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Design of an Assistive Device With Ultrasonic Transducers for the Assistance in Spinal Fusion Operations (Scoliosis)

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Abstract - Abnormal side to side curvature of the spine is termed as Scoliosis. Progressive and perhaps uneven weakening of the spinal muscles leads to gradual inability to support the spine in an upright position, therefore the weight of the upper body begins to collapse the spine, causing a curve. 85% of Scoliosis cases does not have a clear cause and those with Scoliosis are also likely to have it from the family members who also have the condition although it is unknown what genetic factor causes this familial link. Scoliosis is often remedied by spinal-fusion operation. During the fusion operation, a pedicle probe is inserted manually into the vertebrae to create a pilot hole, a trajectory that the screw follows. A set of rods and screws will be attached to the spine. This allows the spine to be held in place while the bones fuse with the help of some vectors. The screws are misplaced in approximately 20% of the cases, causing nerve damage and requiring re-operation. The probe is mostly inserted with the help of fluoroscopic guidance and requires constant revaluation. Our device is designed to combat this specific problem, it uses 3 ultrasound transducers to measure the bone density in multiple axes. When the surgeon breaches hard bone from soft bone, the density change will be detected and signals will be sent to the feedback system on the handle of the assistive device consisting of Ultrasonic transducers and LED lights. It helps in reducing operating time by 20% and cost by nearly 15%.

Keyword: **LED, Transducers, Signals**

I. INTRODUCTION

In our existing technology the usage of normal transducer is used without the probes which results in some minor errors because of its wear and tear. In our model, As the ultra sonic transducers are used, it reduces the abrasions of the device.

The Device can be manufactured in smaller size and lesser cost compared to the traditional device and can be used in almost every spinal surgery. If the device is further modified it can be used in lot of applications like finding the layer of skin in plastic surgery (which we are working out).

TARGETED ORGAN:

1. Spinalcord
2. Vertebrae.

SCOLIOSIS

As mentioned earlier Scoliosis is the abnormal curvature of the spine caused by several causes which causes pain in the surrounding tissues, damage in the nerves and may also result in paralysis.

Major classifications of the Disease:

The disease may be classified based on the Age like

- **Infantile scoliosis –** Infants from birth to 3 years old.
- **Juvenile scoliosis –** Children from 3 to 9 years old.
- **Adolescent scoliosis –** Children from 10 to 18 years old.

Based on the origin of the disease, It is of types like

- **Idiopatheic –** Has no specific cause, Most common
- **Neuromascular –** A result of abnormal muscles and nerves.
- **Congenital –** Caused by bone abnormality in birth.

Further based on the location of the curvature in the spinal region,

- **Thoracic scoliosis** is a curvature in the middle (thoracic) of the spine which is the common location for spinal curvature.
- **Lumbar scoliosis** is curvature in the lower (lumbar) portion of the spine.
- **Thoracolumbar scoliosis** is a curvature that includes vertebrae in both the lower thoracic and upper lumbar portion of spine.

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When the curvature is towards left it is known as **Levoscoliosis,** found in the lumbar spine which is a rare case. If the curvature is towards left then it is called as **Dextroscoliosis** which usually occurs in Thoracic spine. It can occur on its own (forming a C shape) or with another curve bending the opposite way in the lower spine (forming an S). This kind of curvature is common between the two types.

II. PROCEDURES:

There are two major types of procedures for the Scoliosis i.e. Invasive and Non-invasive type. In non Invasive type the therapist evaluates the strength and flexibility first and followed by the posture and based on the results difference type of exercises like stretching are given and a separate customised treatment plan is given to the patients. In moderate cases injections are given in epidural space (space is within the spinal canal and the space surrounding spinal cord).

Surgical Procedures:

Discectomy

Surgical procedures are high risk and done only when the non-invasive methods cannot be used to treat the patient. There are various types of surgery like

- **Disectomy** (minimally invasive surgical means used to remove a herniated nucleus) which usually takes an hour.
- **Kyphoplasty** is a minimum invasive procedure and is for compressed fractures of the spine due to osteoporosis. This is usually for immediate pain relief and stabilizations. The whole process is done in 45 minutes duration through a small incision.
- **Laminaplasty** is used for correcting the compressions in spinal cord. Here instead of removing the lamina completely, it is hinged on one side and it is rotated away from the spinal cord. No spinal fusion is involved but it results in high stability.
- **Laminectomy or spinal decompression** can be accomplished on all thoracic, lumbar, cervical region to relieve pressure on the spinal cord or the nerve roots. The lamina is removed on both sides and gives space for the nerve roots and spinal cord.
- **Spinal Fusion** is a procedure which makes use of the bone grafts which joins each vertebrae together. This procedure is done with or without the help of the apparatus like plates, screws etc.

Spinal fusion with instrumentation

Spinal fusion is the most widely performed surgery for scoliosis. It may be also called spondylodesis. It is a neurosurgical or orthopaedic technique which joins two or more vertebrae. In this procedure, bone either removed from anywhere else in the body (auto graft) or from a donor (allo graft) is grafted to the vertebrae.

So when they heal, they form one solid bone mass resulting the vertebral column to be rigid. This procedure prevents worsening of the curve, at the expense of some spinal movement. The modern pedicle screw (metallic screws made of titanium) system has largely induced the need for this.In recent years all-screw systems have become the gold-standard technique for Adolescent idiopathic scoliosis. The screws are highly bio-compatible and good in its bio-mechanical properties. Hence this enables greater correction of the curve in all planes.

In most cases, the fusion is augmented by a process called fixation, involving the placement of metallic screws, plates, rods to stabilize the vertebrae and support bone fusion. The fusion process typically takes 7 to 12 months after procedure. During this time, the requirement external bracing which is an external supporting device which modifies functional and structural characteristics of spine may arise. In case of failure of the fusion, Re operation is required.

In spinal fusion surgery, the accuracy level of screw insertion into the spinal vertebrae is directly proportional to the success rate of the operation. Accurate placement can be only achieved by highly trained and highly experienced professionals (Senior doctors). The result of misaligning even a single pedicle screw may affect the patient.

III. LITERATURE VIEW

'To choose the appropriate treatment approach for scoliosis we need to understand its etiology and pathogenesis first' **[2]**.The spinal fusion surgery in the year 1998 was 174,223 which increased drastically during a period of 10 years to a count of 413,171 and the results of cervical fusion is also observed to be increased.**[3]**

ULTRASONIC TRANSDUCER:

The main component required in the apparatus we design is the ultra sonic transducer. Ultrasonic

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transducers are transducers that convert ultrasonic waves to electrical signals vice versa. An ultrasonic transducer consists of both transmitter and receiver in a single apparatus thus it contains a transceiver altogether. The result is obtained by analyzing the sound waves reflected back from the object which works on a principle of Echoes from sound waves. It also works on the basis of difference in the velocity of the sound wave**[4]**.

Active ultrasonic sensors produce high-frequency sound waves and analyze the echo which is reflected back to the sensor, measuring the time difference between the transmitted and received signal to determine the distance to an object.

Passive ultrasonic sensors aregenerally microphones that detect ultrasonic noise that is present under certain conditions which converts the sound signal to an electrical signal and delivers it to a computr.

Ultrasonic transducer is a device that converts AC signal into ultrasound as well as sound into AC. In ultrasonic, the term typically refers to piezoelectric transducer or capacitive transducer. Piezoelectric crystal changes its size and shape when a voltage is applied to it. AC voltage makes them oscillate at the same frequency and produce ultrasonic sound waves. Capacitive transducers usually use electrostatic fields between a diaphragm and a backing plate.

As the piezoelectric materials generate a voltage when pressure is applied to them, they can also act as ultrasonic detectors. Some times usage of separate transmitters and receivers is required, while rest of the time combination of both functions into a single piezoelectric transceiver.

IV. SYSTEM DESIGN:

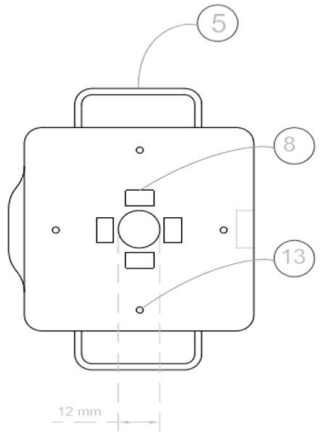
The instrument consists of all solid components which are tested to be bio-compatible. The main base is completely made of bio-compatible plastic which should not react with any of the solutions used in the surgery where the design of the base should not be slippery to avoid accidents. The base should also be safe to the OT (Operation Theatre).

Inside the block is our Information processing circuits which consists of a micro-controller circuit to manage the data, ultrasonic transducer circuit which isin contact with the external pedicle screws with the help of magnets. The screws are made up of Titanium or cobalt-chrome**[7]**. Titanium is a weak magnetic metal so it helps the screw to just be in contact. The screw also acts an a waveguide for the Ultrasonic waves to propagate. This total information processing circuits are used to analyse the signals from the transducer and calculatethe density difference between the bone and the soft tissues surrounding it. When the whole information is processed it is displayed using an LCD or LED screen present externally and is not a part of the device. As the safety of the patient is the most important factor considered in an operation theatre every test on the apparatus is made. First of all a stable component is used in the production of the apparatus. Since the handling is done by the surgeons the grip of the base is very much required so extra handles are also designed and these handles are designed in such a manner that the base could be fixed in certain stabilizing stands (like mono-pods and tri- pods used in photography).The Ultra sonic transducer is used here as a **diagnostic sonography.** The sensors transmits a sound wave of desired frequency which is programmed and the change is frequency of wave after hitting the bone or tissue comprises of different wavelength from which thickness can be calculated. Single sensor acts as both transmitter and receiver.Basically the screws are the usual screws used for the procedures at present. The screws are made up of Titanium or cobalt-chrome**[7]** as they are highlybio-compatible when compared to other alloys.. Titanium is a weak magnetic metal so it helps the screw to just be in contact The screw also acts an a wave-guide for the Ultrasonic waves to propagate. The dimension of the screw are of 30mm to 60mm in length and the **diameter** ranges from 5.0mm to 8.5mm (up to 1/4 inch)**[8]**. Depending on the age of the patient the size of the screws vary. The plates are further attached to the screws in order to straighten the spine. The procedure is little complicated and takes a lot of time.

DIAGRAM
CROSS SECTIONAL VIEW

BOTT OM VIEW

PARTS OF THE DIAG RAM



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TOP VIEW

1) Cavity for the placement for the screw.
(2) Transmitter and reciever part of the transducer.
(3) Ultrasonic transducer circuit.
(4) Microcontroller circuit.
(5) Handle for more stability.
(6) Wires to and fro the external circuit.
(7) Dense plastic for withstanding hammering.
(8) Magnets (4 numbers).
(9) External circuits (For example power supply, output monitors)
(10) Plastic casing.
(11) Red LED (Indication to stop hammering).
(12) Green LED (Indication to continue hammering).
(13) White LED (Provide Lighting).

WORKING

The plastic casing consists of the Ultrasonic circuit and the microcontroller circuit for which the power supply and output display monitors (optional) are connected externally. The two LED indicates whether the hammering should be continued or stopped. The device is held with the help of handles which is also proposed to be made up of titanium.

The screw is held in position with the help of the magnets provided. Then the Device is hammered at the top of the casing where plastic is made thick to withstand impacts of hammering.

After the screw is in position the Red LED glows which indicates the hammering to be stopped. Extra White LEDs are given in the bottom to give visual support for the surgeon.

V. APPLICATION

The one and only major application is the usage of this assistive device is in the spinal-fusion procedure. The apparatus provides extra support in the surgery resulting in the perfect positioning of the screw. Since the accurate density difference is found the damage to surrounding tissues can be reduced to a higher level.

VI. CONCLUSION

Thus the Assistive device can be used in the Spinal fusion surgery which can be stated as portable and effective device.

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