KNEE FRIEND

Smart Care for your Knees

Designing for Assisted Rehabilitation & Health Care
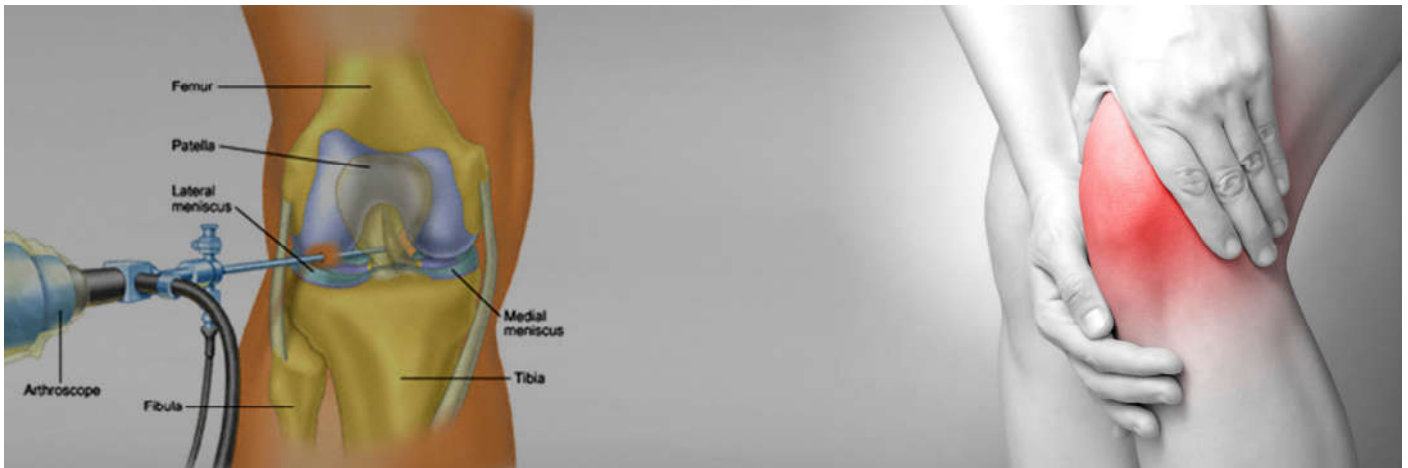
www.kneefriend.in

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Knee Prosthetics & Surgical Implants

When my uncle was pursuing his sedentary lifestyle with his teaching profession that got worse after his retirement at 60, little did he knew about his sedentary lifestyle choices that one day led him to a health nightmare. At 70, he started experiencing severe knee and joint pains that resulted in difficulties while walking and performing daily routine tasks. The doctors prescribed him a knee transplant surgery for both his legs. The procedure itself was very painful and the poorly designed program for his rehabilitation post surgery didn't proved to be of much help to him. His condition deteriorated with time showing no signs of improvements and his body was not able to adapt to the prosthetics due to lack of proper care and assistance. Struggling for another 2 years with his deteriorating health condition, his body finally gave up and he passed away at 72. This incident shocked me and made me question the procedure for knee surgery and rehabilitation. After doing my research in the same, I was convinced that I needed to design a better system for the patients to go under this procedure. Meeting with many doctors and discussing this case made me realise that even doctors are incapable of providing one to one health care and rehabilitation assistance to the patients due to lack of a proper system, massive work loads and lack of trained people and physiotherapists in place.

Of the 100 patients that come to me with knee pain in a month, only 10 percent are cases for replacement surgery," says Navi Mumbai-based physiotherapist Vivek Kakkar. The rest of the cases, he explains, are usually the result of weak thigh and hip muscles or incorrect foot posture. "These are what we call mechanical errors, and result in the degeneration of the bone under the patella or knee cap, leading to pain," he says. Temporary use of knee braces or regular physiotherapy is often enough to fix the problem. In any case, believes Kakkar, if the knee joint is attacked for correction without fixing the muscles, complications are likely to crop up again. A study recently published in Arthritis & Rheumatology, a journal of American College of Rheumatology, proves that the situation is identical in the US. Over one-third of all knee replacement surgeries carried out in America are unnecessary. While India-specific data isn't available, top Mumbai orthopaedics agree that often, knee replacement surgeries are not only

unnecessary, they can even prove detrimental to the patient in the long run. A leading Mumbai surgeon, who didn't wish to be named, says, "There is a certain amount of aggressive practice in place. Here, a replacement surgery is recommended earlier than absolutely necessary, for instance, when symptoms are not all that severe. It's mirroring the American way of practising medicine. The argument that this school of thought puts forward is that conducting the surgery before the patient is disabled leads to better results. Of course, the theory is subject to interpretation."

A knee replacement surgery involves, to put it simply, surgically inserting a metal alloy plastic ceramic prosthesis in the knee that will continue to function like the damaged joint. And it's not cheap. In India, just the prosthesis ranges from Rs 75,000 to Rs 1 lakh. Add to this hospital costs, surgeon charges, time in the operative theatre, and you have a bank balance shock. Dr Pranjal Kodkarni, a joint preservation specialist who consults at Bombay Hospital, says, often, a surgery is required only when the damage is in the last stage or "when the bones are touching each other", with degeneration and wear and tear having destroyed the cartilage between the bones altogether. In all other cases, he adds, it's best to try and preserve the natural joint.

The global hip and knee surgical implants market is anticipated to grow at a compound annual growth rate of 9.54 percent to 2022, according to Digital Journal. The market is expected to reach $34.57 billion by 2022, up from $18.26 billion in 2015.

After realising the depth of the matter and market for such a problem, I decided to take on the situation with following objectives-

> Designing a better system for patient recovery and assistance.
> Designing a program for rehabilitation that can be customised for each and every patient as every patient is different.
> Bring all the stakeholders like patient, doctor and physiothera pist to one platform making sure they are available for help anytime.
> Designing a prevention system that can help middle-aged person to pursue a healthy and active lifestyle escaping from the health conditions and lifestyle choices that lead to such severe conditions in future.

Designing for Assisted Rehabilitation & Health Care

KNEE **FRIEND**
Health Care

Monitor

Improvise

Consult

Get fit

Device Placement On
Posterior Tibial Artery
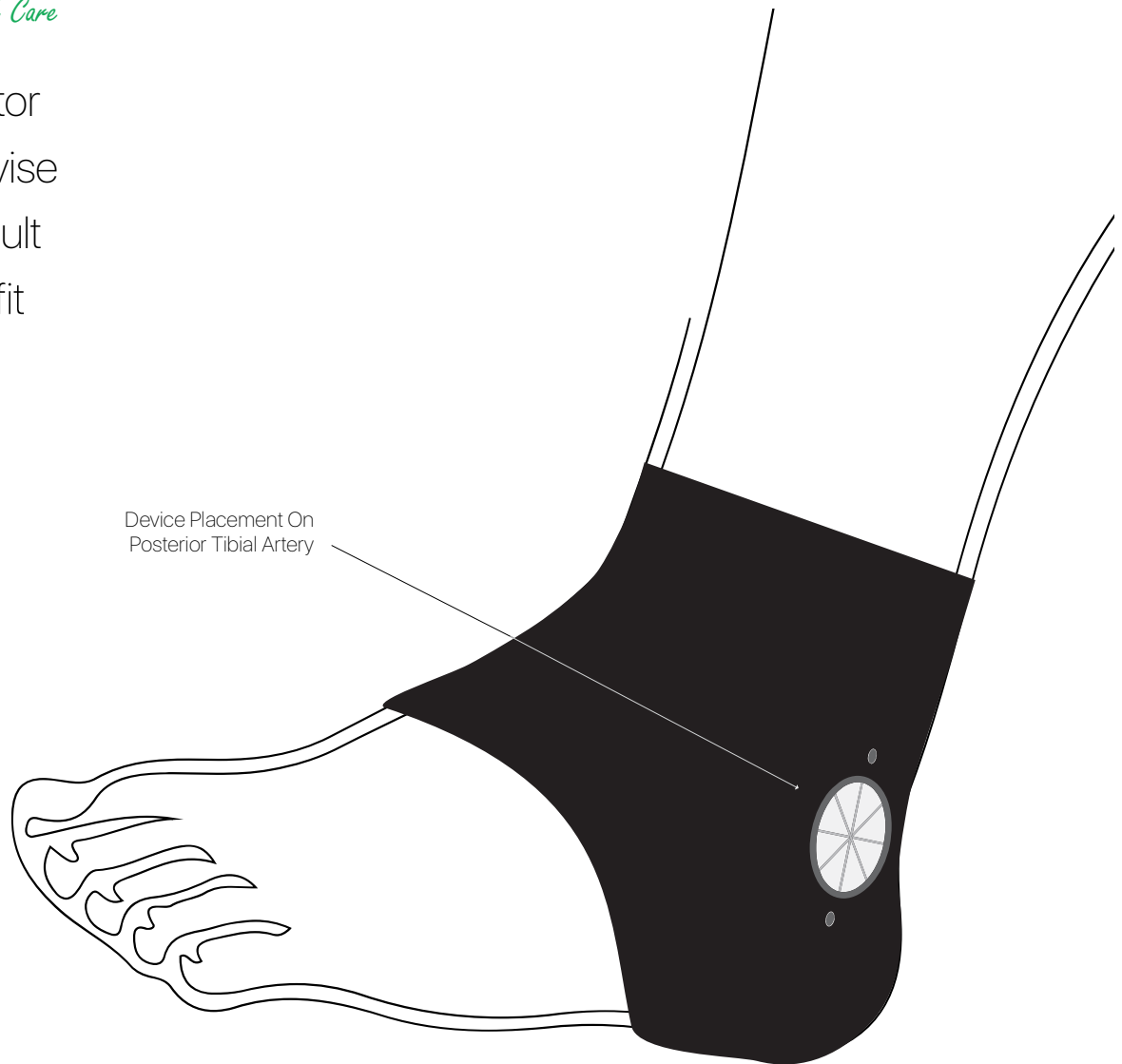
After learning about the problem in detail, at first, I decided to design a healthcare device that can inform, assist and monitor a patients progress and can help doctors and physiotherapists to standardise a rehabilitation program that can be customised as per patient's needs. To begin with, I started with designing a health care device that can be wore under the knee area and can measure the accuracy of doing rehabilitation program exercises by sensing the movements of the leg and assist a patient if he or she fails to do an exercise correctly. Moreover, the entire program can be gamified to motivate a patient by a reward mechanism that gratifies him/her when a set of task is completed. These activities are recorded and reported to the doctor for further treatment and consultations.

Designing a healthcare system is not easy and needs a lot of factors to be considered while working, such as usability, minimal learning to adapt, accuracy, user experience etc. The device thus proposed here can be mounted on a sock like wearable that makes sure the position of the device while making it comfortable for the user to wear at the same time. This device measures the angular and forward- backward motion of the leg and compares the results with the values fed in the system to decide whether an exercise is performed correctly or not, if not the user can learn from the exercise documentations and videos available on the bluetooth connected mobile device in absence of the physiotherapist. The critical placement of the device on legs makes sure the accurate measurement of heart rate.

1st Layer

NOTIFICATION LAYER
Outer covering shell with threaded bottom base to fit onto the 4th layer, includes 8 RGB LEDs placed in 8 grooves of translucent acrylic sections with connections extending towards bottom 3rd layer Micro-controller section.

2nd Layer

SENSING LAYER
The second layer is perforated with 8 holes to let pass the connections from top layer's 8 RGB LEDs, in addition to this 2nd layer is mounted with a bluetooth module to facilitate communication with a smartphone. The layer has a 6DOF accelerometer with an inbuilt gyro sensor to measure movement and angular displacement of lower leg of the wearer.

3rd Layer

COMPUTING LAYER
This layer has a microcontroller and various I/O ports to link with all components of the device. Presently I am using a Arduino Lilypad, wearable microcontroller which facilitates 14 digital I/O pins with 6 analog connections. This board features an ATmega168 microcontroller which suffice my application needs.

4th Layer

BATTERY, VIBRATION NOTIFICATION & HEART BEAT MONITORING LAYER
The bottom most, 4th layer is mounted with a heart beat sensor, a battery module and a vibration motor. This layer powers the entire device, takes heart beat readings of the user and notifies errors in excercises or actions via its vibration facilitated by a tiny vibration motor, installed next to heart beat sensor.

Knee Friend Health Care

Knee friend consists of a wearable device and a mobile phone app that comes in three versions- Patient app, Doctors app and Physiotherapist app if needed. The device consists of two major parts- a wearable sock and an electronic device mounted on it. The electronic device is facilitated with a 6DOF or 9 DOF accelerometer, a heart beat sensor, a bluetooth module, RGB LEDs, vibration motors, batteries and an arduino micro-controller. The LEDs can be customised as per the number of tasks included in a rehabilitation program, once a patient completes a set of task the LED glows green and if he/she fails the LED glows red, making a user realise that he needs to finish the remaining tasks for the day without using a mobile phone.
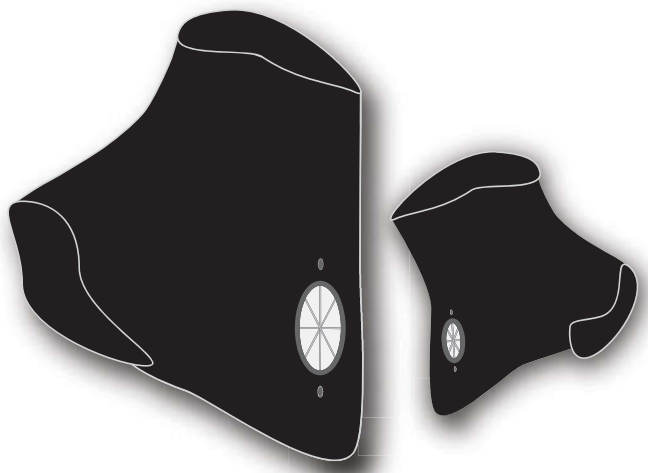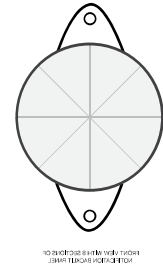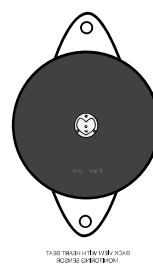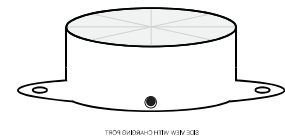

The device above shows the proposed design of the device that can be mounted on the sock via a rivet or snap button mechanism. The top layer of the device has 8 sections backlit by 8 different RGB LEDs to notify completed or pending tasks, where the bottom most layer holds a heart beat sensor that remains in touch with the skin at the tibial artery point.

If a user does any exercise incorrectly then the device can alert by blinking respective LED and sending a vibration on the wearable device. Please refer to the above layer configuration image to understand the components of the prototyping method used.
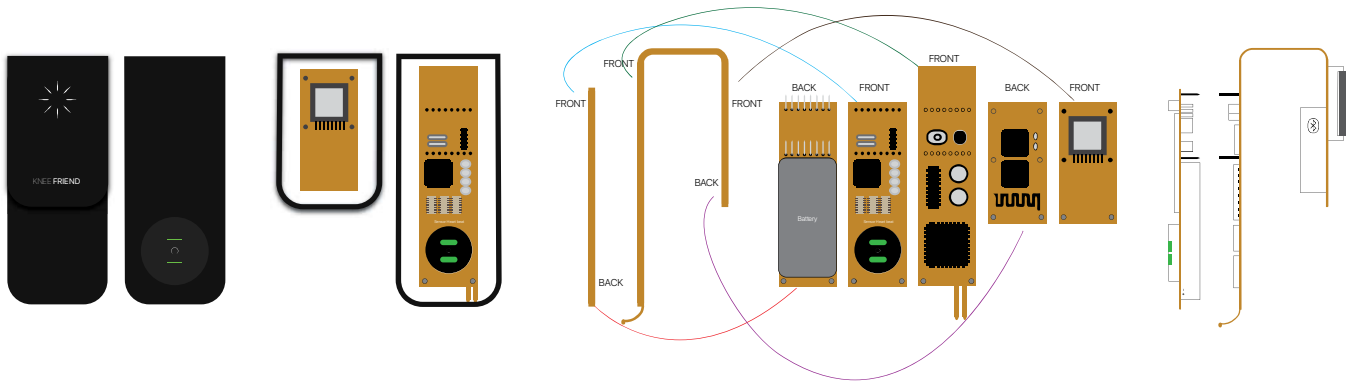
Let's get **Active** today !

KNEE **FRIEND**
Healthy living
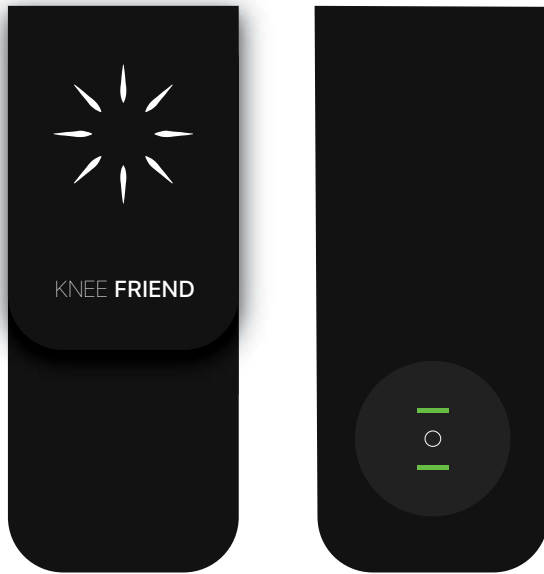

Monitor
Improvise
Self care
Stay fit

In the second part of this project, I am proposing a device that is minimally designed to help maintain an active and healthy lifestyle, saving a normal user from almost all conditions that lead to a knee and related problems in future.


Designed to give a lifestyle appeal and ease of use, this device can be wore on the elastic band of a ankle length sock or a normal sock if the needed. This device offers a customised activity plan to a user with a set of daily activities that needs to be completed to stay fit as per the proposed plan. As described from the image above the device is about the size of a small pen-drive making it easy for a person to wear and use on a regular basis. This device offers leg movements like running, walking and alerts a user when sitting idle for long duration to take a walk or do some stretching exercises described in the plan.

These daily activities and completed tasks are recorded in a mobile device connected via a bluetooth connection and reports are generated for the user to analyse and improvise.
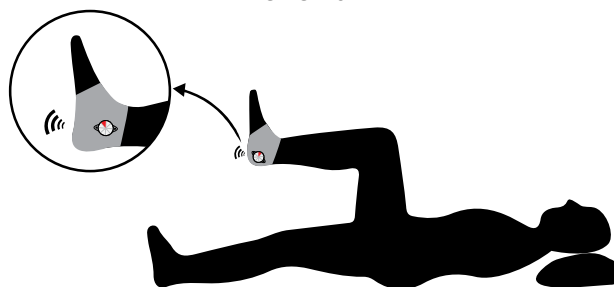
Carefully monitored exercises to help recovery keep you fit
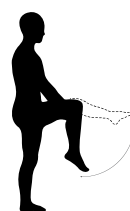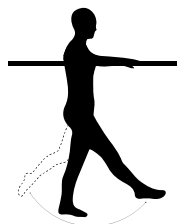
The 6DOF sensor mounted in both the devices facilitate the measurement of angular movements and other activities of the leg, giving a user and stakeholders an accurate report on a patient's progress with prescribed rehabilitation program.
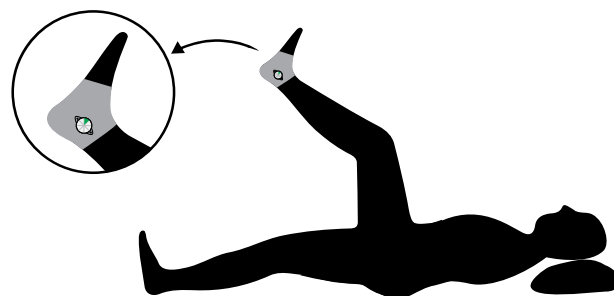
CASE 01

CASE 02

CASE 01- As shown in the above diagram, in the Case 01, a patient is doing prescribed exercises correctly and this is leading him to get a green completed activity LED glow on the wearable device. This achievement is recorded in the system and based upon that the patient is gratified and the generated reports are shared with the doctor and physiotherapist to monitor patients recovery.

CASE 02- In Case 02, as shown in the above diagram, a patient is doing an exercise incorrectly and this is causing the device to send a vibration feedback with a warning red LED glow on the device, with a alert on the mobile phone. This system intends to inform the user about the correct body/ leg postures and methods to exercise that is much needed for a optimum recovery.

What if someone told you that you haven't stretched your legs beyond 155º since past three months ?

As illustrated here, the entire system consists of a wearable device and an app. The Knee Friend app is connected with the wearable device via a bluetooth connection that monitors and alerts users, while the app holds all the information about the prescribed plan for rehabilitation and acts as a communication medium among the stakeholders where progress reports are shared and doctor, physiotherapist and the patient remain in constant touch to discuss health, recovery and medication issues.

4/8 COMPLETE

1.2 KM WALK TODAY
2.9 KM RUN TODAY
BEST STRETCH 156°
BEST SPEED 10.3 KM/HR
HEART BEAT 92 BPM
WEIGHT 78 KG
REPORT AT 15TH NEXT MONTH
CALORIES BURNT 400

Conclusion

Let's get **Active** today !

KNEE **FRIEND**

To know more, please visit **www.kneefriend.in**
Email us at **info@kneefriend.in**

This Integrated Design Project can solve a major healthcare problem. I believe that under the inspiring guidance and compassionate support from my mentors, I will be able to take this solution from prototype stage to a market ready product, helping millions of elder people around the world to get proper recovery assistance and care for an effective rehabilitation after going through the painful process of knee and joint replacement surgeries. On the other hand this project can help people to maintain a health and an active lifestyle to avoid the conditions that lead to such cases.

I am passionate about building this solution with an integrative design methodology, where we are creating meaningful product and service by bringing many design streams, tools, methods and people together.

By doing this project, I intend to design and develop a process for innovation and problem solving that can be standardised and implemented to build a future organisation that implements innovation and design methods in its operations and decision making, to become a key element of social and economic growth of a nation.

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Please contact at **info@kneefriend.in**,
to know more about Smart Care make an inquiry here-

Inquire Now