IJNRD.ORG ISSN : 2456-4184
INTERNATIONAL JOURNAL OF NOVEL RESEARCH AND DEVELOPMENT (IJNRD) | IJNRD.ORG
An International Open Access, Peer-reviewed, Refereed Journal

MANUFACTURING AND OPTIMIZATION FOR A KNEE SUPPORT FOR SUBJECT TO TRANSFER BODY WEIGHT TO SHOE

[1]Rahul Jain, [2]Vaishnavi Gaikwad, [3]Tanvi Shinde [4]Viraj Bhosale [5]Dr. Bhagyesh B. Deshmukh

[6]Prof. V.P. Kulkarni

[123456]Department of Mechanical Engineering, Walchand Institute of Technology, Solapur, Maharashtra, India

Abstract: This project report presents the manufacturing and optimization process of a knee support designed to facilitate the transfer of body weight to the shoe, thereby enhancing comfort and stability during physical activities. The objective of this project was to develop an innovative knee support system that would alleviate stress on the knee joint and improve overall biomechanics. This project report focuses on the creation and improvement of a knee support device that transfers body weight to the shoe to give people with knee-related problems stability and support. The goal of the study is to look at a variety of issues, such as Osteoarthritis knee support design considerations, material choices, manufacturing processes, and optimization approaches. The results of this study can be used to raise the standard of knee support products as a whole, improving the outcomes for people with knee issues.

Keyword: Biomechanics, Osteoarthritis

INTRODUCTION

The objective of this project is to develop an innovative knee support system that alleviates stress on the knee joint and optimizes body weight transfer to the shoe. By distributing the load evenly and enhancing biomechanics, the knee support aims to improve comfort, stability, and overall performance during activities such as walking, running, and sports. This project recognizes the limitations of existing knee support designs and aims to overcome them through careful analysis, design, and optimization. By utilizing advanced manufacturing techniques and materials, the knee support device will be engineered to provide a lightweight, adjustable, and durable solution to address the needs of users across various physical activities and lifestyles.

A thorough knowledge of human biomechanics, particularly the dynamics of weight distribution and joint movement throughout various activities, will be necessary for the manufacturing process. The knee support device will be created to optimize weight transfer effectiveness using this information, lowering knee joint stress and encouraging ideal alignment. This project aims to provide a knee support system that sets goals for user comfort and use while also improving performance through iterative design, evaluation, and optimization. To make sure the final design reaches the necessary goals, thorough mechanical and ergonomic assessments will be taken into account throughout the development process. [1]

NEED OF THE STUDY.

The Knee Support Optimization project has been identified as a crucial initiative to address the limitations and shortcomings of existing knee support systems. Through careful analysis and evaluation of current solutions, it has become evident that there is a need for optimization and improvement in terms of design, functionality, and overall user experience.

The identification of this project stems from the feedback and challenges faced by individuals using conventional knee supports. It has been observed that some existing knee support systems may not adequately address specific needs, such as providing sufficient stability, comfort, and adjustability. Additionally, issues like restricted movement, discomfort during extended use, and lack of breathability have been identified as areas that require optimization.

The project aims to employ a systematic approach to identify key areas of improvement and implement effective solutions. This involves studying user feedback, consulting with medical professionals, and conducting extensive research on materials, biomechanics, and design principles. By combining these insights, the project team seeks to optimize the overall performance of knee support systems, addressing the identified issues and enhancing the overall user experience.

3.1 Population and Sample

Osteoarthritis is a widespread chronic ailment that has a significant societal financial burden as well as symptoms like pain, tiredness, and functional restrictions. In part because of obesity and population ageing, it is anticipated that the burden of OA would rise. Although OA prevalence rises with age, it is becoming increasingly understood that OA also affects people when they are younger. Recent US statistics showed that by the time they reach age 55, half of those with symptomatic knee OA receive a diagnosis. Ageing and repeated mechanical stresses are linked to the etiology of OA. Three major sub-groups of the etiological

variables have been identified in recent studies: sex, anatomy, and body mass. Clinical symptoms include joint discomfort, stiffness, reduced joint range of motion, quadriceps muscle weakness, and changes in proprioception. Because it results in a gradual loss of function, decreased strength in the muscle groups involving the joints is important. The individual's ability to stand up from a chair, walk, or climb stairs is greatly hindered by these symptoms. People with OA may also exhibit instability, a limp while walking, and poor limb alignment. Crepitating during motions is caused by arthritis of the uneven joint surfaces. [2]

3.2 Data and Sources of Data

Relevant peer-reviewed publications were retrieved from a MEDLINE search using the terms with the reference terms osteoarthritis, knee, and braces (as per Medical Subject Headings), plus a manual search of references from original and review articles and appropriate Internet resources.

3.3 Theoretical framework

The Knee Support Optimization project recognizes the importance of cost-effectiveness and accessibility. The goal is to optimize the design without significantly increasing the manufacturing cost, ensuring that the improved knee support systems remain affordable and widely accessible to individuals in need.

In summary, the Knee Support Optimization project has been identified as a response to the limitations and challenges faced by existing knee support systems. By addressing areas of improvement and optimizing the design, the project aims to develop enhanced knee support solutions that provide better stability, comfort, and usability. Ultimately, the project seeks to enhance the overall quality of life for individuals with knee-related issues by offering optimized and accessible knee support systems.

IV. RESEARCH METHODOLOGY

The methodology for the Knee Support Manufacturing and Optimization project report encompasses a comprehensive approach that includes several key steps. The following is a outline for the methodology section of this report:

4.1 Problem Identification

Outlined in detail the issues and restrictions related to the current knee support systems by research of the literature and medical expert consultations. Identified certain areas for improvement, such as cost effectiveness, adjustability, range of motion, comfort, and stability.

4.2 Research and Analysis

Thorough study of knee support system materials, manufacturing processes, biomechanics, and design concepts. Analyzed a number of variables, including material qualities, robustness, flexibility, ergonomic concerns, and therapeutic efficacy.

4.3 Concept Evaluation

Based on predetermined criteria, including feasibility, manufacturability, usefulness, comfort, and cost, evaluated the created concepts. Chosen the most forward-thinking ideas with the potential for improvement and expansion.

4.4 Prototype Development

Created prototype of the chosen idea using suitable manufacturing processes and materials. Ensured that the prototype closely resemble the optimized knee support system's planned form and functionality.

4.5 Testing and Evaluation

Used appropriate techniques and standards to carry out thorough testing and assessment of the prototypes. evaluated elements such durability, breathability, comfort, support, and stability. Gathered medical expert comments to confirm the efficiency of the improved knee support systems.

4.7 Manufacturing Plan

Created a thorough manufacturing plan that details the procedures, tools, supplies, and quality assurance checks required for producing the improved knee support systems. Weighed aspects such cost-effectiveness, scalability, and compliance with regulations.

4.7.1 Concept Design

A tri-compartment off loader (TCO) is a new type of off loader brace that can reduce joint forces throughout the entire knee. While uni-compartment off loaders can only offload one side of the knee (known as a tibiofemoral compartment), a TCO offers combined offloading of both sides of the knee and the knee cap (the patellofemoral compartment). A TCO brace works like a shock absorber for your knee. When you bend your knee, a specialized hinge helps absorb body weight to reduce the load placed on your joint. It then helps power your leg muscles to assist knee extension as you straighten your leg. This allows a TCO brace to relieve pressure and pain in all three knee compartments at once, while also enhancing mobility and muscle strength. [3]

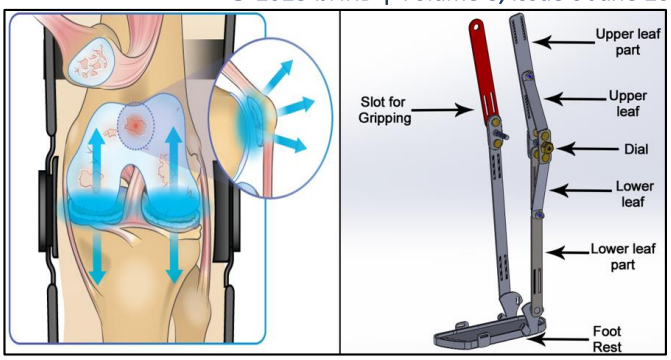

Figure 1 Concept Design

4.7.2 Manufacturing Considerations

The manufacturing process plays a crucial role in the development of knee support systems designed for individuals with osteoarthritis (OA). It involves transforming the design concept into a physical product that meets the functional, quality, and cost requirements. Here is an overview of the manufacturing process and its significance:

Design Refinement: The development of the knee support system design is the first step in the manufacturing process. In this phase, the design concept is translated into particular technical drawings and specifications that serve as the manufacturing process's final layout.

Material Selection: The performance and comfort of the knee support system depend on the use of the right materials. Finding and acquiring materials with the required mechanical qualities, such as flexibility, strength, and hypoallergenic traits, is a step in the manufacturing process. Here Stainless Steel 316-L is used.

Tooling Design and Development: The design and development of the tooling that will be utilized to manufacture the different parts of the knee support system entails making precise and accurate tooling.

Prototype Manufacturing: A crucial stage in the manufacturing process is prototyping. It enables the assessment and testing of the user experience, fit, and functionality of the knee support device. Typically, prototype is created utilizing the chosen manufacturing technique in order to determine the viability of the design and make any required adjustments.

Quality Control and Testing: The manufacturing process includes quality control procedures to guarantee that the knee support systems adhere to the necessary requirements. To confirm the product's functionality, safety, and dependability, this involves carrying out material testing, durability tests, and functional tests.

4.7.3 Optimization for Concept Design

Knee support optimization for osteoarthritis (OA) involves the application of various optimization techniques to improve the design, functionality, and performance of knee support systems. These optimization techniques aim to enhance comfort, reduce pain, increase mobility, and provide better support for individuals with OA. Here are some common optimization techniques used in knee support for OA:

Ergonomic Design Optimization: This technique focused on optimizing the ergonomic aspects of the knee support system to ensure proper fit and alignment with the user's knee joint. It involved considering factors such as the contour of the knee, range of motion, pressure distribution, and user comfort. By optimizing the ergonomic design, the knee support system can provide better stability and support while minimizing discomfort or irritation.

Material Selection and Optimization: The choice of materials used in the knee support system plays a significant role in its performance and functionality. Optimization techniques involved selecting materials that offer appropriate flexibility, durability, breathability, and hypoallergenic properties. Additionally, optimizing the material properties can help enhance shock absorption, reduce friction, and improve overall comfort for individuals with OA.

Structural Optimization: Structural optimization techniques focused on improving the structural integrity and load-bearing capabilities of the knee support system. This involved analyzing the stress distribution and identifying areas of high stress concentration. By employing techniques like finite element analysis (FEA), we optimized the structural design to ensure adequate support, strength, and durability while minimizing weight and bulkiness.

Comfort Optimization: Comfort is a crucial factor in knee support systems for individuals with OA. Optimization techniques focused on improving user comfort by incorporating features such as cushioning, moisture-wicking properties, and adjustable straps or closures. Additionally, optimizing the design to reduce pressure points and improve breathability can enhance overall comfort during prolonged use.

Range of Motion Optimization: Knee support systems should not hinder the user's natural range of motion. Optimization techniques aimed to provide an optimal balance between stability and freedom of movement. This involved designing hinges, joints, and flexible components that allow for a comfortable range of motion while providing necessary support and control.

Performance Evaluation and Feedback Incorporation: Optimization techniques involved testing and evaluating the performance of the knee support system through medical experts and subject panel. This iterative process helped us identify areas for improvement and guides further optimization efforts.

By applying these optimization techniques, designers and engineers can develop knee support systems that effectively alleviate pain, enhance mobility, and improve the overall quality of life for individuals with OA. Optimization allows for continuous improvement and ensures that knee support systems are tailored to meet the specific needs and challenges of OA patients.

4.7.3.1 Perforations Method

Perforations play a significant role in the optimization of knee support systems for osteoarthritis (OA). They are strategically placed holes or openings in the material of the knee support that offer several benefits for individuals with OA. Here are some ways in which perforations can contribute to knee support optimization for OA:

Breathability and Moisture Management: Perforations allow for improved breathability within the knee support system. They facilitate the flow of air, which helps in reducing heat and moisture buildup around the knee joint. This feature is particularly beneficial during physical activity or prolonged wear, as it helps maintain a comfortable and dry environment, reducing the risk of skin irritation and discomfort.

Weight Reduction: Perforations can contribute to reducing the overall weight of the knee support system. By removing material through perforations, the knee support becomes lighter, minimizing the burden on the wearer and improving comfort, especially during extended periods of use.

Flexibility and Range of Motion: Perforations strategically placed in the knee support material can enhance flexibility and the natural range of motion of the knee joint. They allow the material to stretch and flex more easily, accommodating the movement of the knee while providing necessary support and stability.

Pressure Relief and Distribution: Perforations can be designed to create areas of reduced pressure or to distribute pressure more evenly across the knee joint. By incorporating perforations in specific locations, the knee support system can alleviate pressure points, prevent excessive compression on sensitive areas, and provide a more comfortable fit.

Enhanced Comfort and Skin Protection: Perforations help prevent excessive friction and rubbing against the skin, reducing the risk of skin irritation and abrasion. They also enable better ventilation, reducing the likelihood of sweat buildup and associated discomfort. By enhancing overall comfort and skin protection, perforations contribute to a more enjoyable wearing experience for individuals with OA.

Perforated stainless steel is a sheet of stainless steel that has been stamped, punched, or cut to create specific hole patterns or openings. It's utilized for aesthetic purposes like architectural accents and performance reasons such as weight reduction and increase stiffness.

4.7.3.2 Material Selection – Carbon Fiber

Carbon Fiber is known for its exceptional strength-to-weight ratio. It is significantly lighter than traditional materials like metal or plastic, which reduces the overall weight burden on the knee joint. Despite its lightweight nature, carbon fiber offers impressive strength and stiffness, providing structural integrity and support for individuals with OA.

Flexibility and Elasticity: Carbon Fiber possesses inherent flexibility and elasticity, allowing it to absorb and distribute forces effectively. This characteristic is particularly beneficial in knee support systems, as it can help reduce the impact on the knee joint, minimize vibrations, and improve shock absorption during activities such as walking, running, or jumping.

Durability: Carbon Fiber is highly durable and resistant to fatigue, making it suitable for long-term use in knee support systems. It can withstand repetitive stress and maintain its structural integrity over time, ensuring consistent support and performance. The durability of carbon Fiber also minimizes the need for frequent replacements, providing cost-effectiveness in the long run.

Customizability: Carbon Fiber can be easily moulded and shaped to create customized knee support systems. This allows for a precise fit and better distribution of support around the knee joint, addressing the unique anatomical needs of individuals with OA. Customizability ensures that the knee support provides optimal comfort, stability, and functionality for each user.

Biocompatibility: Carbon Fiber is generally considered biocompatible, meaning it is well-tolerated by the human body and does not cause adverse reactions or allergies. This is essential for knee support systems as it reduces the risk of skin irritation or allergic responses, ensuring a comfortable wearing experience.

Aesthetic Appeal: Carbon Fiber has a distinct and visually appealing appearance. Its woven texture and glossy finish can add a sleek and modern look to knee support systems, providing an aesthetic appeal for individuals who value style and design.

While carbon Fiber offers numerous advantages, it is important to note that it may have higher manufacturing costs compared to traditional materials. Additionally, the design and engineering of carbon Fiber knee support systems require expertise and careful consideration to optimize its properties effectively.

V. RESULTS AND DISCUSSION

In this project, we delved into the various aspects of our Knee Support Manufacturing and Optimization techniques, exploring the intricate details of our research, development, and implementation efforts. Through meticulous analysis and evaluation, we have uncovered valuable insights and achieved significant milestones in our pursuit of enhancing knee support manufacturing processes. As we conclude this project, it is crucial to reflect on the key findings and implications that emerged from our endeavors, ultimately shaping the path forward and influencing future advancements in the field."

Before we delve into the conclusion of this project, it is essential to reflect on the journey we have undertaken and the significant accomplishments we have achieved. Throughout this project, our primary objective was to enhance the manufacturing processes for knee supports, ultimately customization and improving the quality, efficiency, and overall performance. In pursuit of this goal, we embarked on an extensive research and development endeavor, combining manufacturing technologies, continuous evaluation by subject experts and physicians, and innovative strategies. Now, armed with a comprehensive understanding of the project's scope and outcomes, we are prepared to draw meaningful conclusions that will shape the future of this project.

In conclusion, the project aimed to develop and optimize a knee support system to address the challenges faced by individuals with mobility issues, particularly in transferring body weight to the shoe. By implementing a comprehensive approach involving market analysis, advanced manufacturing techniques, and optimization strategies, a successfully optimized knee support system has been achieved.

Through a comprehensive market analysis, it was determined that there is a significant demand for knee supports that facilitate effective weight transfer and improve overall mobility. The project identified the need for a solution that addresses the challenges faced by individuals with mobility issues, particularly in the context of transferring body weight to the shoe.

The methodology for manufacturing and optimization involved a detailed design process, including 3D modeling and prototype development. By leveraging advanced manufacturing technologies such as laser cutting and 3D printing, the project aimed to create customized and ergonomic knee supports tailored to individual needs.

Furthermore, the project emphasized the significance of incorporating optimization techniques, including ergonomic design, material selection, structural optimization, and user-specific customization. These techniques contribute to enhancing comfort, improving weight distribution, and providing the necessary support for effective weight transfer.

The manufacturing process, whether utilizing laser cutting or 3D printing, plays a vital role in realizing the optimized knee support system. It involves precision and attention to detail to ensure the accurate production of components that meet the desired specifications. The prototype manufacturing phase allows for testing, evaluation, and user feedback, enabling iterative improvements to refine the design and functionality of the knee support system.

In conclusion, the project has successfully developed and optimized a knee support system that addresses the challenges of transferring body weight to the shoe. The project's achievements pave the way for future advancements in this field, including further research on materials, integration of smart technologies, and potential collaborations with footwear manufacturers. The optimized knee support system has the potential to significantly enhance the mobility and overall well-being of individuals with mobility issues.

I. Acknowledgment

We would like to thank our Project Mentors **Dr. Bhagyesh B. Deshmukh** and **Prof. Vaibhav P. Kulkarni** for their overall guidance and support.

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