World Academy of Science, Engineering and Technology
International Journal of Biomedical and Biological Engineering
Vol:6, No:12, 2012

Scope and Application of Collaborative Tools and Digital Manufacturing in Dentistry

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***Abstract*—**It is necessary to incorporate technological advances achieved in the field of engineering into dentistry in order to enhance the process of diagnosis, treatment planning and enable the doctors to render better treatment to their patients. To achieve this ultimate goal long distance collaborations are often necessary. This paper discusses the various collaborative tools and their applications to solve a few burning problems confronted by the dentists. Customization is often the solution to most of the problems. But rapid designing, development and cost effective manufacturing is a difficult task to achieve. This problem can be solved using the technique of digital manufacturing. Cases from 6 major branches of dentistry have been discussed and possible solutions with the help of state of art technology using rapid digital manufacturing have been proposed in the present paper. The paper also entails the usage of existing tools in collaborative and digital manufacturing area.

***Keywords*—**Customisation, collaborative tools, dentistry, digital manufacturing.

I. Introduction

DENTISTRY like any other field is facing newer and higher challenges every day. In order to obtain solutions to these new problems it is often necessary to seek help from experts in other fields like engineering. An attempt to incorporate technological advances in the field of engineering into the field of dentistry has led to formation of quality collaborations in the two contrasting fields. The improved communication and interaction tools have reduced the barriers of long distances. Faster communication tools have enabled different experts from different lands to discuss ideas, share their knowledge and improvise on their thoughts and get instant feedbacks.

Collaboration can be defined as a recursive process where two or more people work together on an intersection of common goals, by sharing knowledge, learning, and building consensus.

Collaboration tools can be the devices or media that enable remote collaboration Advances in information and communication technology (ICT) have opened new possibilities of collaborations among doctors, engineers, suppliers, manufacturers and partners to effectively tackle digital manufacturing.

Collaboration can begin at any point of time. Collaborations are of two types, online or offline. In offline collaboration usually people meet and get the work done. In online collaboration, people will exchange ideas, share files and meet virtually and get the work done. In this paper a framework is designed for online (Web-based) collaboration wherein a separate portal is created. The designed parts/ assembly are manufactured using RPT in forward and reverse engineering.

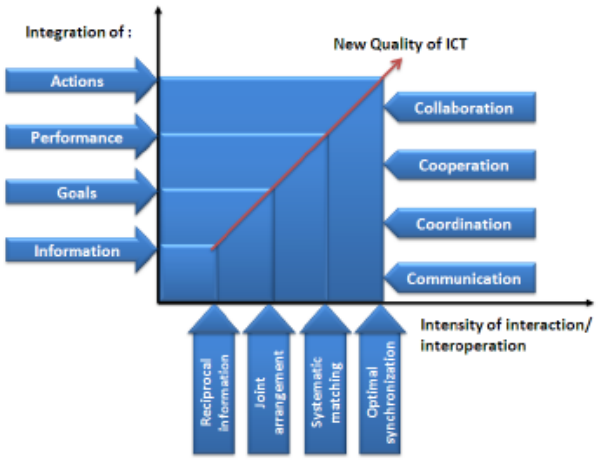

Fig. 1 Collaboration ability enabled by advanced technology [1]

Problems faced by doctors working in 6 different departments in dentistry were tackled with the help of web-based collaborative tools. Web based collaboration enabled effective problem solving with phase control.

Rendering the best quality treatment is the ultimate goal of dental health services. The therapeutic modality should be precise, cost effective, and easy to handle or operate and should reduce the possible risks which the conventional modalities bear. These all goals can be achieved by customization of the treatment. These requirements can be fulfilled by good collaboration and incorporation of digital manufacturing in all branches of dentistry. Cases from all the dental specialties and their possible solutions drawn by collaboration and digital manufacturing will be considered in this paper.

II. Methodology

A separate web portal has been created for collaboration with a framework inclusive of collaboration and digital

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manufacturing. Collaboration can be achieved by sharing files, photos, videos and other information between doctors, engineers, patients, etc. The digital manufacturing can be tracked and controlled by different phases based on the product to be manufactured. Phases can be identified by different color code.

Forward and reverse digital manufacturing usually consist of computer aided design (CAD) and rapid prototyping technology (RPT). Most of the applications require a 3D scan of the patient which is then converted into a virtual model. Either this virtual model is converted to a physical model to plan the treatment or the prosthesis is designed on this virtual model and is manufactured using digital manufacturing techniques. The process of RPT is divided in 6 steps [2]:

- Imaging using CT/MRI Scan
- Acquisition of DICOM files
- Conversion of DICOM files into .STL files
- Evaluation of design
- Surgical planning and superimposition if required
- Additive manufacturing and creation and validation of the model

A. Department of Prosthodontics

Deals with removable and fixed treatment modalities for dental and maxillofacial prostheses

Case 1: Missing ear due to accident or a congenital anomaly. It is 2nd most common craniofacial malformation after cleft lip and palate. This problem can be solved by surgical correction or fabrication of artificial ear as a substitute. As surgical correction is extremely expensive, it is not opted by most of the patients. Conventionally, implants are placed in the region of missing structure for anchorage. Impressions of missing ear area are made, poured in dental stone, wax carving is done. The wax up is flasked and packed with silicone in 3 parts with different shades. This process is laborious, time consuming and technique sensitive.

Proposed method: The existing ear can be scanned; a virtual mirror model is made for accurate duplication [3]. The virtual mirror model is converted into prosthesis using RPT. Shade adjustments can be made by controlling the color change achieved by differing the laser exposure during layer wise deposition in the manufacturing process. A maxillofacial prosthesis thus made will simulate the pre-existing structure in all dimensions including color and esthetics. This method reduces the time, less laborious and enhances the quality due to maximum precision [4].

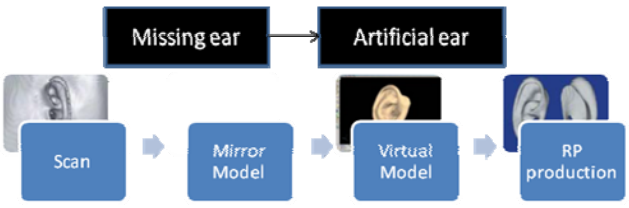

Fig. 2 Proposed method for ear replacement

B. Department of Oral and Maxillofacial Surgery

Deals with a wide spectrum of ailments from extraction of teeth, carcinoma resective surgeries, treatment of craniofacial anomalies including clefts, trauma and orthognathic surgeries. To simplify the surgical planning, 3D models depicting the actual anatomy and pathology are made.

Case 2a: Myxoma of Temporo-mandibular joint (TMJ) needing resection. This rare benign tumor of viral origin affects the normal movement of the temporo-mandibular joint restricting the mouth opening. This problem can be solved by surgical resection of the joint and replacement by artificial joint either of metal or contoured bone graft with intervening muscle flap. Conventionally, CT scan is made and the extent of pathology is judged from the CT slices, accordingly resective surgery followed by reconstruction surgery is planned.

Proposed method: The pathology is delineated in the 3D scan and differentiated in the actual model with contrasting colors using a 2 color modeling process. The resin used has 2 dose responses, initial dose solidifying the resin followed by colour change dose [5]. This helps the surgeon to actually gauge the extent of lesion and reduce the time duration of the surgery thus reducing the anaesthetic exposure to the patient. Templates are made on the 3D scans to guide the surgeon at the time of the surgery. Similarly metal prosthesis can be designed before surgery and can be placed at the same time as the resective surgery so as to minimize the psychological and functional trauma to the patient. Similarly, artificial TM joints can be designed for TM joint ankylosis cases or hemifacial microsomia cases.

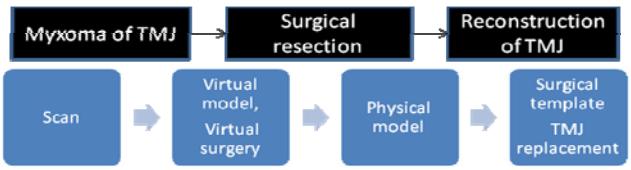

Fig. 3 Proposed method for resection and reconstruction of TMJ

Case 2b: Craniofacial anomalies, like clefts, are common congenital defects with multifactorial etiology. Conventionally, reverse pull head gears or extraoral distractors are used to advance the maxilla. These treatment modalities adversely affect the velopharyngeal competence worsening the voice clarity. Anterior maxillary distraction is a preferred treatment modality which advances the maxilla while maintaining the voice clarity. For better prediction of treatment outcome maxillary distraction requires maximum customization as every patient and each defect is unique. Distractors need to be custom made or adjusted to the desired vector of bone formation. Rapid palatal expansion screws are used intraorally to carry out anterior maxillary distraction. But their activation has a side effect of anterior open bite stressing on alteration in the plane of orientation of the appliance.

Proposed method: These customized appliances are designed in CAD and converted into .STL files and then

manufactured using RPT. The treatment outcome is more predictable in such cases enhancing the quality, reducing the risks for the patient and decreasing the technique sensitivity.

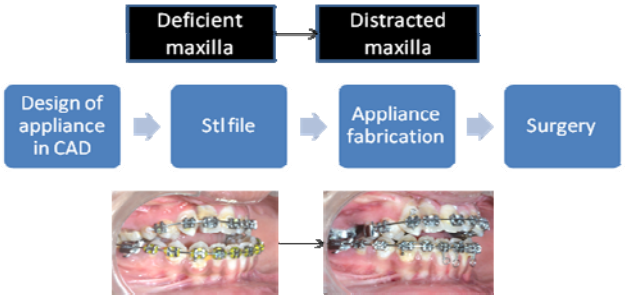

Fig. 4 Proposed method for customisation of Distractors

C. Department of Orthodontics

Deals with alignment of teeth control and redirection of growth and surgical correction of disproportionate jaws

Case 3: Delayed tooth movement. Delayed response can be attributed to many factors one of which is inappropriate archwire fabrication. Each appliance, right from bracket design, prescription, wire dimension, arch form, anchorage devices need to be customized. The wires are shaped into an archform custom made for each case to maintain the intercanine width and improve the stability. Traditionally, impressions of the dentition are made and the wires are formed and co-ordinated for both the jaws. Any error in the archwire fabrication delays the treatment and expansion of the arch form increases the tendency of relapse. At present either preformed wires are used or wires are formed into customized arch forms at the chair side. Preformed wires tend to increase the inter-canine distance, reducing the stability of treatment outcome [6]. Hence, custom made wires are preferred [7]. But this demands skill and inaccuracy in fabrication leads to distortion of arch form and increased treatment duration. Fabrication of lingual arch wires is more critical as even thinner wires exhibit more stiffness due to increased inter bracket distance. For lingual treatment a template is made using silicone material which guides the archwire fabrication.

Proposed method: The dentition is scanned and treatment is simulated on virtual models. This simulation can be used to determine the best possible approach for the patient as well as to educate the patient about the possible outcome of the treatment. Precise fabrication of archwires using RPT avoids unnecessary and undesired tooth movement and thus reduces the chair side time and total treatment duration.

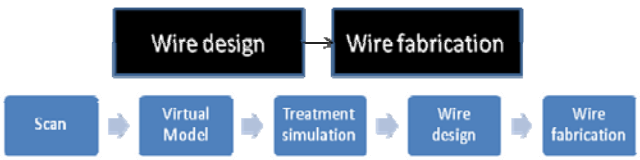

Fig. 5 Proposed method for Orthodontic archwire fabrication

D. Department of Endodontics

Mainly deals with restorations and root canal treatments

Case 4a: Extensively carious teeth. Grossly destroyed carious teeth require fabrication of post and core for restoration. Conventional method includes post space preparation, making impression of the post space and casting of post which is laborious and technique sensitive. Readymade posts are also available but not as accurate as custom made posts [8].

Proposed method: Post space is scanned for digital output. This makes digital designing and accurate manufacturing of posts possible improving the fit and saving the time of the patient and doctor.

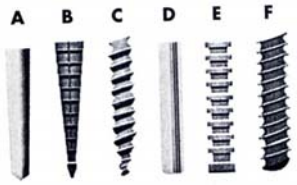

Fig. 6 Perfabricated posts for restoration of endodontically treated teeth

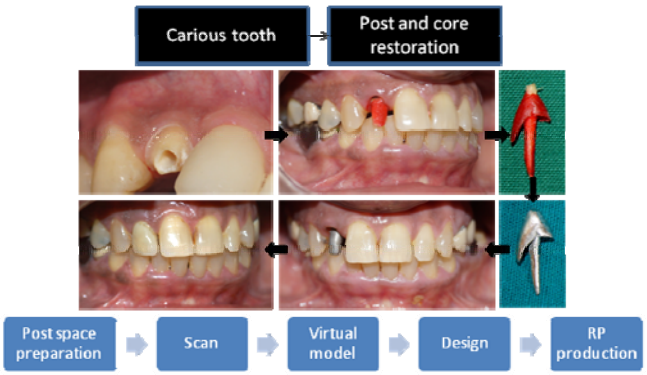

Fig. 7 Proposed method for restoration of endodontically treated teeth

Case 4b: Displeasing smile due to irregularly arranged teeth. Orthodontic alignment of teeth requires period of 12-24 months. Many patients demand for quick treatment. Conventionally, such cases are treated with minimal tooth reduction and placement of veneers for upper 6 front teeth for smile designing [9]. The treatment simulation is done using softwares like Adobe photoshop, crown preparation is done, impressions are made and casts are poured. One impression is made to fabricate the temporary restoration. This procedure requires a lot of lab work and is technique sensitive. Accurate shade matching and characterization are essential for rendering a beautiful natural smile.

Proposed method: 3D scan of dentition is obtained and converted into virtual models which are used for treatment virtually, simulation of treatment is viewed and finally veneers are designed. .STL files of veneers are manufactured using RPT followed by post processing for esthetic enhancement. This procedure reduces the treatment duration to a single

sitting cutting down on the need of temporization. This also minimizes the element of error leading to a better fit.

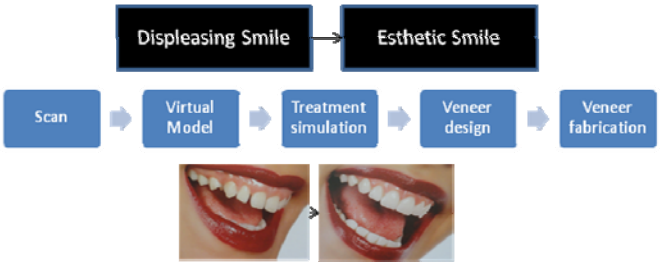

Fig. 8 Proposed method for esthetic dental treatment

E. Department of Pedodontics

Deals with dental treatment of children

Case 5: Patient requiring early extraction of milk teeth due to extensive caries. Premature exfoliation of milk teeth has deleterious effects on the dentition of the child. It can prolong the eruption of the succedaneous teeth and lead to migration of adjacent teeth resulting in crowding of teeth. To avoid this, space maintainers are placed after loss of the milk tooth. Conventionally, impressions are made after extraction and space maintainers are fabricated on the cast. This is technique sensitive and requires time.

Proposed method: Designing and fabrication of space maintainers is accomplished before the extractions are done on the virtual models derived from 3D scans, thus minimizing the time gap and hence the space loss subsequent to extraction of milk teeth. It improves patient compliance and comfort.

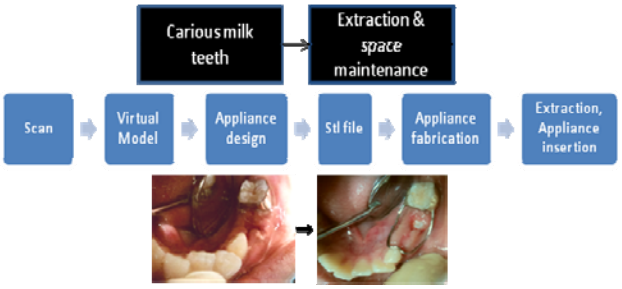

Fig. 9 Proposed method for pedontic applications

III. Discussion

The entire process from posting requirements to dispatch of the product can be explained in the form of a flow chart (*Fig10*).

After examining a particular patient, if the doctor needs to customize any appliance, he/she posts the requirement on the portal. If the company decides to take up the project, the company engineers design the appliance and send it to the doctor for acceptance. The doctor specifies any modifications if needed or gives acceptance or rejection. After the doctor accepts the design, it is referred to the experts for opinion. If the doctor accepts the expert suggestions, the modified appliance is finalized. The patient can view total process, final appliance design and comment on it. Then the appliance is manufactured, assembled, post processed if required and dispatched. The digital manufactured part/assembly/appliance is used in surgery to get a quality treatment and other advantage over conventionally manufactured appliance.

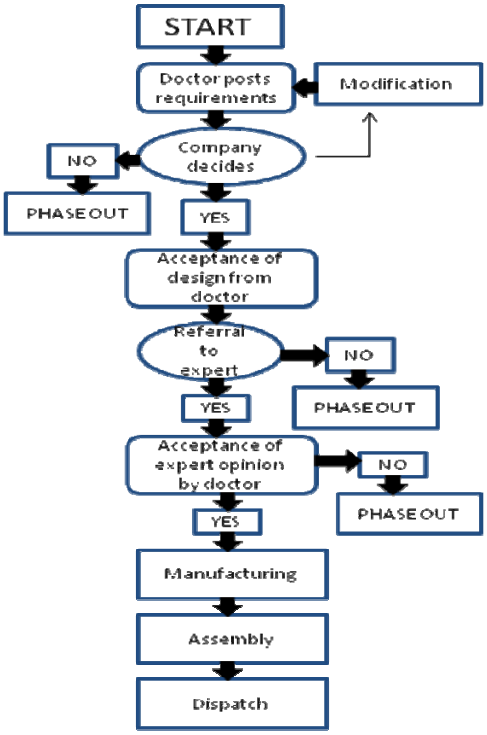

Fig. 10 Flow chart depicting the process of collaboration and digital manufacturing

During the treatment by collaboration and digital means, the patient can tract and seek any sort of clarification during all the phases as illustrated in the Fig. 11.

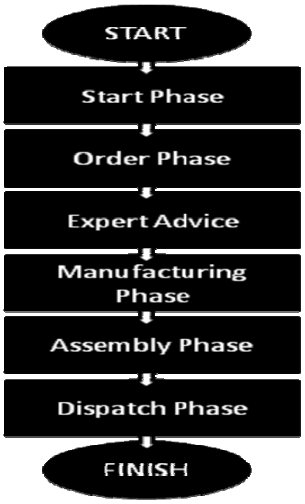

Fig. 11 Flow chart depicting the phases of web-based collaboration for digital manufacturing

IV. Results

Conventional and proposed methods were compared with critical qualities of the treatment modalities as shown in the table. The proposed methods are less technique sensitive with better prediction of treatment outcome which have quality treatment and patient satisfaction.

TABLE I
COMPARISON OF METHODS

	Conventional Method							Proposed Method						
Case No.	***S***	***T***	***Q***	***L***	***A***	***R***	***D***	***S***	***T***	***Q***	***L***	***A***	***R***	***D***
1	√	√	x	√	x	x	▲	x	x	√	x	√	x	▼
2a	√	√	x	--	x	√	▲	x	x	√		√	x	▼
2b	√	√	x	√	x	√	▲	x	x	√	x	√	x	▼
3	√	√	x	√	x	--	▲	x	x	√	x	√	--	▼
4a	√	√	x	√	x	--	--	x	x	√	x	√	--	--
4b	√	√	x	√	x	--	▲	x	x	√	x	√	--	▼
5	√	√	x	√	x	--	▲	x	x	√	x	√	--	▼

S: Technique sensitivity, T: Chairside time requirement, Q: Quality of treatment, L: Laborious, A: Accuracy, R: Risk/ surgical re-exposure, D: Treatment duration, ▲Increase, ▼Decrease

V. Conclusion

The typical cases of dentistry which are to be dealt with recent tools and applications of collaborative digital manufacturing are discussed in the paper. The paper is an outcome of the real synergy and collaborative research between the SDM College of engineering and technology and the SDM College of Dental Sciences, Dharwad, Karnataka, India. The case of maxillofacial prosthesis, missing ear clearly indicates the saving in time, labor and dupliation in every aspect. The case of myxoma of TMJ is yet another case in which the surgeons deploy virtual model and within no time produce the physical RP model and have a choice of material for actual scope of production of artificial TM joints for ankylosis, hemifacial microsomia etc. Similarly, the case of deficient maxilla and all other craniofacial anomalies which demand rapid and accurate production of mechanical elements, digital manufacturing is an ideal tool. The paper throws light on the entire range of application of RPT or digital manufacturing and use of the state of the art CAD, CAE and other digital technologies in the departments of orthodontics and endodontics which give faster solutions for routine high volume popular treatment like root canal therapy, esthetic replacements and also pedondontic applications. In a nutshell, the paper emphasizes the need of integration of engineers practicing doctors for a much better, long awaiting productive treatments with the proper application of the presently available tools and strategies of digital and collaborative manufacturing.

Finally the authors conclude that in addition to the usage of efficient tools and methodologies discussed in the paper, patient inspection and online expert consultation will be the ultimate answers in terms of time lags, accuracy of treatment and patient satisfaction.

Acknowledgment

The authors would like to thank Dr. Srinath Takur, Principal, SDM College of Dental Sciences and Head of the Departments for providing the necessary information as and when required. Also the authors would like to thank Dr. Mithun Upadhyay, Department of Prosthodontics and Dr. Onkar Haridas, Department of Pedodontics, SDM college of Dental Sciences, Dharwad for the illustrations from the respective specialties.

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