinks[18]

1) Natural biomaterial based bioinks

2) Synthetic biomaterial based bioinks

3) Cell aggregate/pellet-based bioinks

4) Commercial bioinks – Dermamatrix, Novogel

Methods for Bioprinting

1. Stereolithography is the earliest method of 3D printing. It polymerizes photocurable resin layer by layer using a laser beam. Its original purpose was to produce quick, high-resolution prototypes; as a result, its applicability in bio fabrication is restricted by the absence of compatible resins. But as resins become more biodegradable and biocompatible, stereolithography is emerging as a promising bioprinting method. It allows for the creation of intricate shapes and microstructures and can repeat at high resolution.

2. Extrusion-Based Bioprinting is the nozzle-dispensed delivery of viscous bioink containing biomaterials, biomolecules, and cells. molten or viscous liquid extruded as a continuous strand of individual dots through a nozzle. The loose model can be layer-by-layer stabilized after printing[19]. The printed "tissue" appears to have up to 90% cell viability despite increased stresses and temperatures. The viscosity of the material and possible leaks can influence the resolution. It offers restricted mechanical rigidity as well.

3. Laser-Assisted Bioprinting, material is transferred from a source film onto a nearby receptor substrate in the form of a microdroplet with the use of a laser beam guided direct writing technique. In addition to the questionable survivability of the cells in comparison to other 3D printing methods, laser-assisted bioprinting has been demonstrated to print mammalian cells without compromising their functionality. Additionally, this method offers high resolution and works with a variety of biomaterial viscosities. The main drawback is reduced cell viability.

4. Inkjet Printing creates ahighresolution 3D images by using tiny cell droplets. Cell survival at higher temperatures and pressures during the printing process, resulting in low cell density within the 3D biomodelis one of the main disadvantages. This method benefits include printing complicated structures at high resolution and combining different cell kinds.

3D Bioptinted Maxillofacial Application

The current state of bioprinting technology is insufficiently advanced to draw in the funding required for proper development and to proceed to meaningful clinical trials. Since the inks utilized in the technique did not contain any organic components, despite the fact that various medicinal applications have been described, they more closely align with the concept of 3D printing than bioprinting. For instance, implants used in cranioplasty[20] are made especially to address defects in the bone. The protocol states that the patient's tomographic data must be used to determine the implant form and cutting guide. A synthetic bone structure created in vitro is then used to fill the patient deficiency. This procedure has been carried out using printed hydroxyapatite, polyetherketoneketone (PEKK), or polycaprolactone (PCL) inks[21]. Research on oral bone-mucosa composites for palatal defect reconstruction has also been done[22].Within the field of maxillofacial reconstruction, the same 3D printing technique proved beneficial for ear and nose reconstruction[23]. Instead of using cartilage, printed acrylonitrile/butadiene/styrene (ABS) scaffolds coated with hydrogel and chondrocytes or secondary coated with fibronectin for biocompatibility were used to replace the cartilage. Another group even printed an ear that could hear noises that a typical human ear cannot by seeding alginate hydrogel with chondrocytes and combining it with a conductive electronic antenna[24]. The nanoelectronic components' integrated silver nanoparticles allowed the signals from the cochlea-shaped electrodes to be read out. This proof-of-concept ear showed enhanced radio frequency reception auditory perception as well as stereo audio perception.

Monoscopic Photogrammetry in Maxillofacial Rehabilitation

The procedure utilized to extricate 3D data from 2D objects is called photogrammetry. The data is procured by taking pictures of target spots that reflect light, and after that utilizing those photographs to construct a three-dimensional model[25]. Utilizing the suitable facilitate frameworks, the common geometric relationship between the focuses and the picture is computed. This strategy includes taking all of the photographs with the versatile gadget from different statures and points, at that point nourishing the data into program to create a 3D model[26]. Since the mid19th century, photogrammetry has been utilized for 3D photography, which was developed from radar, polygonal and radiometry. Photogrammetry enables "Structure from Motion" (SFM), where software examines the common characteristics of each image describes and can build a 3D image from overlapping features using a complex algorithm that minimizes the sum of errors in the relative displacements of coordinates and reference points. This minimization is called "beam regularization" and is often performed using the Levenberg-Marquardt algorithm[27].

3D Maxilllofacial Reconstruction

1. The geometrically complicated architecture of orofacial structures must be analyzed using several reference points in order to discover lesions in those structures that are difficult to replicate using conventional approaches. This non-invasive technique also enhances appearance, which is crucial for correcting severe flaws. Large flaws including orbital, ocular, and ear malformations can be 3D deformed and their colors characterized more accurately using photogrammetry.

2. Evaluating and reconstructing the face: Digital facial scans are utilized in aesthetic dental planning to identify elements like smile line, symmetry, and prominence of dental treatments. Maintaining precise head alignment and camera distance, along with taking standard photos, is crucial. Imaginary horizontal and inverted lines are used to measure symmetry, with the incision line being homogeneous with the contact line.

3. 3D model production: To build models at various scales, from minute things to landscapes, photogrammetric techniques have been widely applied in multiple ways. In physical anthropology, critical skeletal components like skulls can be precisely analyzed using photogrammetric models. Researchers identified that only a minor amount of heterogeneity is present between point clouds of small objects from the structure from motion (SfM) and structured light scanning (SLS) methods[27].

4. Analyzing, designing, and visualizing facial teeth is essential in a number of related fields, including prostheses. Present methods regulate blockages using mechanical devices and casts, but acceptable and accurate images are only obtained from two-dimensional photographs. Using a novel photogrammetric technique, digital 3D models can be produced.

Procedure

Collection of Data

1. Position of the subject and the user

The patient was placed upright in a 45 cm-high chair, with one meter of floor space between it and the operator's position. The operator had 0° to 180° of lateral clearance, with 90° serving as the main area of interest to record. Floor clearance gave the operator enough space to maneuver around the subject while capturing the image. The wheelchair that the operator had wheels for mobility and was 30 to 50 cm tall adjustable. The subject should remove caps, glasses, accessories, and other objects that might obstruct the frame before capturing the photo.

2. Lighting

The room was lit enough to capture clear images with ambient light without flash or over or under exposure of the camera.

3. Applications and mobile devices

A 5 GHz Wi-Fi network connection was used to connect to the Internet. Using a smartphone free photogrammetry application from the Android store Google Playstore can be downloaded. The application configures the automated functions of the mobile phone to activate data collection when necessary.

4. Acquisition of images

The region of interest was the center of 15 conventional 2D images captured by a photogrammetry application. The operator raised the mobile phone to the level of his eyes, keeping a distance of 30 centimeters between his eyes. Standing, sitting and sitting on the wheelchair were the three heights at which the photos were taken. The application's "spatial location widget" checked the locations of the images and counted the number of images. After quality control, the item was removed from the site and the images were loaded for processing.

5. Overview of Photo Capture and 3D Editing

All photos captured on mobile have been downloaded from the 123D Catch® website and optimized for blending with the desktop version of 123D Catch®. The desktop version of 123D Catch® was used to open and review the *.3Dp file for initial analysis, while Autodesk Meshmixer (California) was used to open and edit the *.stl file. In Meshmixer®, the model was simply repositioned in space (using the x-y-z transform tool) to a straight position, the triangles outside the face were removed, and the model was rescaled to the clinically recorded internasal distance. Descriptive analysis was performed through 360° observation and all x-, y-, and z-axis angles, and the patient's facial model was captured. This final processed digital model, represent the correct shape and proportions of the original patient printed in polyamide model.

Discussion

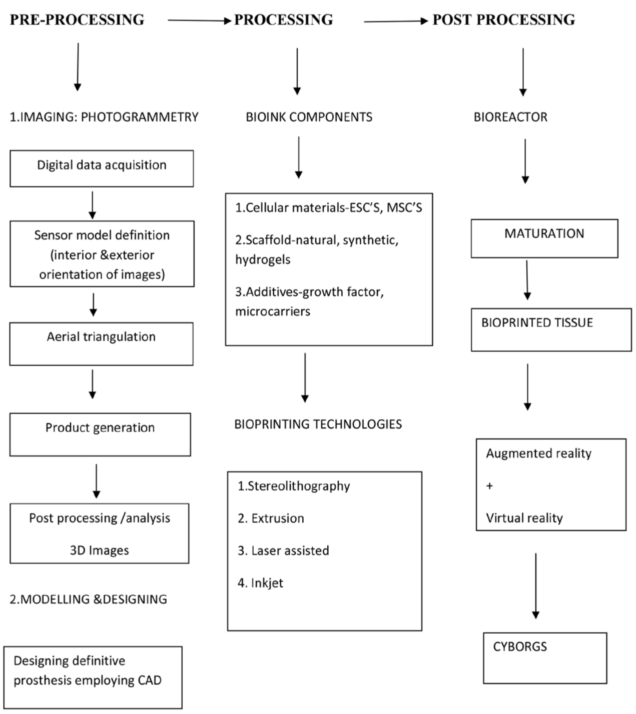
The new biotechnological methods promises a vast array of potential maxillofacial applications, but their entrace on the healthcare market is still undefined. The human organs are made up of different cell types, matrices, and complex configurations within each organ. Currently no method can produce an entire organ or tissue because of limitations in biomaterial compatibility, vascularity, resolution, and no defined regulatory framework for bioprinted constructs. As technology progresses in the realm of printing, and as more efficient and affordable printing techniques emerge, it's essential to establish and maintain quality control standards at every stage of the process, including during model design, choosing the bioink, verifying the printing, allowing the bioink to mature after printing, and evaluating the quality of the final product.

Bioprinting involves a series of steps, each of which must be carefully coordinated with the others. Perfusion bioreactors are anticipated to play a crucial role in the further integration of bioprinting technologies. However, beyond these future prospects, the most critical aspect will be the incorporation of bioinks with enhanced bioprintability and biofunctional characteristics. Currently, the majority of bio-based materials employed in bioprinting are derived from polymers typically used in tissue engineering, and they often lack the necessary rheological and crosslinking properties that are essential for a successful bioprinting process[29]. Moreover, given that the primary goal of bioprinting is to create functional tissue constructs, there is also a need for the development of more advanced assays capable of evaluating cell functionality within 3D structures. Given the rapid advancement of bioprinting technology and the widespread interest in this field across various scientific disciplines, it is anticipated that these challenges can be addressed, leading to the availability of bioprinted constructs for translational research and accelerating the drug development process.

Cyborgology modifies maxillofacial prosthesis, altering the wearer's body depiction and self-image, resulting in new body sensations and perceptions of their inner selves and surroundings[1]. More research is required to combine bioprinted organic materials with artificial structures to create a robotic, living entity. In the near future, beneficiaries of this multidisciplinary approach may be able to receive transformed tissues and organs along with better neurophysiological links to their surroundings. The advancement of maxillofacial prosthetics for the future needs constant ethical oversight[3]. Unfortunately, the scientists and engineers tasked with developing tomorrow's biotechnologies may not completely comprehend the implications of their creations for human evolutionary futures. This goes beyond simply replacing parts; it also includes restoring sensory capacities, which improve the brain's ability to comprehend information.

Digital facial impressions using mobile device photos enabled monoscopic photogrammetry to generate 3D models. A less expensive option to record the facial anatomy of patients using inexpensive free software. This would allow for the creation of physical working models, templates for facial prostheses, improved patient communication before and during treatment, and increased access to digital clinical solutions for clinical centers with limited technological resources. Standardizing a photo capture strategy[28] for data capture and processing is crucial since prolonged capture times with multiple images are prone to errors. The capture-to-print prototype process will be made simpler with a common photo capture technique.

In the fields of biotechnology and 3D scanning, extensive research is being conducted which promises, better future by overcoming challenges. While many of these technologies are in the developing state, this integrated approach can revolutionize future maxillofacial rehabilitation



Conclusion

This review has highlighted the role of various digital and biotechnologies 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. Advancement in technology has a profound impact on the maxillofacial restoration of form and function. However, creating indistinguishable maxillofacial prostheses continues to be a challenge.

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