Digitalising Dreams into Reality- Digital Orthodontics

Paridhi Gupta, Bhagyalaksmhi A, Raghunath N
JSS Academy of Higher Education and Research
Mysore, India
{pari_199311@yahoo.com} {drbhagyalakshmia@jssuni.edu.in} {dr.nraghunath@jssuni.edu.in}

ABSTRACT: *Digitalisation has been the talk of the town since the invent of mobile phones in our life and their continuous transformation. From diagnosis to treatment planning, practice of diagnostically driven robotic assisted (DDRA) orthodontics all have improved to a great extent. 1974, marked the year for a technological boon in the field of dentistry. Orthodontics has been reinventing itself to patient specific needs, evidence based care to establish new benchmarks. Virtual treatment planning is very common now-days along with digitally driven appliance manufacture using CAD/CAM techniques and 3D bioprinting. From Computed aided manufacture of hyrax devices, customized bracket production, soft tissue quantification in surgical cases to robotic wire bending, has led to the shift of the paradigm of orthodontics.*

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1. Introduction

Integration of the digital world with diagnosis, treatment planning, appliance design and manufacture is booming since the invent of CAD /CAM (computeraided design/computer-aided manufacturing). 1974, marked the year for a technological boon in the field of dentistry[1]. Digital radiology and photography have made most offices paperless. Recording of impression, construction of dental casts etc have now been replaced successfully by intra oral scanners.

Technology has enabled us to construct a virtual orthodontic patient, where bone, soft tissue and teeth can be recreated in three dimensions. The panacea of three dimensional digital conversion has been by the advent of CBCT (cone beam computerized tomography)[2].

From Computed aided manufacture of hyrax devices, customized bracket production, soft tissue quantification in surgical cases to robotic wire bending, has led to the shift of the paradigm of orthodontics.

Digitization has helped in:

• Diagnosis and treatment planning

• Appliance manufacture

• Compliance monitoring

• Individualized bracket manufacture

• Robotic wire bending

• Efficient biomechanics

• Reduce labour time

• Reduction in errors related to recording of impressions, and construction of appliance and wire bending

1.1. Diagnosis and Treatment Planning

The process of recording impresssions and pouring casts is no longer messy due to the advent of intra-oral scanners.

Traditional impression recording technique	**Intra oral scanners**
Time consuming Less time consuming	Increased gag reflex No gag reflex
Distortion of material over time	No distortion as it is saved as an image
Errors involving the pouring of casts	Models produced digitally
Difficult to transport	Files can be sent via internet
Problems in storage	Easy storage
Time consuming diagnostic setups and wax-ups required surgeries.	Softwares allow the orthodontist to perform virtual treatment plans and
Reduced patient motivation	Chair side patient motivation

Two dimensional radiography has been replaced by the three dimensional CBCT. Their accurate and efficient assessment in case of TMJ problems, orthognathic surgeries, pathologies, impacted teeth, root position andresorption, bone density is invaluable.

Three dimensional facial photography which is the latest trend can now be combined with CBCT and digital study models using various available softwares to give an overall outlook of the patient. Softwares also helps in inculcating smile designing along with mandibular movements in all planes for a full representation. It can help as follows:

1.1.1. 3D Surgical Simulation

Traditional methods have employed PA-cephalogram, lateral cephalogram etc for orthognathic surgeries which limit us in understanding the complex anatomy of such three dimensional structures. Registartion of landmarks can be done with multiple softwares like Dolphin Imaging, Maxilim etc. Surgical simulation on 3D models constructed from CBCT softwares.

With the development of CAS (computer aided surgery) and various softwares eg. CMFApp (Switzerland) etc the task can be made more precise and easy. The CAS system along with CMFApp software follows a particular procedure for jaw surgeries which is as follows 3:

• Data Acquisition
From the CBCT images, DICOM files are imported in the 3D software.

• Image Segmentation
Identify anatomic areas of interest both hard and soft tissues are segmented.

• Visualization
3D display of structures using surface based or volume based methods. Surface based methods provide high zoom factor for detailed analysis of facial surfaces.

• Diagnosis
Extract information from the 3D softwares. Cephalometry is performed , identification of landmarks, planes, analysis etc. Mirroring technique is applied in cases of asymmetries by using the contralateral side as reference. The software also integrates dental surface data obtained from scanning for occlusal evaluations and jaw movements during orthognathic surgeries 4.

• Planning and Simulation
To prepare a virtual surgical plan.orthognathic surgeries involve reconstructive or corrective interventions.Corrective interventions involve determining the site of surgical cuts without the need of an extrinsic graft. Whereas, reconstructive procedures involve to determine the shape and size of the graft or the implant 5.

• Intra-operative Guidance
Guidance during intra operative surgical treatment. Surface matching algorithms are used to register 3D photographs with CBCT skin urface. CAS system uses operative plans, real time measurements to guide the surgeon from a virtual surgery to the real time surgery.

Various Tracking Technologies are used for this Purpose such as:

A. Direct contact

B. Ultrasound

C. Electromagnetic

D. Optical

Registration establishes correlation between virtual and tracking coordinate systems.The non deformable bony structures are called rigid transformation which constitutes the relation between the coordinate systems. The monitor displays the location of the pointer with graphic movement guides and cephalometric as well as movement of pointers being updated in real time.

Registartion of landmarks can be done with multiple softwares like Dolphin Imaging, Maxilim etc. Surgical simulation on 3D models constructed from Registartion of landmarks can be done with multiple softwares like Dolphin Imaging, Maxilim etc. Surgical simulation on 3D models constructed from CBCT softwares.

1.1.2. Printing of Surgical Splints and Prediction of the Soft and Hard Tissues
Three dimensional imaging technology provides us with new computerized tool for more accurate fabrication of surgical splints. Aboul-Hosn Centenero S, Hernandez-Alfaro F. et al conducted a study to evaluate the efficiency of surgical splints fabricated using 3D printing vs standard protocol. To construct surgical splints using CAD/CAM technology three steps were followed

• Three Dimensional Image Acquisition
Images from CT/CBCT images were stored in DICOM(Digital Imaging Communication in Medicine) software. 3D images were obtained from DICOM files using various algorithms.Dental casts were scanned using an optical 3D laser with a resolution of 20 micron, by surface rendering.The CAD/CAM Centre constructed 3D images of the patient's craniofacial skeleton together with images of their dental casts superimposed on their dental arches and images of facial soft tissue surrounding these structures.

• Three Dimensional Planning

Using the images osteotomies, repositioning of segments were performed.

• CAD/CAM Surgical Splints

3D treatment plans were sent to the CAD/CAM centre for the manufacture of stereolithographic surgical splints. software used various algorithms to orient the cast in centric occlusion.After the simulation of the surgical cuts linear and angular measurements from preoperative images were used to predict the results.

1.1.3. Aid in the placement of Mini-implants

TAD(temporary anchorage devices) or mini-implants are now the bread and butter of anchorage preservation, but placing them can be challenging especially palatal mini-implants. Gabriele et al decribed a guide called as Easy driver for palatal mini-implant insertion and placement[6].

Procedure

• Silicone impressions are recorded and then scanned to create stereolithographic files.

• These images are superimposed with lateral cephalogram or CBCT scans

• Precise location of implants in accordance with the anatomical location is decided based on virtual planning softwares.

• Prototyping process aids in construction of an Easy Driver surgical guide for the location of implant and the implant can be inserted using this guide through a contra-angled hand-piece.

1.2. Digital Appliance Manufacture

• CAD/CAM technology has been used for printing models for aligner therapy. It uses the virtual setup technology to create the desired outcome and then manufacture appliances to fulfill these pre-set outcomes. Inter-proximal stripping, positioning of precision attachments for tooth movements all is done well in advance.

• Robotic archwire bending is more efficient and precise as compared to that of manual bending techniques which are laborious and time consuming. Robotic wire bending method utilises three dimensional digital expression. The archwire segment between the bracket grooves is the straight segement and the end point of the bracket are used to define the tooth positions. The shape, position, and constraint relationship of orthodontic archwire in threedimensional space are expressed by the Bessel curve[7].The archwire bending can be done by adjusting the control points and a series of parameters.

• Wire bending is required during finishing and detailing which is cumbersome and time consuming. Sure Smile system provides intra-oral scanning of both the arches with fixed appliance therapy in place. Virtual models are then created and wires are bent robotically with precision to bring about desired tooth movement[8]. Data from CBCT scans can also be merged with the intraoral scans to determine root positions for efficient biomechanics. 3D facial photopgraphs can also be added for smile analysis.

• Indirect Bonding trays can be manufactured using intra-oral scanning and CAD/CAM technology for accuracy and overall reduction in time[9,10].

1.3. Direct Applaince Manufacturing

With the advent of 3D printing technology and biocompatible resins appliance can be directly manufactured. But with this booming technology now metallic appliance too can be constructed and hence eliminating the need for banding, soldering, impression taking etc.

1.3.1. Computer Aided Hyrax Appliance Construction

• Graf and his colleagues studied the feasibility of digitally constructed hyrax expanders. To construct the expanders oral scans were recorded and were sent to a laboratory. The hyrax was designed using 3Shape Appliance Designer software. Clasps on molars replaced bands and were moulded to surround the molars and cover the palatal surface. Hooks were placed on buccal as well as palatal side to facilitate debonding. A screw (12mm) was digitally inserted and the apliance was constructed with ideal welding area to accomodate the screw. After the final designed was approved by an orthodontist it was sent to laser melting machine. The metal alloy chosen was Remanium Star as it is available in powdered form. After which the screw was welded onto the prepared surface[11].

1.3.2. Quantification of Soft Tissues using 3D

Soft tissue and their modification with growth are pretty complex and hence two dimensional study are not reliable. The CBCT scans to study facial changes are acquired in high voxel size to study the entire face. Acording to Cevidanes et al the images to evaluate changes over time were analyzed in a sequence of 4 steps:

- Model construction
- Image registration
- Transparency overlay
- Quantitative measurement

3D Surface models were constructed using open- source software (ITKSNAP). Surface based model was created for registration as opposed to volume based models. Surface-based method helps in establishing boundaries between anatomic structures and assigns different colours for maxilla, mandible, cranial base etc. The IMAGIne software was then used to mask structures that have been displaced due to growth. The grey level intensity is of each voxel is compared to register the different CBCT images. In individuals where growth is complete data from entire cranial base is used for comparison. For growing individuals, first registration involves head orientation using whole cranial base followed by second registration on the stable structures of anterior cranial base.

After this, CMF software (Switzerland) 3D models are registered in the same coordinate system. This software identifies bone, soft tissues and measures the change in facial proportions and displays them as coloured maps.change are quantified using coloured maps where blue indicates inward and red indicated outward movement.

1.3.3. 3D Visualization of Root Resorption during Orthodontic Treatment

Use of micro CT for visualization of the resorption craters and their volumetric study using the softwares . It can also help in determining the shape of root canals and making RCT (root canal treatment) easy[12,13].

1.4. Compliance Monitoring

Compliance in orthodontic patients has always been a mattter if concern. From wearing orthopaedic appliances to removable ones, elastics etc. Digital monitoring of appliance by incorporation of some monitors can help us achieve better and efficient orthodontic treatment in terms of compliance.

Stocker et al. recorded the wear time of a facemask in a class III patient using a sensor chip wear time[14]. A 9-year-old boy with a Class III malocclusion was treated with alternate rapid maxillary expansion and constriction protocol along with application of a protraction facemask. In order to monitor and ncrease the compliance of wear TheraMon chip was integrated into the frontal support pad of the facemask. The chip consists of a battery and temperature sensor which is adapted to an extra-oral threshold. The data is then transferred to the computer and the TheraMon software calculates and draws a wear-time graph. It hepls in assessing a patient's compliance, assists in the determination of the effectiveness of the treatment protocol.

An italian group SuperPowerMe brought about customization and gamification of facemask wear[15]. In addition to 3D printed customized facemask for better comfort, sensors are incorporated into the appliance to measure the compliance and also to link it up with a smart device application that turns to a computer game. The child can play the game only while wearing the facemask. This not only encourages compliance but makes wearing the orthopaedic appliance more fun and entertaining for children.

1.5. World of Applications and Technology

• People reply more and more on mobile phone apps and technology.Using various apps patient can scan their teeth and face and send the data to the orthodontist, hence patients are not required to attend the office physically until an adjustment is necessary.

• Apps can be paired with 3D technology and can alert the patient when the wire becomes passive so that they can schedule an appointment with the dentist[16].

• Clear aligner and technology have taken one more step where the technology not only alerts the patient if the aligner is a slight misfit, it also guides the patient and the orthodontist on whether they are ready to progress to the next aligner or not.

Conclusion

It is likely that with the rapid increase in simplicity and availability of rapid prototyping and 3D printing orthodontic manufacturing will change dramatically. In the future orthodontic clinics will have desktop printers and most appliances will be constructed locally and custom made for every patient. Wire bending robots would be easily available. Smartphones will be able to perform accurate intraoral scans obviating the need for intra-oral scanners. Technology will bring about a shift of paradigm towards smarter dentistry.

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