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DESIGN AND DEVELOPMENT OF MOBILE C-ARM X-RAY SYSTEM

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ABSTRACT: Inhealthcarewhile surgery specialists to work together, with guidance from X-ray and echo to visualize critical anatomy. Whether it's trauma procedure, vascular surgery, or any fracture in body in 3-D imaging enhances identification of target points, simplifies device deployment, and offers immediate evaluation of results. Procedure specific tools and integration of imaging modalities boost confidence and enhance workflow among the heart team. Previous to this many minimally invasive procedures was usually performed with help of x-ray guidance which indicates only 2-D projection of the anatomy, which gives lack of depth of information so by mobile fluoroscopy this drawback eliminated. The work involves complete design and development process of mobile c-arm x-ray system starting from design process to till get end final complete machine. In the development process we went through some process firstly we studied the all associated components and structure that used to make the final system then we went through development of individual components the development of individual components include firstly its design significance mean what is role of that part in machine, secondly considering design significance we freeze design parameter these parameters are important as design point of view and some parameters freeze based on the clinical needs also. And then comesdesign methods that we used to design the parts. Once the parts design finalized then have to select the manufacturing method, by which method have to make a particular thatpart based on the how precise components we wants and based on that accuracy required can select the suitable and cost effective manufacturing method. Last stage includes the assembly and testing or individual testing of parts to assure about parts are meeting the required specification or not. If not then part is rejected only the accepted part are used for assembly purpose. After assembly we have successfully performed all movement (degree of freedom) of the mobile c-arm x-ray systemhere also checked the movement of c-arm it should be smoothly.

I. INTRODUCTION

General Introduction

Over the years, orthodontic and dentofacial orthopedic diagnosis and treatment planning have depended mainly upon technological and mechanical supports like imaging, jaw monitoring, and functional analyses. The aim of these devices are to describe the anatomic and physiological facts exactly and to display the three-dimensional (3-D) anatomy precisely. Imaging is play vital role for specialist to evaluate and record size and form of bone structures. specialist routinely use 2-dimensional (2-D) static imaging techniques to record the anatomy structure, but depth of details of structures cannot be obtained and localized with 2-D imaging. 3-D imaging has been developed in the early of 1990's and has gained a precious place in dentistry, especially in orthodontics, and also in facial surgical applications. In 3-D diagnostic imaging, a series of anatomical data is gathered using some technological equipment and processed by a computer and later showed on a monitor screen to present the illusion of details.

Facial soft, hard tissues and dentition are three main zone, also named as triad, in orthodontics and orthogenetic surgery. The triad has a important function in planning of orthodontic diagnosis. Therefore, imaging of these structures is one of most important and useful diagnostic tools for clinicians/specialist to make decision treatment modality.

Mobile fluoroscopy(c-arm) x- ray system

Mobile fluoroscopy x- ray system is a healthcare device which provide fast 2-D Image and displaying complex anatomical details in 3-D to specialist to visualize critical anatomyin the trauma procedure, bone displacement, spinal trauma etc. 3-D imaging enhances identification of target points, simplifies device or tools placements, and offers immediate evaluation of results. Procedure specific tools and integration of imaging modalities boost confidence and enhance workflow among the heart team.

Objective of mobile fluoroscopy device

Objective of present work is

- To design and development a mobile fluoroscopy (c-arm) system with that specialist able to make a fast and accurate diagnosis without moving patient that is crucial in the emergency room.
- Cost:provide overall best patient care with minimum cost, it easily available in all clinics.
- Mobile C-arms are designed in such a way so we can perform multiple procedures quickly and easily.
- It Simplify tools placement while surgery in operation room. Simply point and shoot.
- This device takes less space and provides more space to team member so that they easily coordinate the task.

C-arm with image intensifier and X-ray tube has designed fully balanced for smooth and supple positioning. They adapt to different anatomy automatically to promote first time right imaging.

Visualizing complex bone structures for precise device placement and getting the right quality images is critical. Mobile surgical imaging solutions provide the flexibility and access to support a wide range of open and minimally invasive orthopedic procedures and patients. Distortion-free images to enhance clinical confidence during challenging spinal surgeries and fracture repair in the operation room it helps in visualizing kidney drainage, abdominal repair, vascular surgery, orthopedics, pain managements and neurology procedures. Mobile c-arm used image intensifier which offer better image quality and smaller system that takes up less room in operation room and allow more room to see surrounding team members and coordinates tasks.

II. LITERATURE REVIEW

Discovery of X-rays has been done by W. C. Roentgen in 1895, when he noticed a barium platinocynaide screen fluorescing as a result of being exposed to what he would later called x-ray, Thomas Edison in the 1890s began investigating materials for ability to fluoresce when x-rayed, and at the end of century he had invented a fluoroscope with enough image intensity to be commercialized. Edison very fast investigated that calcium tungstate screen create brighter image. Health hazards that accompanied use of these devices because of that Edison abandoned his researches in 1903. At Edison laboratory lab equipment and tubes was repeatedly exposed, suffering radiation poisoning, later succumbing to an cancer. He also damaged himself eye in testing these early fluoroscopes. [1] Fluoroscopy revolutionized by analog electronics. X-ray image intensifier development by Westinghouse in the late 1940s [2] in the integration with closed circuit tv cameras of the 1950s allowed for brighter image and well radiation protection. With addition of camera user enable to view the image on monitor screen. And also allowing to a specialist to view the image in another room away from the risk of radiation. In the early 1960s digital electronics applied to the fluoroscopy when Frederick weighart [3] [4] and jamesMcnulty [5] (1929-2010) at automation industries, inc and then in California produced on a fluoroscope the world first real time image to be digitally generated.

After development of improved detector system digital imaging technology was reintroduced to fluoroscopy from the late 1980s onward.Modern improvement in screen phosphor, digital image processing analysis have allowed for increased image quality while minimizing the radiation to the patient.

Today the word fluoroscopy is widely understood in medical literature for moving image taken with x-ray which explains why it is the most commonly used and declining the uses of others.

In the health science 3-D Imagining technique has been improved to use in different areas. Improved old photogrammetric techniques have been introduced to give extra extensive and exact assessment of the captured things. 3-D modal can be constructed and monitored by using one or more converging pairs of views from any perspectives and measured in directions.

Around 40 years ago the first CT scanning device was developed. After to this in a short duration a stack of CT Sectional image was used to get 3-dimension information. At beginning of 1980s, clinicians used 3-D imaging craniofacial deformities after this considering craniofacial surgical needs first simulation software was introduced in 1986. And then principle and application of 3-D CT and MRI based imaging in medicine were published.[20]

2.13-D imaging methods

Following are thesame techniques which used some special x-ray equipment to generate 3-D image of the body.

Computed tomography (CT): CT imaging also known as computerized axial tomography (CAT) imaging, it's also used special x-ray equipment to generate 3-D image of the body CT devices are classified into two categories : cone beam and fan beam [6] using conventional fan beam CT devices the x-ray source that also called emitter or generator and flat detector panel with circular metal frame both rotate around the patient. When scanner works patient to be placed in a horizontal position on a table. Then table pass through the center of a big x-ray machine slowly slowly. this procedure gives no pain but its require a contrast material to make some components of body create better image

CT scanner working:

Firstly with motorized table patient moved into the circular opening of the CT imaging.Operator starts the CT imaging system once the patient is ready and complete the rotation of x-ray source and detector in one second then the CT device generate a narrow, fan shaped beam of x-ray scanning a section of patient body. There is one detector opposite of x-ray source which record the a snapshot of image and collect and transmit the data to a computer for each turn of the scanner and detector and where one or more multiple cross sectional image of the body part were reconstructed. Computed tomography (CT) are using very widely in dentistry such as in the diagnosis of some pathologies and in the contents of boundaries in the determining the salivary gland pathologies,[7] examination of the structure of the temporomandibular joint [8]

Drawbacks/Limitations of CT are following

- Its Costly
- It is not available in every clinic.
- Skip lesions far away from the sections.
- Foreign objects like restoration and prosthetics create artifacts,
- CT data also insufficient comparative to other soft tissue imaging technique.[9]

Cone beam computerized tomography (CBCT): To remove the drawbacks of conventional CT devices Craniofacial CBCT devices are designed [10] there are many difference in CBCT devices like scan time, patient positioning, resolution, radiation dose and clinical ease of use of cross sectional area. [11] and some CBCT Devices can scan all head area where others able to scan only chin area Dental and therapists are able to achieve 3-D (volumetric) data with very low radiation dose at one time in CBCT.[12] And it also allows realignment of 2D images in oblique and various incline plane. And in CBCT compare to CT patient visualization is possible with less radiation dose. CBCT devices provide 15times less radiation dose compare to conventional CT devices. This technology has increased the ability of providing 3-D image of craniofacial structure with minimum amount of distortion.

Following are the some advantages of CBCT

- Cost: CBCT devices are in smaller size compare to CT devices so these devices are with less price compare to computed tomography devices and also image process is easier.
- Quick scan: CBCT devices are able to obtained all raw data in a single turn so here patient diagnosis time also reduced and increased patient satisfaction.
- Dimensional reconstruction feature: CBCT devices able to display and arrange 3-D data in personal computers.

Drawbacks of CBCT Devices: following are some limitations of CBCT devices

- Main weakness in image quality is image artifacts, like metal brackets.
- The actual skin color and image of soft tissue can't be determined.
- More patient movement so unwanted patient movement may cause image disorder.
- These devices required more space.

Magnetic resonance imaging [MRI]: This technique is the highest contrast resolutions medical imaging technique. It operates by getting a resonance signal from the hydrogen nucleus. Radio waves are sent to target point for examination in magnetic field. Hydrogen atoms produced the energy in the cells stimulated by radio waves are converted into the image. This technique is very convenient for study of tumors, skeletal physiology.

When detailed information needs about the joint pain, adhesion, intracapsular joint effusion then MRI is a preferred choice and the information given by this technique and the determination of the position of the disk is successful in about 90%.

Advantages of MRI:

- It provide valuable information about the position and excellent soft tissue resolution with radiation free technique.
- This also able to display detailed osseous tissues based on the changes in the signal intensities.
- The patient who are allergic to the contrast agent in such case it can safely used.
- Without repositioning the patient we can obtained the image with this technique.
- This technique also gives opportunity to examine inflammatory processes and scar tissues.

Drawbacks of MRI:

- This technique needs expensive and advanced equipment
- Not available in every clinic
- It consume more time in the process

2.2 Motivation to present work

Fracture in the body often result from high speed motor vehicle accident or fall from height its required immediate medical attention. During the operative procedure surgeons rely on direct visualization of the operating area in the combination with indirect visualization from imaging devices for their orientation of the anatomy. Most widely used devices for spinal applications in healthcare are computed tomography and we have describe the above major drawbacks of computed tomography that is its very expensive. And it requires expensive tools it is not available in every clinic and another major drawback is that it takes more room and provides less room to team member to co-ordinate the task.

Considering the all drawbacks in the devices used in above imaging technique a new device introduced which is having advantages of both fluoroscopy and computed tomography known as mobile c-arm x-ray system. And the 3-D imaging technique which used this device is known as three dimensional rotational x-ray imaging technique.

Three dimensional rotational x-ray imaging technique: in this technique c-arm moved around the patient and allow for an acquisition run during which multiple fluoroscopy images are obtained and amount of radiation exposure during full acquisition run typically less than one tenth of computed tomography. Provide overall best patient care with minimum cost, it easily available in all clinics. Mobile C-arms are designed in such a way so we can perform multiple procedures quickly and easily. It Simplify tools placement while surgery in operation room. Simply point and shoot. This device takes less space and provides more space to team member so that they easily coordinate the task.C-arm with image intensifier and X-ray tube has designed fully balanced for smooth and supple positioning. They adapt to different anatomy automatically to promote first time right imaging.

III. MOBILE C-ARM X-RAY SYSTEM

Work involves complete design and development process of mobile c-arm x-ray system. While designing and development of mobile c-arm system we have followed this process

All associated components/ structures of device:all parts as shown in figure 1.1 that required to make a top level system that known as mobile c-arm system. We considered the mainly the major parts which play vital role in the mechanical structure.

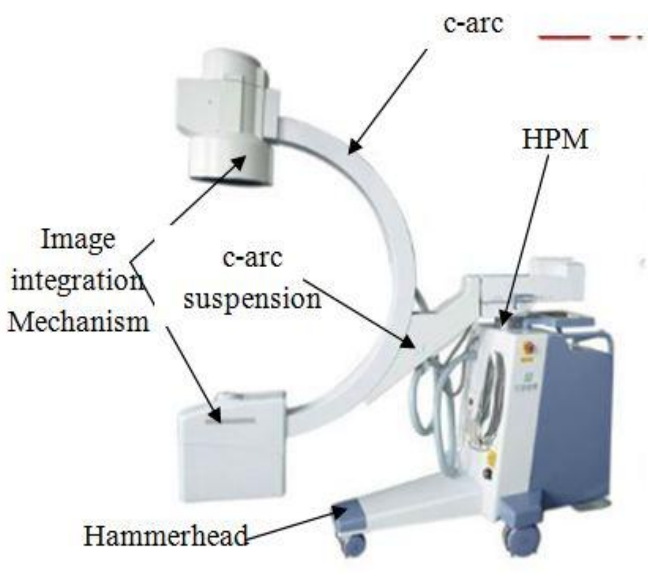

Fig. 1 Associated Components with mobile c-arm x-ray system

Design significance: how significantly each part play role in the system and what are the major significance of part that we kept in considering while designing the all parts.
Design parameters: considering the design significance of the part we designed the parameter also for each part to meets the design significance.
Design methods: we have also described the detailed design method for each part. Considering the design significance and parameters in mind how they designed.
Materials and manufacturing methods: as per significance of the parts we have assigned material and manufacturing methods also for them to achieve the required qualities of the particular part.
Testing/ results: we did the testing at two level at part level and at system assembly level once we designed, and manufactured the parts we also inspect/test the parts to assure about its as per specifications or not. If it meets to all specifications then weuse it for assembly purpose. And second level testing we did it at assembly level to be check all degree of freedom (shown in figure 1.2) of the system.
Degree of freedom of Mobile c-arm with image intensifier in all directions
Following are the possible movements of system in different different directions. That helps to the specialist to accommodate the image at any orientation around the patient so he can simply point and shoot the target and also simplify device or tools placement.

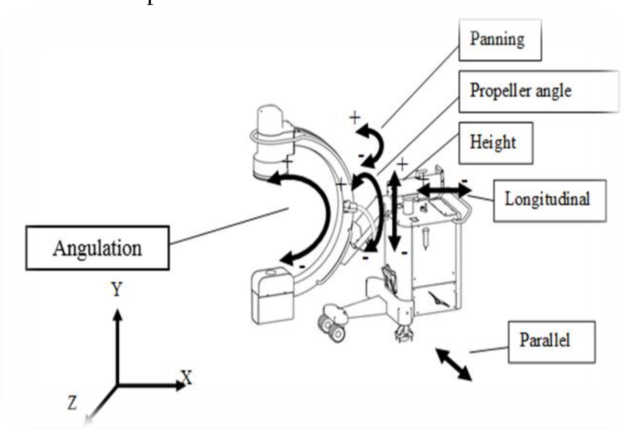

Fig. 2.0 : Degree of freedom of mobile c-arm x-ray system

Following are the possible movements of system in different different directions. That helps to the specialist to accommodate the image at any orientation around the patient so he can simply point and shoot the target and also simplify device or tools placement.

Table 1: degree of freedom of mobile c-arm x-ray system

Sr. No.	Descriptions	Movements
1	Longitudinal	0 – 200 mm
2	Height	0 – 480 mm
3	Propeller angle	0-180°
4	Panning	-12° to +12°
5	Angulation	+90° to -65°

Counterweight design
Ideally, for a chosen C-arc radius, the component weights of the orbital assembly should be distributed in a way that their CG coincides with the center of rotation. If there is some unbalance is present then in such cases we add dead masses to counter balance.
However, if the C-arc depth is not optimized for orbital counterbalance, then there is offset between the orbital CG and the center of rotation.
Counterweight is a dead mass added to the assembly for the sole purpose of shifting its CG to reduce the imbalance. It has an amplified impact on the system weight, as other weight bearing components need to be designed for higher strength after addition of a counterweight. Therefore, it should be kept to a minimum value. Effectiveness of counterweight increases as it is placed farther from the center of rotation in a direction opposite to that of the offset.Desired characteristics of the counterweight material are low cost and high density. High density counterweight occupies less space/volume. Therefore, it
is relatively easy to position it within the assembly without modifying other components
Graduated scale in degrees
The change in the angular position of the orbital is measured using a graduated angular scale placed on the C-arc. With the help of it, one can make precise movements of the C during a surgery. X-ray can be repeated in the same position during examination with the help of position measurement
Anodized surface finish
C-arc surface comes in contact with the bearing block rollers. These two components have relative motion, leading to friction. High operating force due to friction reduces usability. Therefore, anodization process is employed as the final step of C-arc manufacturing in order to improve surface finish and reduce friction. High quality surface finish leads to reduced operating forces.
Anodizing changes the microscopic texture of the surface and the crystal structure of the metal near the surface. Anodized Aluminum surfaces, for example, are harder than Aluminum but have low to moderate wear resistance that can be improved with increasing thickness or by applying suitable sealing substances. Anodic films are generally much stronger and more adherent than most types of paint and metal plating, but also more brittle. This makes them less likely to crack and peel from aging and wear, but more susceptible to cracking from thermal stress. Anodized surface reduces friction between bearing rollers and the C-arc, contributing to reduction in operating forces.

IV. RESULT AND DISCUSSION

In the present work we have tested the Performance of mobile c-arm x-ray system as per clinical needs.
8.1 Angulation travel
C-arm should operate smoothly with whole angulation travelAngulation travel should be as large as possible basic requirement is 125º (-35º to + 90º) (+1°/-1°).We achieved it 128º
8.2 Counterbalance
Tested balance of C-arc in the following orientations

Evaluation criteria

System must not move spontaneously for a time of 5s in any of the below mentioned orientations. We have successfully tested the system for all orientation

Case-1:Place C-arm in 00 Orbital. Place rotation in 00, 300, 600, 900, 1200, 1500 and 1800

Case-2:Place C-arm in 300 Orbital. Place rotation in 00, 300, 600, 900, 1200, 1500 and 1800

Case-3:Place C-arm in 900 Orbital. Place rotation in 00, 300, 600, 900, 1200, 1500 and 1800

Case 4: Place C-arm in -400 Orbital. Place rotation in 00, 300, 600, 900, 1200, 1500 and1800

8.3 Angulation movement force

Initial operating force at grips for C-arc angulation should be <150 N. Continuous movement force at grips for C-arc angulation should be <100* N, except when C-arc angle is 90°, Orbital force <150N. However, specific regulatory requirements should be taken into account while designing.

V. CONCLUSION

- Mobile c-arm x-ray system is available at cheapest cost. Cost is approx. one third of comparative fluoroscopy devices
- Presented mobile c-arm x-ray system is a new visualization tool for spine trauma combining the advantages of both fluoroscopy and computed tomography.
- In several human cadaveric experiments it was shown that three dimensional rotational x-ray [3-DRX] imaging is an accurate and valuable tool that is performing both conventional fluoroscopy and computed tomography tasks
- Providing fast two dimensional Projection images and displaying complex anatomical structures in three dimensions with multiplanar reformatting capability
- With help of mobile c-arm x-ray system specialist can perform multiple procedures quickly and easily.
- It Simplify tools placement while surgery in operation room
- This device takes less space comparative to another computed tomography and provides more space to team member so that they easily coordinate the task.

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