Network Enabled Medical Diagnosis and Education in Skeletal Imaging using X-Rays

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Background

Synergy of expertise of varied domains

Enhancing research collaboration through NKN

Synergy of expertise of varied domains

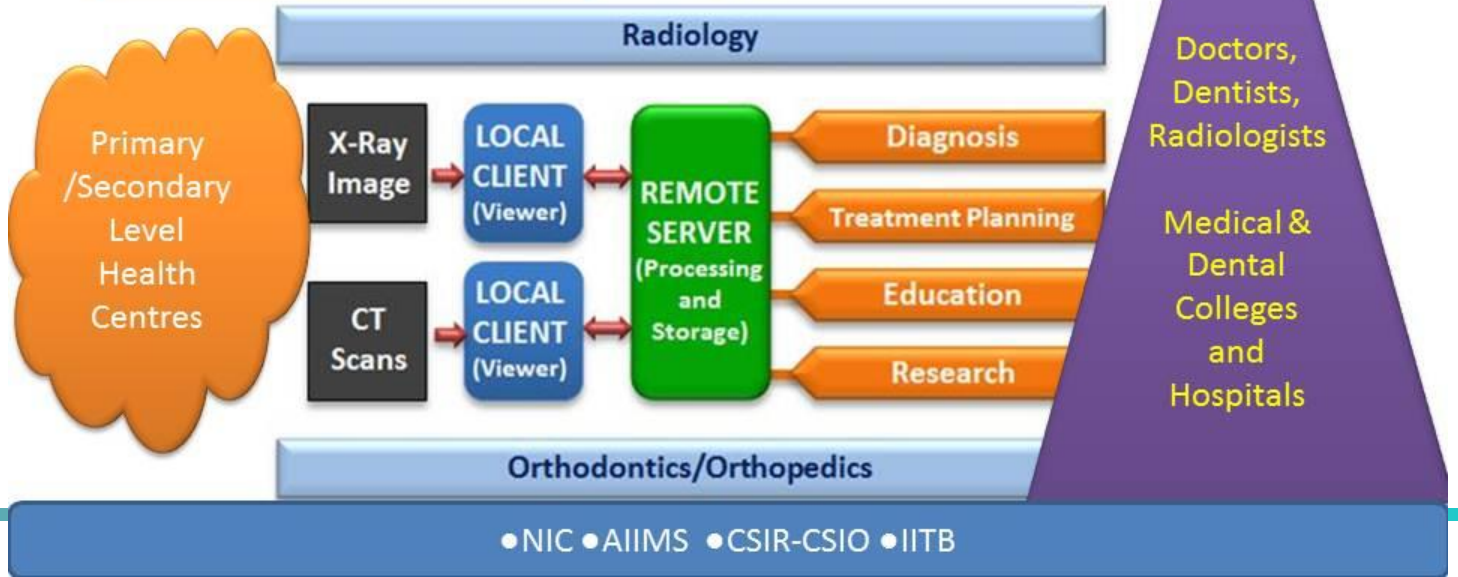
- Medical and Dental disciplines
  - Dentistry-Orthodontics
  - Medicine-Orthopedics, Radiology
- Computational Methods
- CAD/Rapid Prototyping
- Image Processing & Pattern Recognition
- Medical Imaging

NKN-CollabDDS: Collaborative Digital Diagnosis System

Bridging the divide between Rural and Urban Health – Towards Inclusive Society

CollabDDS
Digital Diagnosis System

Bringing Expertise of Radiologists and Orthodontics to Primary/ Secondary Health Centres through National Knowledge Network



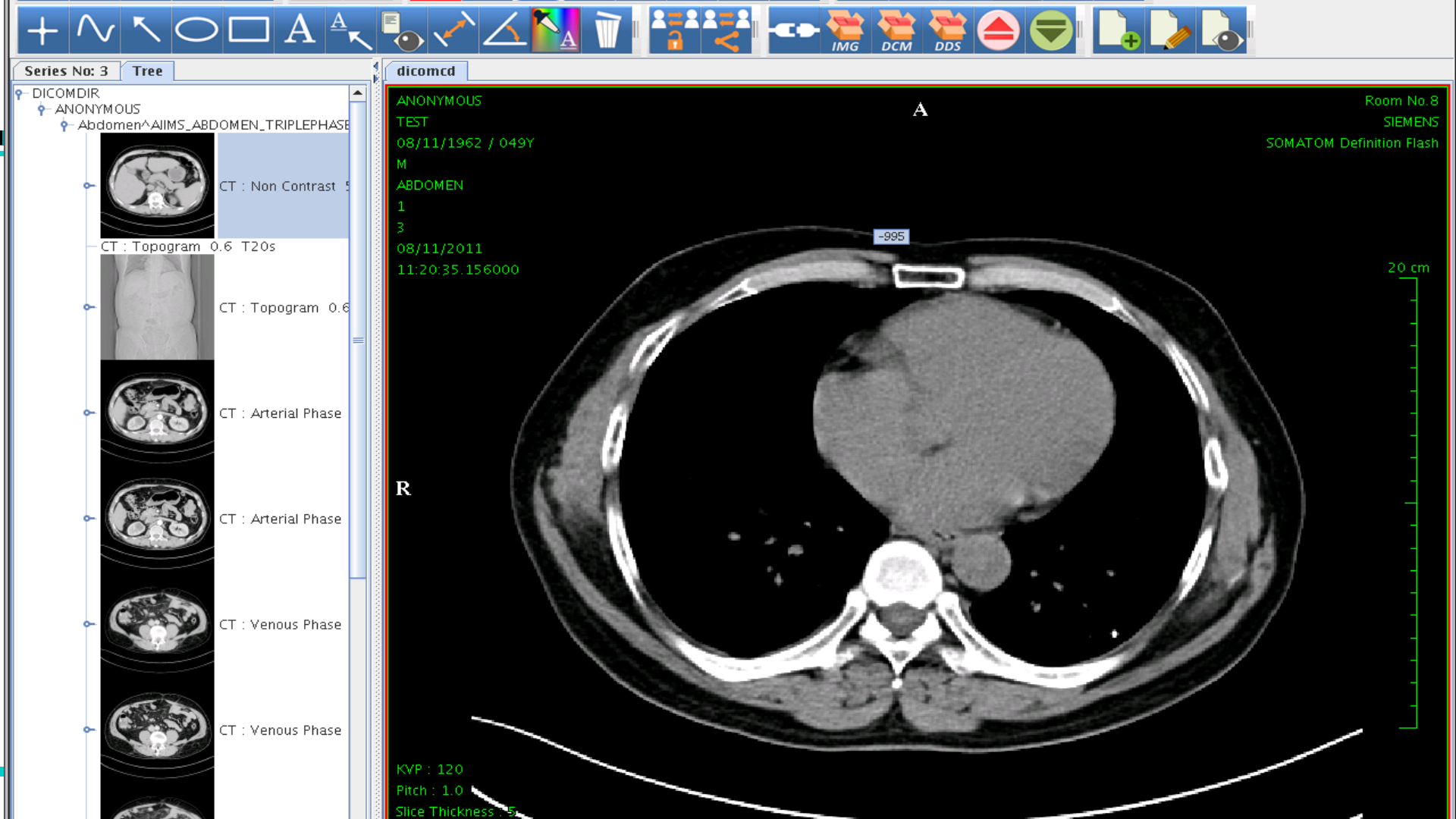
V1.0 July, 2012

V1.1 October 2012

V 1.2 Feb 2013

V1.3 June 2013

V1.4 October 2013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CollabDDS 1.2

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CollabDDS Digital Diagnosis System

Image No: 2

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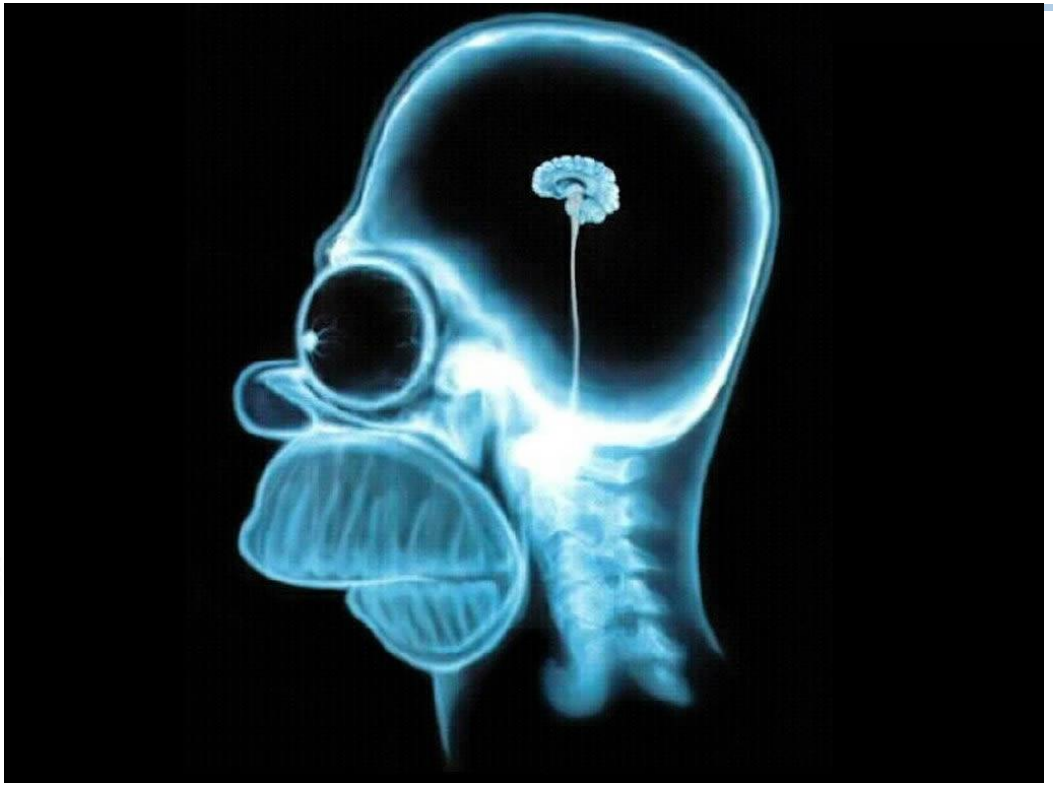
Ultimate objectives

- Connect Health Centres with expert radiologists and doctors in Centres of Excellence

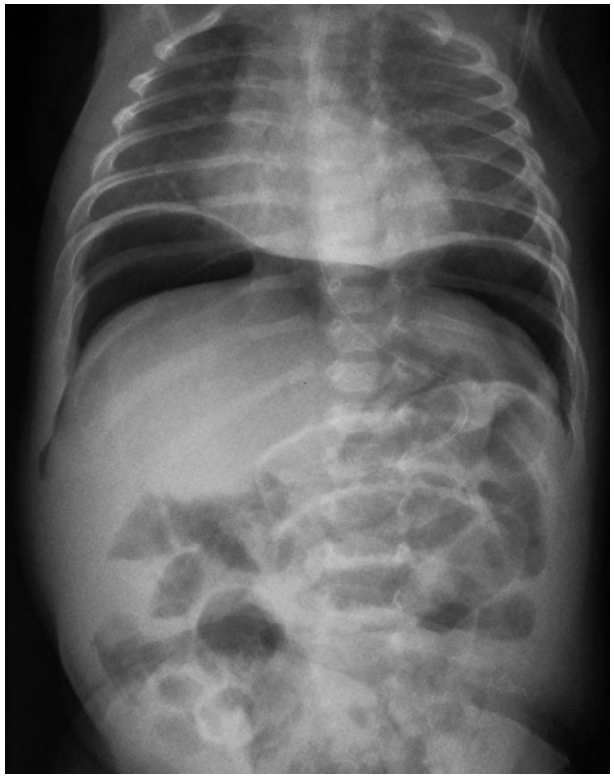
- Provide medical and dental experts a common network to collaborate for diagnosis.

Collaborate : Diagnose and Serve

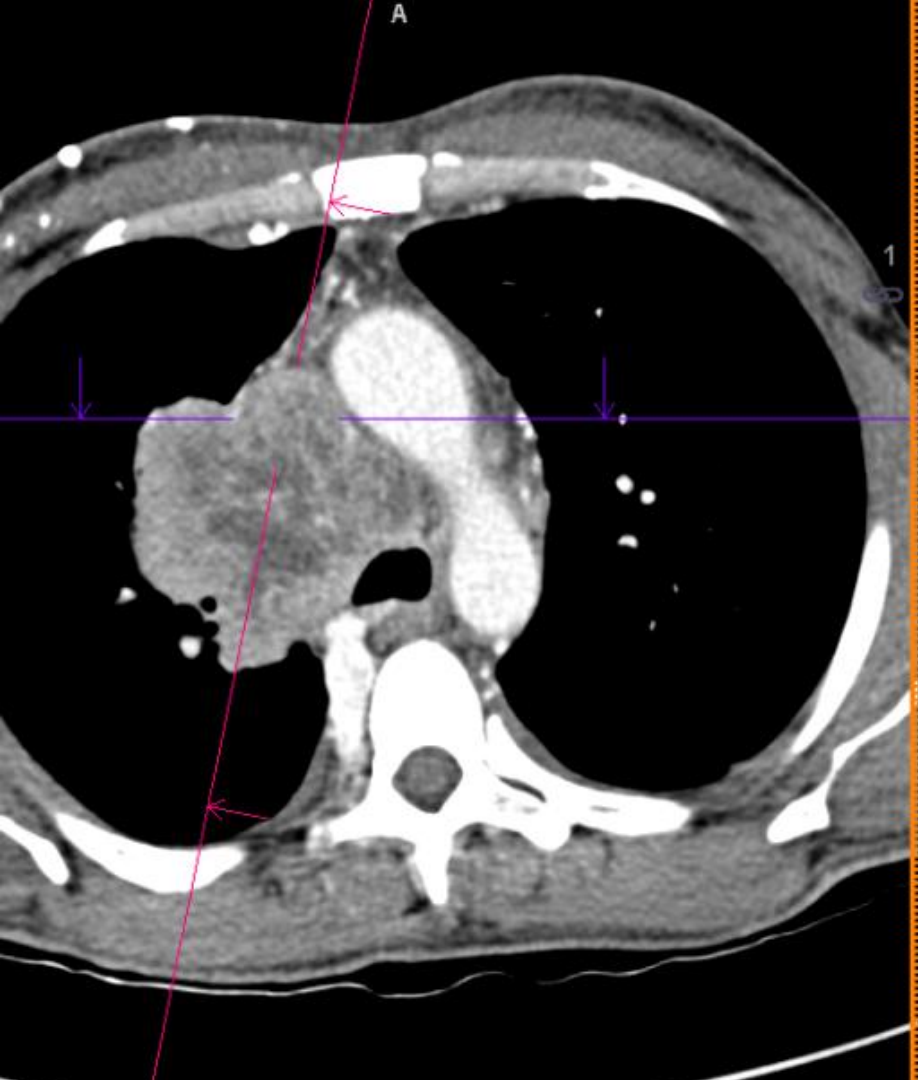
Simposns.....



Diagnosis key to success



- Child came to emergency with severe abdominal pain
- Finding - Free air within abdomen diagnostic of bowel perforation
- Needs urgent surgery
- If not diagnosed correctly it would be life threatening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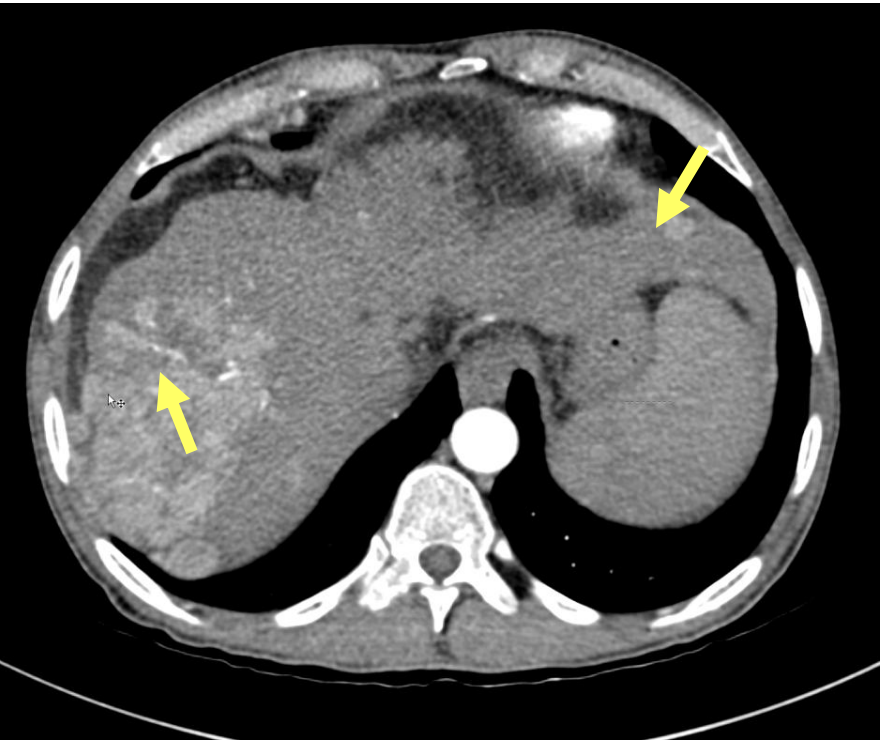
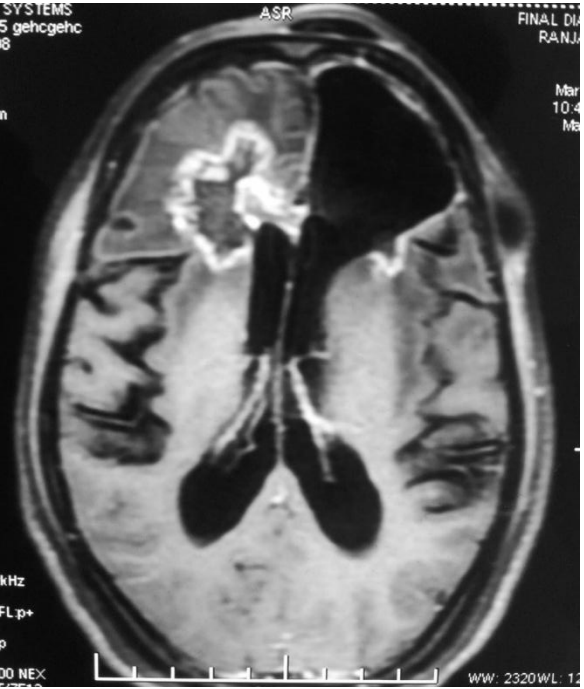


- Tumor in cirrhotic liver
- To the untrained eye there is only one lesion for which surgery is the treatment
- But an experienced radiologist can detect an additional small lesion in left lobe which rules out surgery as treatment option

Brain MRI



- Follow up patient of brain tumor –treated with surgery & radiation
- Problem
  - Is this tumor recurrence for which radiation is the treatment

    or
  - Is it radiation induced change for which conservative treatment is the option instead of radiation
- Wrong diagnosis can worsen the patient's condition

- Ultimate Beneficiaries – Patients
- Savings: Time & Money
- Saving of national man-work hours

Medical and Dental Education is at cross roads

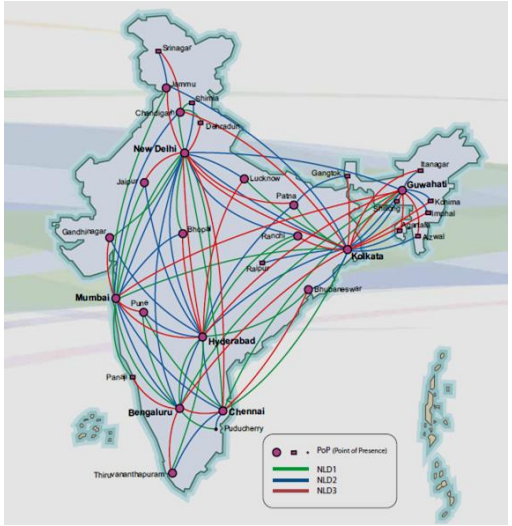
- More Institutions
- Scarcity of teachers

Quality of training is difficult to sustain with numbers

Solution(S)

Open knowledge : opening our teaching and learning resources for positive change in country

Collab DDS
Digital Diagnosis System



- NKN has already connected 1200+ institutions
- 144 Medical and Dental institutions
- Ayush colleges

High band width and low latency

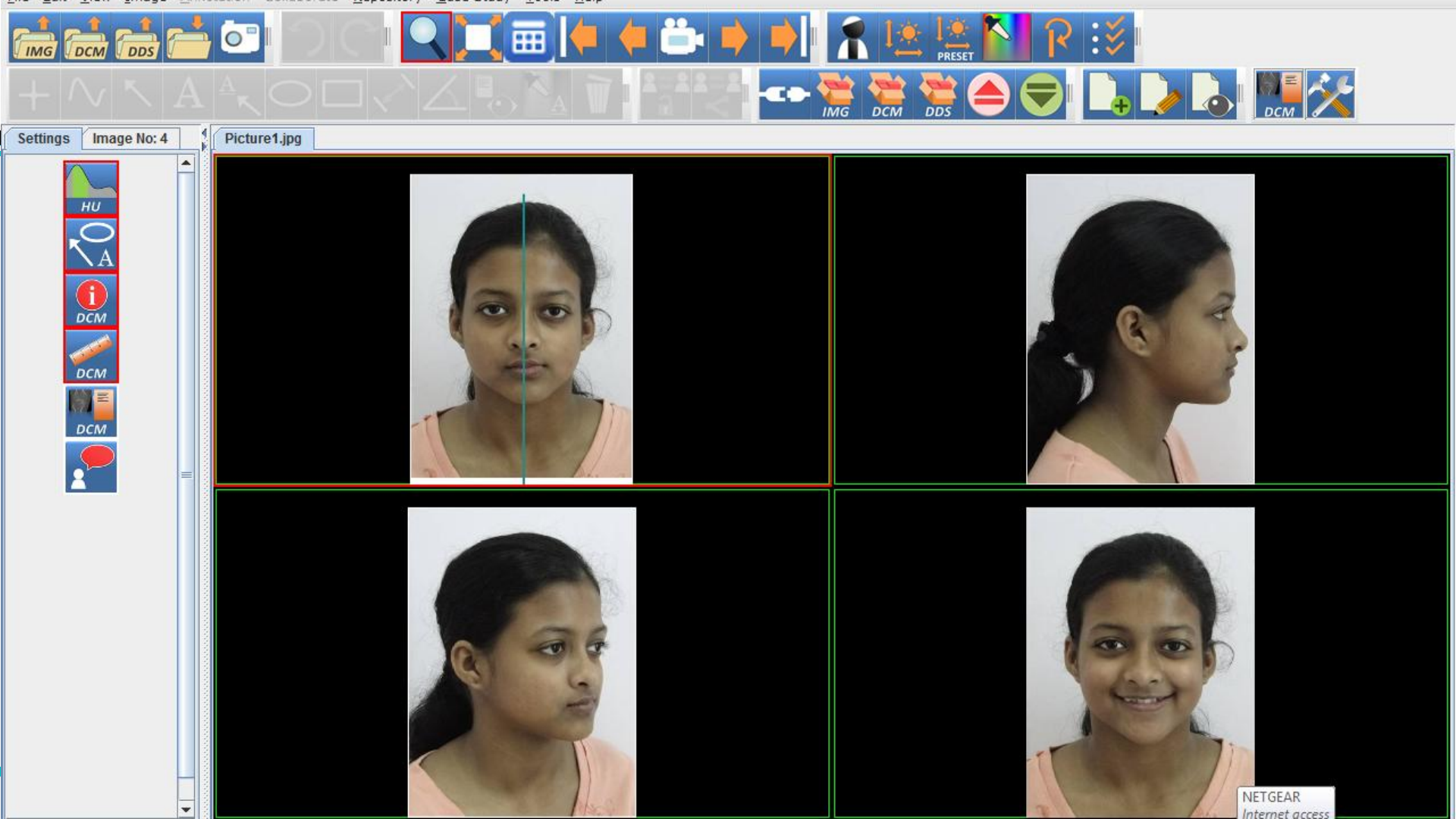
Education

Faculty and Students of Medical and Dental Colleges can use CollabDDS for discussions of complex cases with other academic centers

- Patient care
- Education
- Research

Collab DDS
Digital Diagnosis System

Repository of case studies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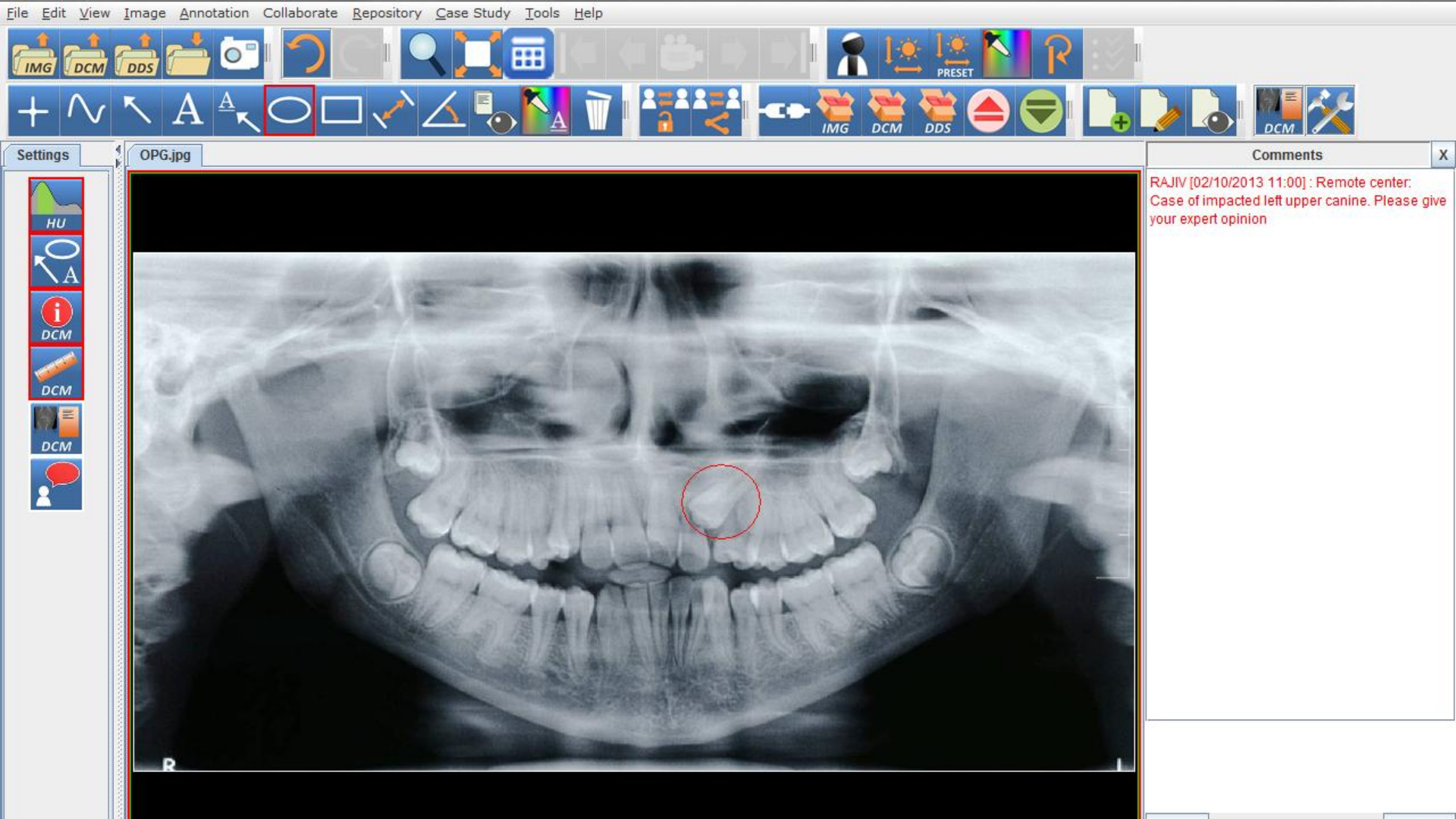
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Comments
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RAJIV [02/10/2013 11:00] : Remote center:
Case of impacted left upper canine. Please give
your expert opinion
R
L

Expert from apex centre like AIIMS asking more details Regarding the case.

- Familial history
- TMJ status
- IOPA x-ray
- Occlusal x-ray
- PA cephalogram
- Vitality status of left lateral incisor

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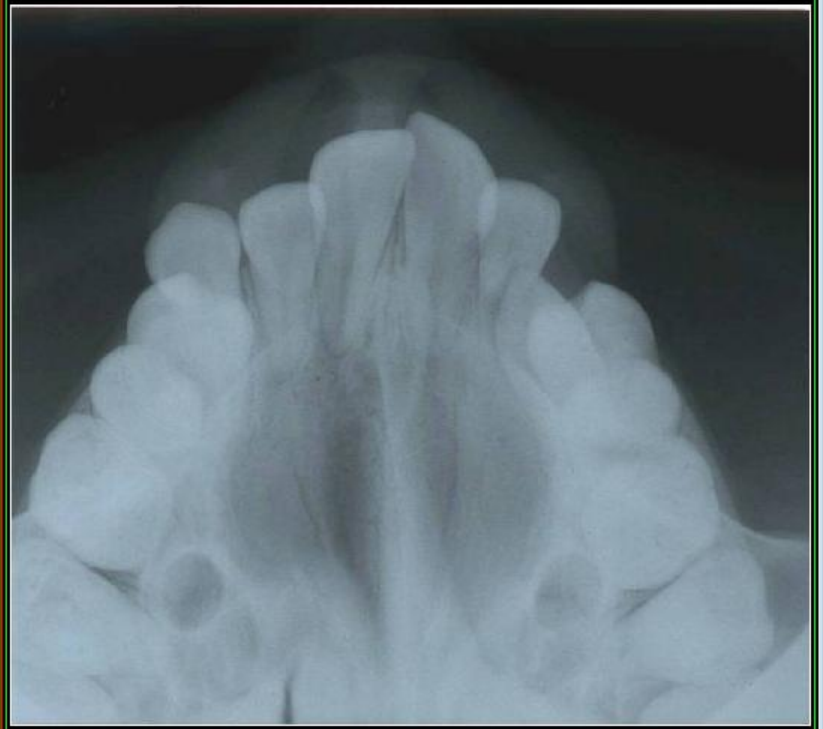
IOPA.jpg



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Picture2.jpg

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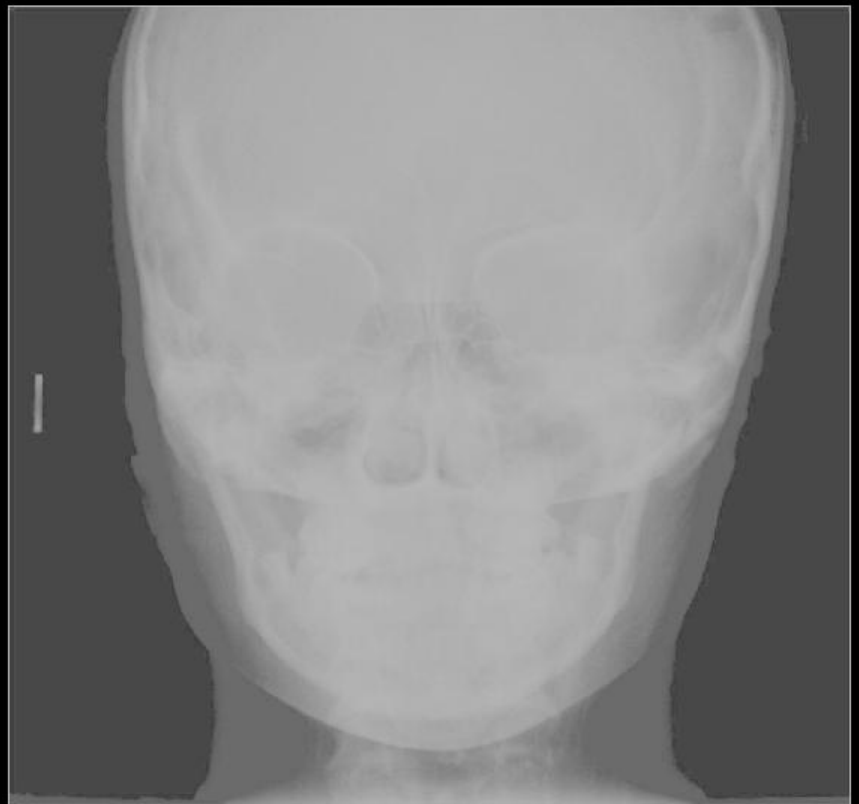
PA.jpg



Comments

X

The Dentist collected more details

- Diminished vitality response of left lateral incisor
- Mild clicks on left TMJ while opening and closing
- Mother has mild facial asymmetry, with chin deviated towards right side.
- Due to complex nature of this case expert requires advanced imaging modality.

Expert advised the dentist for 3D imaging (CBCT)

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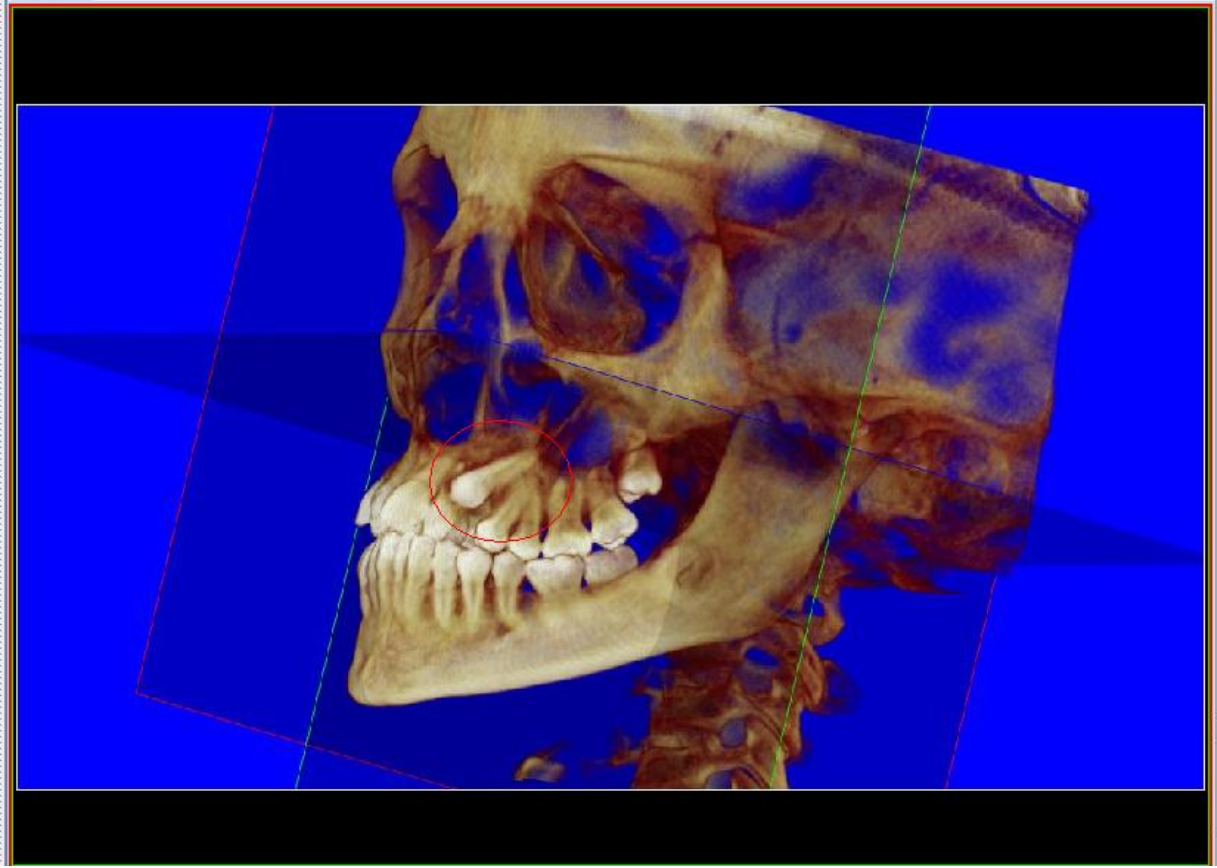
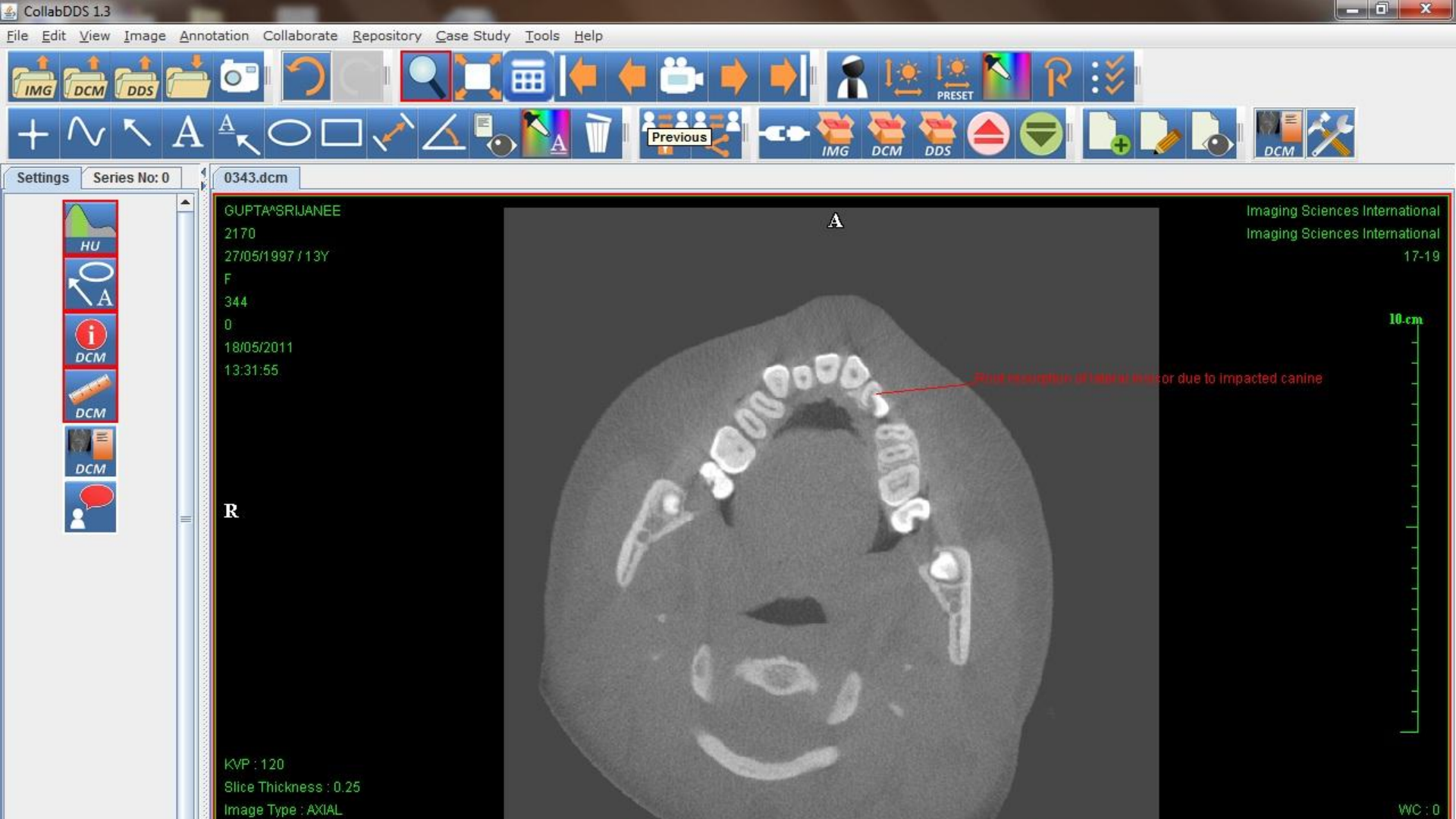


Comments

RAJIV [02/10/2013 11:16] : AIIMS: The volume rendered image shows the labialy impacted canine.

Add Clear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10 cm
Root resorption of lateral incisor due to impacted canine
KVP : 120
Slice Thickness : 0.25
Image Type : AXIAL
WC : 0

Problem List

1. Asymmetric face with deviated chin towards left side
2. Skeletal Class III malocclusion: Left mandible > Right
3. Impacted left upper canine
4. Root resorption of left maxillary lateral incisor
5. Collapsed maxilla: Posterior cross bite
6. Lower dental midline shifted towards left by 2mm
7. Mild clicks on left TMJ while opening and closing
8. Retruded maxilla
9. Crowding in upper and lower anteriors

Etiology and differential diagnosis

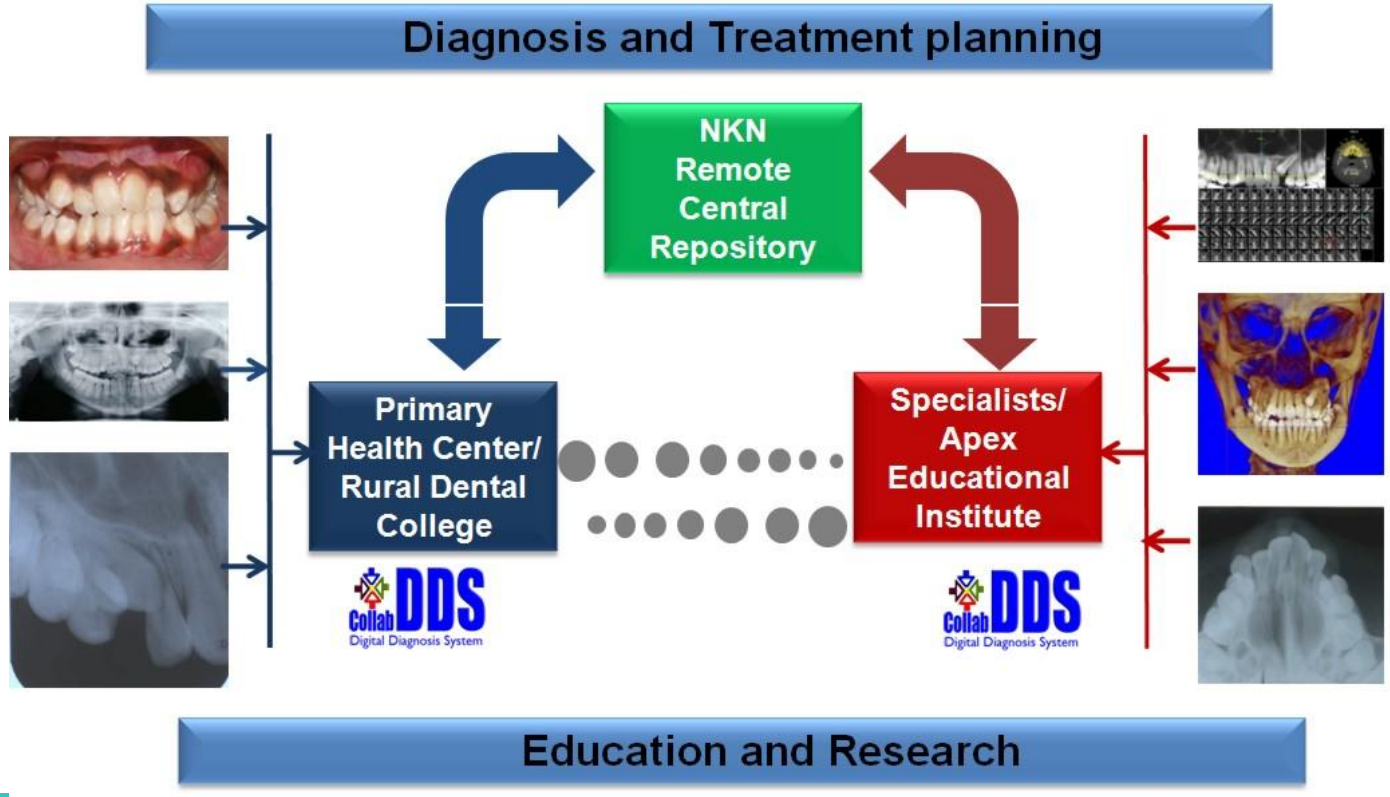
- Final diagnosis: A case of skeletal Class III with chin deviation associated with increased length of mandible.

- The morphology and dimensions of the right condyle are different from left suggesting a mild form of condylar hyperplasia.

Treatment objectives

- Efforts to conserve and retain left maxillary lateral incisor
- De-impact and align impacted left maxillary canine
- Correct facial deformity i.e. chin deviation
- Relief of crowding
- Harmonies transverse and sagittal skeletal discrepancy
- Relief of TMJ symptoms

Real time Collaboration



Schematic arrangement of collaboration using CollabDDS in two centers at a distance

Collab DDS
Digital Diagnosis System

Awareness and sensitisation

THE ida Indian Dental Association

Times

ISSN 0974-3952, ₹ 100/-

The National Voice of the Dental Profession

Mumbai, September – 2013, Vol. IX, Issue 9, 20 Pages

A novel concept in Distant Dental Education and Oral Health Care

CollabDDS Digital Diagnosis System

The medical and dental education in India is passing through a difficult phase of logistics to meet the increasing number of quality admissions. Scarcity of qualified medical/ dental teachers on the one hand and the expanding need for higher education on the other has further worsened the situation. The availability of dental teachers and experts, who are mainly residing in metropolitan cities, shows a skewed distribution whereas rural institutions and hospitals in small towns and villages continue to remain deprived of the services of these experts.

The shortcomings of the traditional methods of teaching and the need for expert opinion can be overcome with the use of technology to a great extent.

Specialists from varied disciplines and knowledge domains together developed CollabDDS through a synergy of knowledge and team efforts. The team members included computer software and communication specialists at National Informatics Center, Orthodontic Faculty at Centre for Dental Education and Research, All India Institute of Medical Sciences, Faculty and researchers at Department of Radio-Diagnosis, AIIMS, New Delhi, Medical imaging scientists at the Indian Institute of Technology, Mumbai, and a team of 3-D digital imaging scientists at CSIR-Central Scientific Instruments Organisation (CSIO), Chandigarh. CollabDDS has varied applications in distant education and healthcare. Its real potential can be many, including applications in research.

What is CollabDDS

CollabDDS: Collaborative Digital Diagnosis System is essentially a software, which allows real time collaboration for digital diagnosis and treatment planning between two or more remote locations utilizing high bandwidth and low latency of National Knowledge Network (NKN). It may be worth mentioning here that National Knowledge Network has established connections to nearly 150 medical and a few dental colleges and more are on the way. The Government of India is in the process of creating the National Optical Fiber Network (NOFN) for providing Broadband connectivity to Panchayats and is eventually planning to connect all Gram Panchayats with a high bandwidth pathway. Thus, ultimately, CollabDDS would cover a wide spectrum of citizens and benefit those residing in remote areas in getting consultation from the Specialists!

Schematic arrangement of collaboration using CollabDDS in two centers at a distance

Fig. 1

CollabDDS is not a telemedicine system but a much-advanced method of communication between two or more centres. It is a live interactive platform, which allows instant exchange of high-resolution patient data, x-ray or similar images, which can be annotated at both the ends through interactive tools. CollabDDS can be used to disseminate dental education through repository of case report as well as live transmission on a collaborative mode between two remote centres like AIIMS, New Delhi, and say, for example, Goa. CollabDDS also allows marking on the 3-D CT scans and 2-D X-Rays.

It enables real time dental/ radiological consultation and has a host of image processing tools and features, which are of immense help for teaching and consultation. It supports various image input formats like BMP, JPEG, PNG, TIFF and DICOM (Digital Imaging and Communications in Medicine). The images can be obtained through this system by allowing live transmission and interactions. It can help to provide real time consultation between two expert centres or experts.

Next step in this direction is to "roll out" the applications to selective dental/medical colleges to ascertain the usefulness of such applications. Three medical and dental colleges have been identified for the pilot implementation of CollabDDS (SN Medical College, Agra, Government Dental College, Goa and Government Dental College and Hospital, Ahmadabad). More dental schools pan India will be included after this trial run.

CollabDDS will also allow interactive teaching and use of cephalometric analysis through AutoCEPH software. AutoCEPH has been developed by CSIO in collaboration with Department of Orthodontics, AIIMS. Further research in this area is in progress, which includes enhancing automated cephalometric analysis, 3D surface scans, statistical shape models of selected bone anatomies of Indian population and many more eventually looking

enhancement tools for adjusting brightness, contrast, window level and flip, rotate, zoom, etc.

Case Reports

Case 1: Unusual cystic lesion in the maxilla after orthodontic treatment

Fig. 2

The important feature of CollabDDS is that it has an annotation tool through which doctor/specialist from either end can annotate the image with text or marking over specific structure of a radiograph or clinical image that can be viewed and saved by doctors at either end. The images along with annotations, conversations and digital signatures of doctors can be saved in either JPEG or DDS format for future reference. The dental education may be revolutionized

Step 1

An 11-year old female patient approached a dental centre where facility for orthodontic treatment was available. Her chief complaint was the protruding upper front teeth for which she was treated with twin block functional appliance therapy. (Fig. 2)

Step 2

The post-functional OPG, which was taken after 10 months of twin block therapy, showed

Continued on pg.9

Publications

CollabDDS: Real-time Collaborative Digital Diagnosis System using X-Rays

ABSTRACT

Teleradiology allows patients in remote primary health centres (PHC) to consult experts in specialty hospitals by sending medical image data through Internet. The benefits are however, limited by the proprietary nature and complexity of current systems, high cost of deployment, and lack of real-time collaboration between PHC doctors and expert consultants. These limitations can be overcome by the Collaborative Digital Diagnosis System (CollabDDS) developed by a team of medical, engineering, imaging and software experts, as a model project in the National Knowledge Network mission. This article describes the features, inputs and outputs of the system, followed by a hypothetical orthopaedic case study to illustrate its application and benefits.

INTRODUCTION

Over the last 20 years, Information and Communication Technology (ICT) has brought paradigm shifts in the way patient data is stored, viewed, shared and utilized for diagnosis and treatment planning. The most widely used patient data includes x-ray images, which are now available in digital format. These are either directly obtained from the newer generation of x-ray machines, or by scanning the x-ray films produced by older machines. The total digital radiography examinations alone are estimated to be over 200 million per year worldwide [1]. The range of imaging modalities have rapidly expanded and now include Computed Tomography, Magnetic Resonance Imaging, Ultrasound, Nuclear Medicine and others [2].

The medical images are stored along with relevant patient data in industry-standard DICOM format, which stands for Digital Imaging and Communication in Medicine; an international standard (ISO 12052:2006). As the image data grew in file size and numbers, different generations of systems were developed for handling the same. The first generation systems stored the data in a central server of a hospital, which could be accessed by clinicians in their consulting rooms over a Local Area Network (LAN). These were called PACS (Picture Archiving and Communication System) [2]. The PACS gradually embraced Internet Protocol (IP) and web languages (HTML) for developing the back-end storage and front-end user interface. These second generation systems allowed data to be accessed outside the hospital, even from remote locations, over the Internet. Medical images could be sent from primary health centres in villages or small towns to expert radiologists in specialty hospitals located in cities, through e-mail attachments or using File Transfer Protocols (FTP), for purpose of diagnosis or second opinion. This is referred to as teleradiology.

Teleradiology has witnessed rapid strides in the last decade driven by several factors: (i) increasing role and volume of radiology, (ii) severe shortage of expert radiologists, and (iii) falling cost of digital imaging and Internet access on the other hand. Teleradiology can be considered a specialty sub-set of telemedicine, which generally implies remote consultation for diagnosis and treatment. A key feature of recent telemedicine systems is web-conferencing for the patient or rural health worker to discuss face to face with an expert consultant in a speciality hospital. India, Indian Space Research Organisation (ISRO) and Centre for Development of Advanced Computing (CDAC) have developed such telemedicine systems, which connect several major hospitals like AIIMS, New Delhi and Tata Memorial Hospital (TMH), Mumbai with regional hospitals in remote states like Arunachal Pradesh. CDAC has developed a radiology information system (RIS), which enables patient and image data tracking, scheduling and reporting.

In summary, PACS systems provide **digital storage** of medical images on a server, enabling quick retrieval and viewing within a hospital over the local area network. Teleradiology enables **transmission** of the data over long distances using Internet, enabling remote diagnosis by experts. However, three major hurdles remain. The first is the ***proprietary*** nature of the existing systems and services, since most of them are developed by private entities, and are not generally available for widespread implementation across the country. Secondly, most of the existing systems are developed in the West, based on the requirements of their hospitals and patients, and are not sufficiently ***user-friendly*** to be used in primary health centres (PHC) in small towns and villages in India.

Network Enabled Medical Diagnosis and Education in Skeletal Imaging using X-Rays

Third, and perhaps the most important, existing teleradiology systems do not have an integrated built-in mechanism for ***real-time collaboration*** between the technician and patient in PHC and expert radiologist in specialty hospital, which is essential to quickly obtain additional information and answer any clarifications.

To meet the above requirements, a Collaborative Digital Diagnosis System using X-rays was developed by a multi-disciplinary team of medical, engineering, imaging and software experts. The inputs, functions and outputs of the CollabDDS system (Fig. 1) are described next, followed by aorthopaedic/orthodontic case study to illustrate its applications and benefits.

Fig.1. Collaborative digital diagnosis system (CollabDDS).

CollabDDS SYSTEM

The project team was piloted by the CollabCAD Group of National Informatics Centre, New Delhi. Domain experts from the Department of Orthodontics and Dentofacial Deformities, Centre for Dental Education and Research, All India Institute of Medical Sciences, New Delhi, and from the Department of Radio Diagnosis, All India Institute of Medical Sciences, New Delhi and from OrthoCAD Lab, Indian Institute of Technology Bombay, Mumbai; and from Central Scientific Instruments Organisation, Chandigarh. contributed by providing clinical requirements, graphical user interface elements, testing and feedback. This initiative was funded by the Ministry of Communications & Information Technology, New Delhi as a model project under the National Knowledge Network mission. The overall goal was to enable low-cost real-time collaborative diagnosis between PHC technicians or doctors on one side, and expert radiologists on the other side (Fig. 2). This was enabled by

Network Enabled Medical Diagnosis and Education in Skeletal Imaging using X-Rays

CASE STUDY

A patient X approaches a primary health centre (PHC) in the late afternoon complaining of severe pain around her left knee. An X-ray of her left leg is taken the same day using an old machine available at the hospital. The X-ray film exposed by the machine is digitized using a special purpose scanner and viewed in the connected computer (Fig. 3).The patient details including name, age, gender and date of study are entered. The scanned image along with the patient data is saved as industry-standard DICOM file, which is 13 MB in size.

The local doctor D then imports the DICOM file into the CollabDDS system available in the PHC. He flips the image to correct the orientation and zooms it for a better view. He also increases the brightness, contrast and sharpness of the image (Fig. 4). He marks a particular area that he suspects might have a problem, and adds a few questions and comments for a second opinion (Fig. 5). By this time, it is late evening.

Fig.3. X-ray film digitized using a special-purpose scanner

Then the local doctor messages an expert radiologist in a specialty hospital (mentioned in the list in the system) with a request for a collaborative diagnosis. The expert radiologist R logs into CollabDDS installed on his computer and connects to D (Fig. 6). He is immediately able to see the scanned X-ray along with annotations of D. He starts a chat session for a few clarifications, and points out the problem area with an arrow on the image. Doctor D agrees with the diagnosis and saves the image with the final comments into his system. He formulates a treatment plan, and knows that he can connect with an expert orthopaedic surgeon in another medical institute for confirmation, if needed.

The system saves all data related to the case (including annotations and discussions between the PHC doctor and expert radiologist) in a secure repository. Additional information about the treatment and follow-up can also be stored for the case (Fig. 7). This can be retrieved later for future reference and educational purpose.

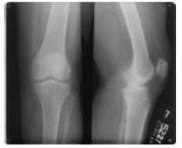


Fig.4. Image processing and manipulation of the patient's X-ray image (before and after)

Publications

- Medical Equipment and automation October 2013
- NIC Informatics October 2013
- Trail Feedback form has been designed

What Next ?

I. Pilot implementation in 6 medical/dental institutes
Explore country wide Implementation

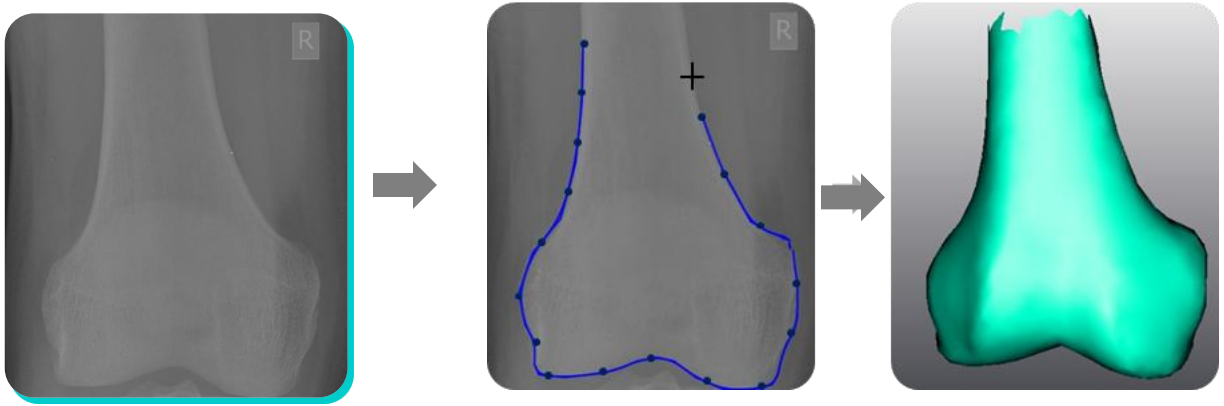
II. Enhancement and applications in 3D imaging

3D Model Reconstruction from X-Ray Images

- **Input**: X-Ray Image, **Output**: 3D CAD model of bone, **Scope**: Femur and tibia
- **Basic Algorithm:**

1. Bone contour identification (currently manual)
2. 3D model (template) deformed to match the bone contour

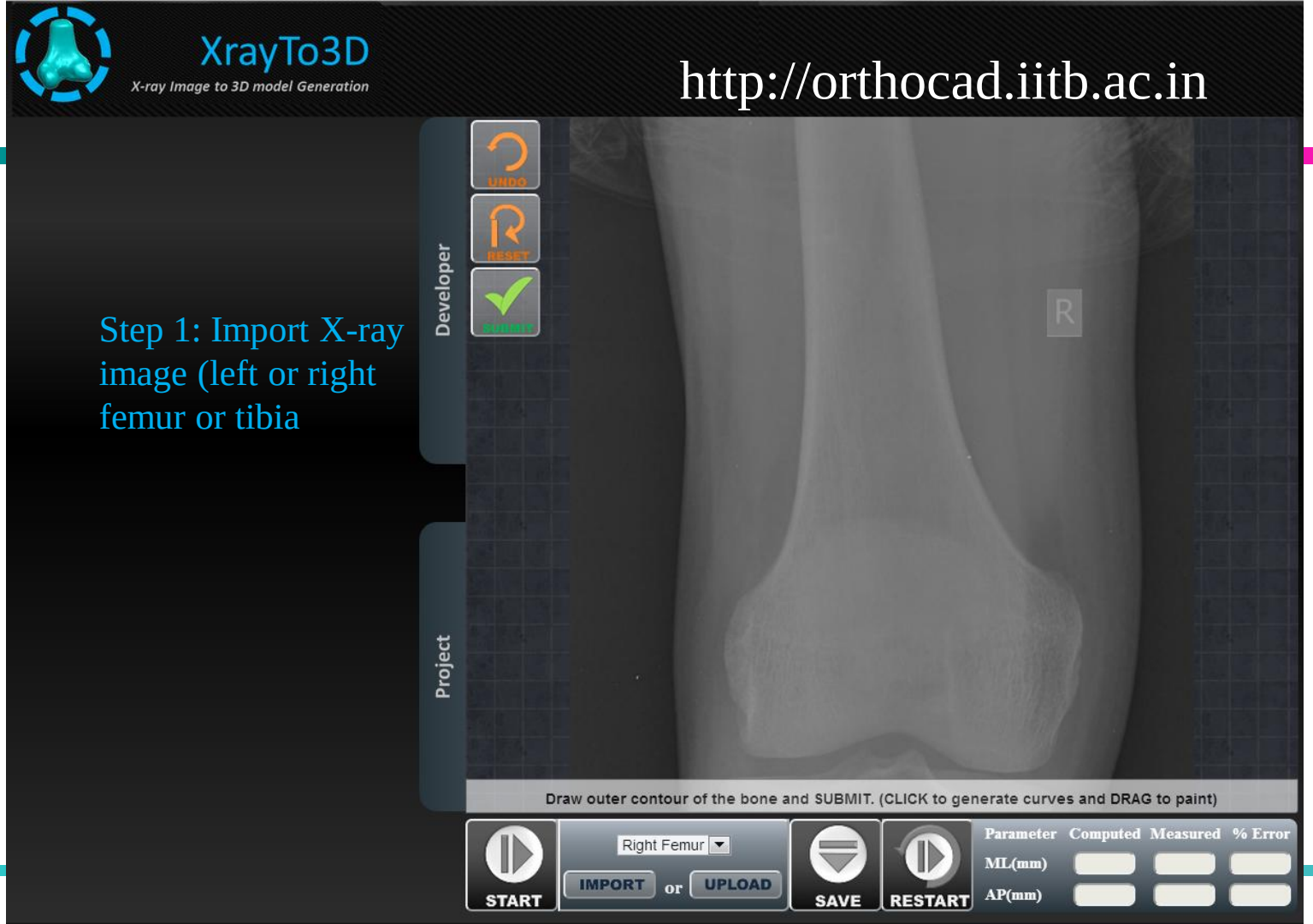
- Implemented at OrthoCAD website for demonstration.

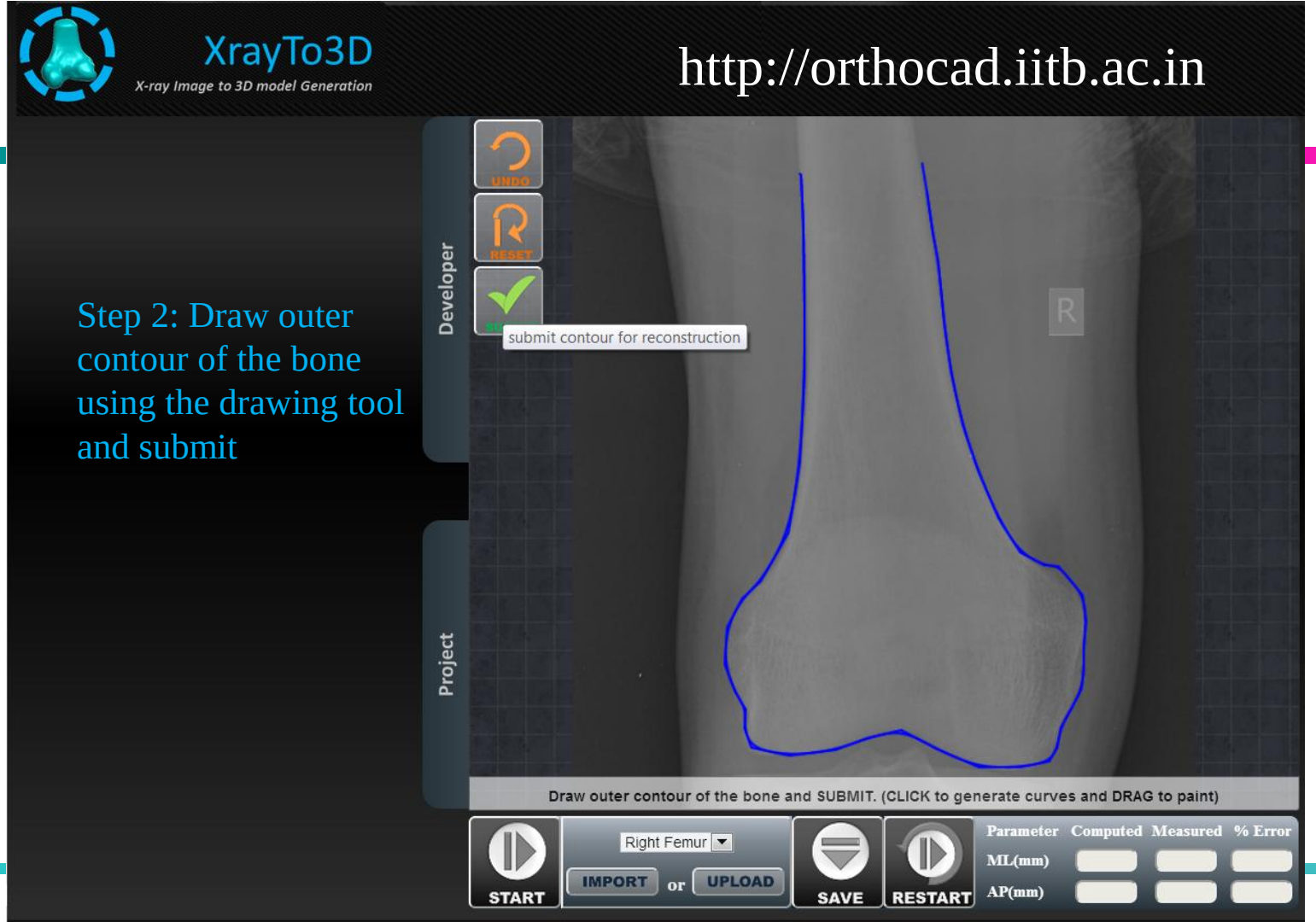


Input X-Ray image

Bone contour identified

3D model of bone


XrayTo3D
X-ray Image to 3D model Generation
http://orthocad.iitb.ac.in
Step 1: Import X-ray image (left or right femur or tibia
Developer
Project
UNDO
RESET
SUBMIT
R
Draw outer contour of the bone and SUBMIT. (CLICK to generate curves and DRAG to paint)
START
Right Femur
IMPORT
or
UPLOAD
SAVE
RESTART
Parameter
Computed
Measured
% Error
ML(mm)
AP(mm)


XrayTo3D
X-ray Image to 3D model Generation
http://orthocad.iitb.ac.in
Step 2: Draw outer contour of the bone using the drawing tool and submit
Developer
UNDO
RESET
submit contour for reconstruction
Project
Draw outer contour of the bone and SUBMIT. (CLICK to generate curves and DRAG to paint)
START
Right Femur
IMPORT
or
UPLOAD
SAVE
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ML(mm)
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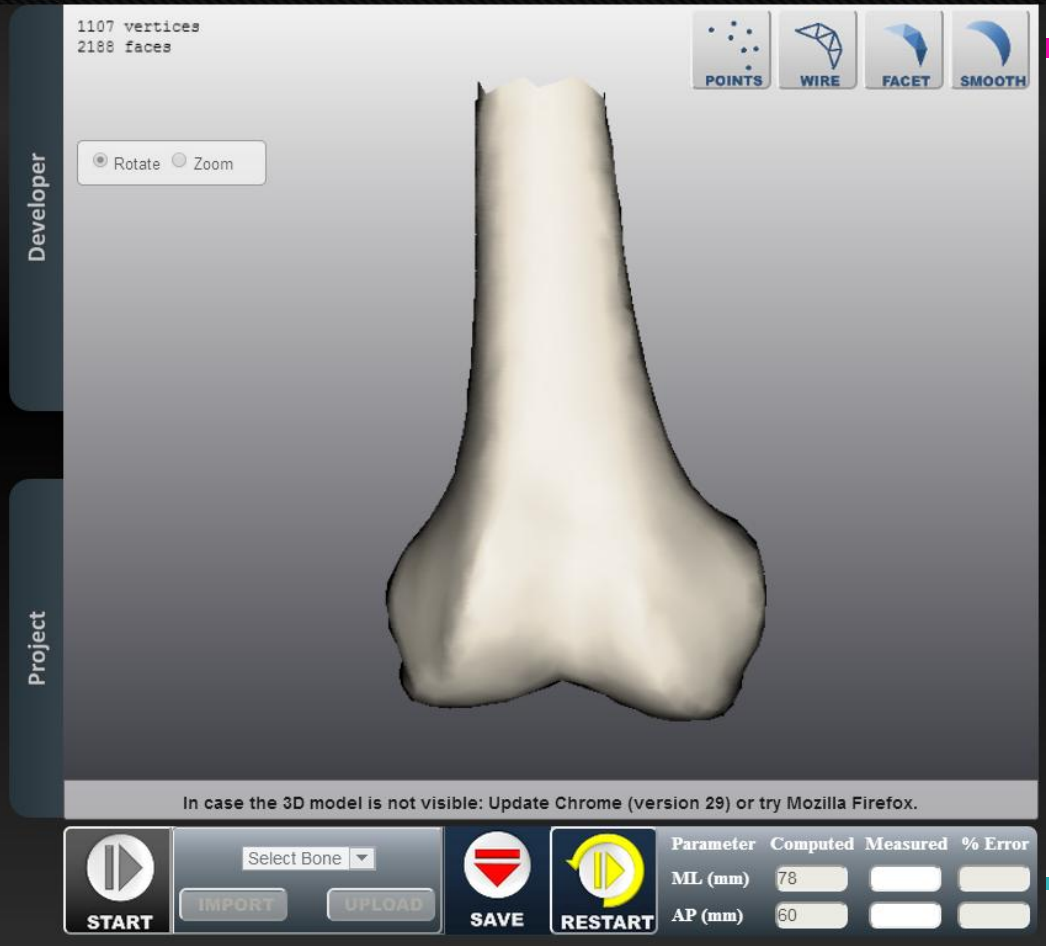
XrayTo3D

X-ray Image to 3D model Generation

http://orthocad.iitb.ac.in

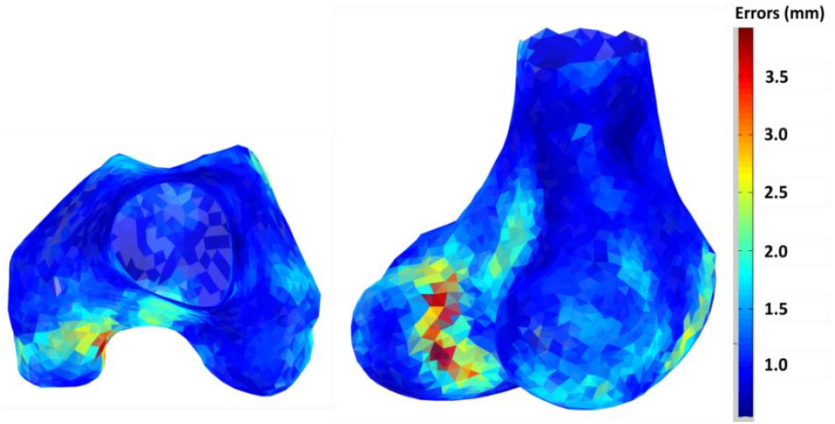
Step 3: 3D model will appear in few seconds. View and save file.



Algorithm Testing

Algorithm was tested for accuracy, using bone contours from 3D CT images.

1. 3D models were created from CT scans of femur using medical software
2. ML and AP contours were generated using a back projection technique
3. Contours were used as the input to the 3D reconstruction algorithm
4. 3D models from algorithm compared with those from CT/medical software



Results: Average error (point-to-surface) = 1.1 mm

File View Tools Draw Export to excel PA Analysis Help

Open Save Zoom Pan Flip Vertically Flip Left-Right Color Filter Show Landmark Image Negative Image Tools

Selected Zoom

ToolBox

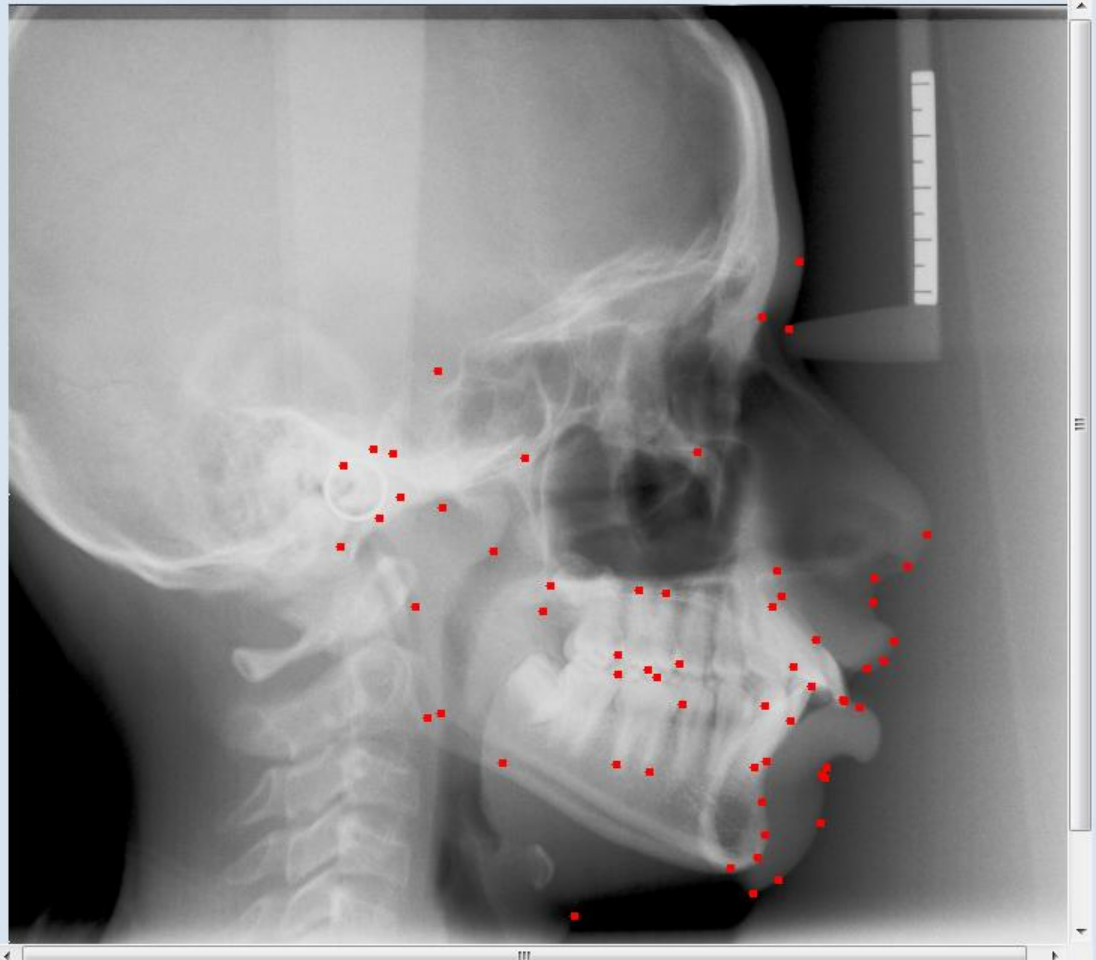
Acc. to Analysis All Landmarks

Auto

Select Landmark

Landmarks for Molar- Incisor

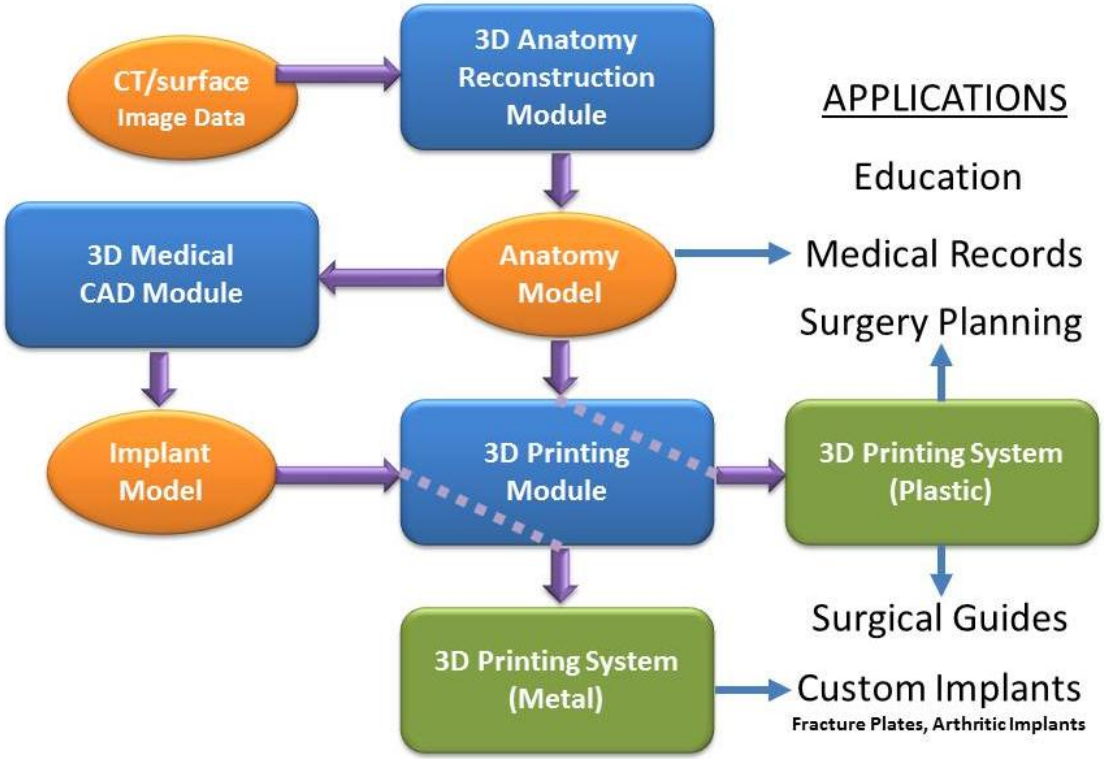
Select Landmark



Lateral Cephalogram

Thinking beyond

3D Printing Technology for Medical Applications



Thank you.NKN

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