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Prosthetics and Orthotics in India: History, Importance of Professionals, and an Interdisciplinary Collaboration Model – A Perspective Article with Case Study from Kerala

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Abstract: The field of prosthetics and orthotics (P&O) is one of the most important paramedical professions that specializes in the rehabilitation of persons with physical disabilities by designing, creating, and fitting corrective orthotic supports and artificial limbs. India's population with disability of more than 26.8 million require the services of skilled P&O professionals, but they are in very short supply. The article traces the history of the profession of P&O in India from ancient times to institutions of the modern era, describes the key regulatory bodies, states the importance of in-patient rehabilitation with the help of a team of P&O professionals, and records the innovative interdisciplinary co-operation between the Bachelor of Prosthetics and Orthotics (BPO) programme at the National Institute of Physical Medicine and Rehabilitation (NIPMR) Kerala, and the Mechanical Engineering Department at SCMS School of Engineering and Technology Kerala. This partnership, which for the first time brought engineering-based material testing and structural failure analysis to BPO students, is a model that can be replicated in enhancing P&O education with the help of cross-disciplinary partnership.

Keywords: *Prosthetics and Orthotics, India, BPO Education, Mechanical Engineering, Material Testing, Interdisciplinary Collaboration, NIPMR, SCMS, Kerala.*

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I. INTRODUCTION

When infected with injury, disease or congenital issues, the human body can lose its ability to move and function independently. This isn't something they can only dream of for millions of Indians. Prosthetics and Orthotics — the creation and implementation of artificial limbs (prosthetics) and orthotic correction supportive devices (orthotics) — is one of the professions with the highest impact in the healthcare field but not widely recognised. India has one of the highest numbers of persons with disabilities (PwD). The Census of India 2011 estimates that there are more than 26.8 million people with disability; more than 20% of whom suffer from movement disorders for which prosthetic or orthotic intervention is required. P&O services are needed more and more year after year as the population grows older, more people are involved in road traffic accidents and diseases like diabetes-related limb loss have made an impact on society.

The annual production of trained P&O personnel from the Indian educational institutions is only about 260, which is far below the demand of the situation, especially in rural and semi-urban areas. In the state of Kerala, the only institute running the Bachelor of Prosthetics and Orthotics (BPO) course is the National Institute of Physical Medicine and Rehabilitation (NIPMR) in Kerala which calls for the need of innovative approaches to enhance the educational experience of the students. This article reports one such innovation that has been performed by two students from BPO from NIPMR and a Mechanical Engineering student from SCMS School of Engineering and Technology, Kerala. This partnership has successfully been undertaken in years 2025 and 2026, and provided BPO students with engineering based material testing and structural failure analysis skills which can be directly applied to the design and evaluation of prosthetic and orthotic devices.

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II. HISTORICAL DEVELOPMENT OF P&O IN INDIA

➢ *Ancient Roots*

Prosthetics in India is not only contemporary but ancient also. One of the oldest books in the world, the Rigveda presents images of the Ashwini brothers, or the Vedic gods of healing, fitting Vispala, prince of Khela, with a cast of iron leg, after it was broken in a battle. This mythical story shows a degree of cultural knowledge of assistive devices that predated clinical medicine by thousands of years. Across the centuries, the art of bone setting, traditional healing and even the work of craftsmen was used to create simply made supports and alternative replacement limbs for soldiers and common folk alike. But these were mostly unregulated and unstandardized – the early beginnings of a formal clinical discipline.

➢ *20th Century: The Modern Foundation*

Modern P&O profession in India emerged after the two World wars, polio epidemics in the 1940s-50s and the development of Rehabilitation medicine as a clinical specialty. Key milestones include: Setting of regional units for fitting and rehabilitation of the limbs in the various cities such as Jaipur, Bombay, Lucknow, Calcutta and Madras. In 1972, the Artificial Limbs Manufacturing Corporation of India (ALIMCO), the only government owned company that deals in the manufacturing of rehabilitation aids was established. The founding of the National Institute for the Orthopaedically Handicapped (NIOH), Kolkata, a pioneering national training and service institution. In the early 1990s, the early implementation of upgrading certificate and diploma programs to become bachelor's degrees. The intersection of engineering and P&O is well illustrated by the collaboration between ALIMCO and IIT Madras to develop ‘KADAM' — a low-cost indigenous polycentric knee joint which is now available.

➢ *Regulatory Standardisation*

The establishment of the Rehabilitation Council of India (RCI) under the RCI Act, 1992 was a watershed moment. Under Section 13, registration with the Central Rehabilitation Register (CRR) became mandatory for all P&O professionals. Today, RCI recognises 16 institutions offering diploma, undergraduate (B.P.O.), and postgraduate (M.P.O.) programmes with a combined annual intake of approximately 470 students.

III. KEY INSTITUTIONS AND INFRASTRUCTURE

The P&O ecosystem in India rests on a network of national institutes, regulatory bodies, and professional associations working in concert:

Table 1: Key Institutions and Infrastructure Supporting P&O in India

Institution	Role	Established
ALIMCO, Kanpur	Sole govt. manufacturer of rehabilitation aids; distribution via nationwide camps	1972
NIOH, Kolkata	National training and service centre for orthopaedic disabilities	1978
NIPMR, Kerala	Only BPO programme provider in Kerala; clinical P&O training and services	Active
AIIPMR, Mumbai	All India Institute of Physical Medicine and Rehabilitation	1952
19 CRCs nationwide	Composite Regional Centres offering P&O services under Ministry of Social Justice	Various
RCI	Rehabilitation Council of India — statutory regulator of all P&O professionals	1992
OPAI	Orthotics & Prosthetics Association of India — national professional body	Active
IAPO	Indian Association of Prosthetists and Orthotists — formed 1987	1987

IV. THE IMPORTANCE OF P&O PROFESSIONALS

While devices and technology are crucial, it is the trained professional who transforms a manufactured limb into a functional extension of the human body. The P&O professional is not merely a technician — they are a clinician, a biomechanist, a counsellor, and often the most consistent point of rehabilitation contact for a person with a disability.

A. Clinical Assessment and Customisation

Each patient is an individual. A below knee amputee farmer in a paddy field in Kerala will need a totally different prosthesis than an office worker in a metropolitan city. The P&Os are trained to perform a detailed clinical assessment, which includes evaluating the morphology of the residual limb, its skin integrity, the ambulatory goals, lifestyle and comorbidities, before prescribing and fabricating devices that are truly fit for purpose. This customisation requires knowledge of clinical anatomy, physiology and biomechanics, hands on fabrication skills and material science knowledge, making P&O a uniquely interdisciplinary profession.

B. Functional Rehabilitation and Patient Outcomes

Installation is just the first step. Rehabilitation also includes gait training, alignment adjustments, patient education and follow up care. Research over the years has confirmed that patients' mobility, independence and quality of life are far better when they are cared for by qualified practitioners than by informal carers. When it comes to patients suffering from cerebral palsy, spinal cord damage,

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stroke, diabetic foot complications or loss of a limb following surgery, the role of a P&O professional can make the difference between dependency and independent living.

C. The Engineering Dimension of P&O

P&O is unique to many healthcare professions because of its strong engineering foundation. The principles of load distribution, material fatigue and stress concentrations are all critical to the design of a prosthetic socket. A knee joint is subjected to dynamic loading with repeated and repeated cycles over millions of gait cycles. The stiffness and compliance of the orthotic brace needs to be proportioned to the patient's weight, activity and disease. This engineering dimension involves P&O workers being competent in: Mechanical properties of materials employed in the manufacture of devices (such as polymers, carbon fibre composites, titanium alloys, thermoplastics) Analysis of stress and strain under static and dynamic loading using load cells and strain gauges.Stress and strain analysis under static and dynamic loading, with the use of load cells and strain gauges. Failure mode recognition — understanding failure mode and failure reason in clinical application of the device Rigorous calculations of load-bearing components. Biomechanics and modelling human-machine interaction However, in most BPO programs these engineering concepts are introduced in a theoretical classroom setting, where students do not have the opportunity to conduct hands-on experiments with materials testing equipment or to work in a mechanical laboratory. This is what the collaboration between SCMS and NIPMR is looking to fill.

D. Multidisciplinary Team Integration

In modern rehabilitation medicine, P&O professionals work alongside orthopaedic surgeons, physiatrists, physiotherapists, occupational therapists, and social workers. Their unique expertise in device prescription and biomechanical analysis fills a gap no other profession covers. Increasingly, they also collaborate with mechanical engineers, materials scientists, and biomedical engineers — reflecting the profession's inherently interdisciplinary nature.

E. Community-Level and Innovation Impact

Beyond hospitals, P&O professionals play a vital role in community rehabilitation programmes, disability awareness camps, and school-based inclusion initiatives. In rural India, where over 70% of PwDs live, outreach through District Disability Rehabilitation Centres (DDRCs) remains the primary access point for assistive technology.

At the frontier, Indian P&O professionals are contributing to indigenous innovation. The ALIMCO-IIT Madras 'KADAM' knee joint, designed specifically for Indian users and affordable at scale, exemplifies how cross-disciplinary collaboration between clinicians and engineers can yield transformative outcomes.

V. CASE STUDY: SCMS–NIPMR INTERDISCIPLINARY COLLABORATION, KERALA

> *"When BPO students step into a mechanical engineering laboratory and physically test the materials their devices are made from, the curriculum ceases to be theoretical. They understand — in the most tactile sense — why material selection and structural calculations matter to the patients they will serve." — Anoob Jose, Assistant Professor, Department of Mechanical Engineering, SCMS School of Engineering and Technology*

A. Background and Context

The Bachelor of Prosthetics and Orthotics (BPO) program is a four-and-a-half-year undergraduate course to prepare students for the assessment, design, fabrication, and fitting of prosthetics and orthotics to individuals with physical disabilities. The only institute to provide this programme in Kerala is National Institute of Physical Medicine and Rehabilitation (NIPMR), Kerala which is the only pipeline of P&O professionals in Kerala. SCMS School of Engineering and Technology, Kerala, is one of the leading engineering schools in the state with well-equipped mechanical engineering labs, structural testing lab, material characterisation lab, and failure analysis lab. The Department of Mechanical engineering has substantial past experience in the fields of applied materials science and structural mechanics. It was a natural development from the realization by both institutions that P&O students would greatly benefit from real-world experience with engineering laboratory techniques and that engineering faculty and students would be well served by learning how to apply their technical skills to solve biomedical problems.

B. Objectives of the Collaboration

The collaboration was structured around the following educational objectives for BPO students:

- To develop practical understanding of the mechanical properties of materials used in prosthetic and orthotic devices.
- To perform standardised tensile, compressive, and flexural testing on P&O-relevant materials.
- To understand and apply failure mode analysis to evaluate the structural integrity of device components.
- To perform basic load and stress calculations relevant to device design and patient safety.
- To bridge the gap between classroom theory (as taught in the BPO curriculum) and real-world engineering practice.

C. The 2025 Visit — First Cohort

The inaugural visit took place in 2025, with 19 BPO students from NIPMR participating in a structured laboratory programme hosted by the Department of Mechanical Engineering at SCMS School of Engineering and Technology.

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➢ *Laboratory Activities — Material Testing*

Students were introduced to the Universal Testing Machine (UTM) and related testing apparatus. The session covered:

- Tensile testing of thermoplastic polymers commonly used in orthotic fabrication (polypropylene, polyethylene), including measurement of ultimate tensile strength (UTS), yield strength, and elongation at break.
- Compression testing of foam and rigid materials used in prosthetic socket liners and structural components.
- Flexural (three-point bending) testing to assess stiffness and bending behaviour of orthotic shell materials.
- Hardness testing (Shore A/D scales) of elastomeric materials used in prosthetic feet and socket interfaces.
- Interpretation of stress-strain curves and extraction of Young's modulus, toughness, and resilience values.

➢ *Laboratory Activities — Failure Analysis*

The second component of the programme focused on failure mode analysis — an area of direct clinical relevance given that prosthetic device failure in the field can result in patient falls and injury.

- Identification of common failure modes in P&O components: fatigue fracture, stress concentration at geometric discontinuities, creep deformation, delamination in composites.
- Examination of failed prosthetic and orthotic components (sample specimens) under magnification to identify fracture surfaces, crack propagation paths, and failure origins.
- Structural load calculations: students performed simple beam theory calculations to determine bending moments and maximum stresses in orthotic shells under typical patient loading scenarios.
- Factor of safety analysis: applying safety factors in device design to account for variability in patient loads and material properties.
- Case-based discussion: real-world P&O device failures were analysed using engineering principles, linking clinical observations to materials science explanations.

➢ *Outcomes and Observations*

The 2025 cohort of 19 students successfully completed all planned laboratory activities. Faculty and student feedback highlighted the following key outcomes:

- Students reported significantly improved understanding of the material basis for clinical decisions such as material selection for paediatric versus adult patients, and for high-activity versus sedentary users.
- The practical experience of generating and reading stress-strain curves transformed abstract textbook concepts into tangible, interpretable data.
- Students expressed that seeing actual failure surfaces on prosthetic components made failure mode analysis feel directly relevant to their future clinical practice.
- Engineering faculty noted the motivating effect of biomedical context on student engagement — the clinical application gave engineering concepts a human dimension rarely present in standard mechanical engineering coursework.

D. The 2026 Visit — Second Cohort

Building on the success of 2025, the collaboration was continued and extended in 2026, with 18 BPO students from NIPMR participating. The 2026 programme retained the core elements of the first visit while deepening the failure analysis component in response to feedback from the previous cohort.

➢ *Expanded Material Testing Programme*

The 2026 cohort undertook a broader range of material testing activities:

- Extended testing to include carbon fibre composite specimens — the primary structural material in high-performance prosthetic feet and orthotic ankle-foot orthoses (AFOs) — covering tensile, interlaminar shear, and impact testing.
- Comparative testing of multiple material grades: for example, comparing standard-grade versus high-density polypropylene to understand how material selection affects device stiffness and longevity.
- Introduction to dynamic fatigue testing concepts: simulation of cyclical loading to understand how materials behave under the millions of loading cycles a prosthetic limb experiences over its service life.
- Thermal behaviour: brief introduction to heat forming characteristics of thermoplastics, linking laboratory observations to clinical fabrication processes.

➢ *Deepened Failure Calculations*

The failure analysis component was expanded with more structured calculation exercises:

- Students worked through full structural calculation problems for a below-knee prosthetic pylon under walking and stair-climbing loading conditions — computing bending moments, axial forces, and torsional loads.
- Application of von Mises stress criterion to predict yielding onset in metallic prosthetic components.
- Deformation and deflection calculations for orthotic shells modelled as curved beams under distributed loading.
- Group exercises in which student teams were assigned different patient profiles (body weight, activity level, lifestyle) and required to select and justify material choices based on calculated stress and safety factor requirements.

➢ *Outcomes — 2026 Cohort*

The 202 visit demonstrated measurable deepening of engagement compared to the first cohort. Notable observations included:

- Students arrived with better background preparation, having been briefed on material properties in their BPO coursework prior to the visit, allowing the laboratory time to be used more efficiently.
- The group calculation exercises produced active debate about trade-offs between device weight, strength, and cost — conversations that directly mirrored clinical decision-making in P&O practice.
- Several students identified specific aspects of device failures they had observed in their clinical placements that

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they could now explain using the engineering principles encountered during the visit.
- Faculty at SCMS noted the high level of motivation and clinical contextualisation that BPO students brought to engineering problems — a perspective that enriched the laboratory environment for engineering students observing the sessions.

E. Summary of Two-Year Collaboration

Table 2: Summary of the SCMS–NIPMR Two-Year Collaboration (2025–2026)

Parameter	2025 (First Cohort)	2026 (Second Cohort)
Participating institution	NIPMR, Kerala	NIPMR, Kerala
Host institution	SCMS School of Engineering and Technology	SCMS School of Engineering and Technology
Number of students	19 BPO students	18 BPO students
Faculty coordinator	Anoob Jose, Asst. Professor, Mechanical Engg.	Anoob Jose, Asst. Professor, Mechanical Engg.
Material testing scope	Tensile, compression, flexural, hardness	Extended: + carbon fibre, comparative grades, fatigue concepts
Failure analysis scope	Failure mode identification, basic load calculations, factor of safety	Deepened: von Mises criterion, deflection calculations, group patient-profile exercises
Overall outcome	Successful — strong positive feedback	Successful — deeper engagement, improved preparation

F. Significance and Replicability

The SCMS–NIPMR partnership has several key points of interest for P&O education and for cross-disciplinary education in the healthcare space in general. The engineering knowledge gap is addressed. While P&O professionals are making very critical decisions on engineering on a day-to-day basis, such as selecting materials, calculating load and assessing the integrity of devices, many BPO programmes lack access to the engineering laboratory infrastructure. This can be addressed through partnerships with engineering institutions, in place of P&O training institutions investing in costly equipment. Mutual enrichment The collaboration is mutual. BPO students are valuable to the engineering faculty and students because of the clinical context that they bring. A real patient example (the 70 kg farmer who needs a transtibial prosthesis that will have to support him when he squats and walks over the uneven terrain) adds richness, context and motivation to the engineering problem for all participants. The new body of water is a model for the rest of Kerala and the world. Being the only BPO programme in Kerala, with the state having a well established network of engineering colleges, there is huge potential to scale this model. More engineering institutes, having materials testing and mechanical engineering facilities, can establish the similar tie-up with NIPMR to offer practical engineering education for the BPO students of various batches and specialisations. The model can also be used nationally in states that have P&O training institutions adjacent to or close to engineering institutes. A willing faculty coordinator, the necessary UTM and materials testing devices, and a defined curriculum interface are common in many institutions.

> *The SCMS-NIPMR partnership demonstrates that innovation in healthcare education does not always require new technology or new funding. Sometimes it requires only the willingness of educators from different disciplines to open their laboratory doors to each other.*

VI. CURRENT STATUS AND STATISTICS

The numbers below reveal the significant gap between the need for P&O services in India and the current capacity to deliver them:

Table 3: Current Status and Key Statistics of P&O Services and Education in India

Indicator	Figure
Total persons with disability in India (Census 2011)	**26.8 million**
Estimated percentage requiring P&O devices	**Over 20%**
Annual P&O graduates from Indian institutions	**Approx. 260**
RCI-recognised training institutions nationally	**16**

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Annual undergraduate (B.P.O.) intake seats	**295**
Annual postgraduate (M.P.O.) intake seats	**75**
P&O training institutions in Kerala	**1 (NIPMR, Kerala)**
BPO students visiting SCMS SET (2024)	**19**
BPO students visiting SCMS SET (2025)	**18**
Access rate to assistive technology in LMICs	**Less than 3%**

VII. CHALLENGES FACING THE PROFESSION

- Affordability: High device costs place P&O aids beyond reach for many families without government support or insurance coverage.
- Rural-urban divide: Trained professionals are concentrated in urban centres, leaving rural populations — who bear a disproportionate disability burden — severely underserved.
- Limited training seats: With only ~470 annual intake seats nationally, the pipeline of trained professionals is far too narrow for India's needs.
- Inadequate local device design: Many P&O devices are designed for Western users and do not account for Indian lifestyles (squatting, floor-sitting, barefoot walking), reducing functional utility.
- Engineering knowledge gap in curricula: BPO programmes often lack access to engineering laboratory infrastructure, limiting practical understanding of material behaviour and structural analysis.
- Awareness gap: Many families of PwDs are unaware that prosthetic or orthotic rehabilitation is available or do not know how to access it.
- Employment structure: Structured public-sector employment positions for P&O professionals remain limited, contributing to under-utilisation of trained graduates.

VIII. THE WAY FORWARD

The solution to the P&O service deficit in India needs to be a multi-pronged approach, with the policies of the government, academic institutions, civil society, and interdisciplinary collaboration all playing a vital role. Expand training capacity There should be a great increase in the number of recognised training institutions and intake seats, especially in under-served states, under the RCI. Embed engineering partnerships in BPO education This is a model of engineering-P&O academic partnerships that is both feasible and highly effective, as illustrated by the SCMS–NIPMR model. RCI should encourage and/or make such partnerships a mandatory part of the BPO accreditation criteria so that students in all 16 training institutions can benefit from hands-on engineering education. Institutions lacking in-house engineering facilities can follow the visiting cohort model which is being followed in Kerala. Include P&O services in mainstream health care. P&O services should be included in primary health care systems and not only tertiary health care systems. The CHOs and ASHA workers can be trained for identification and referral of those who need the P&O assessment. Strengthen international collaboration Engaging in partnerships with such countries that have well established P&O systems, e.g., Sweden, with its well-developed assistive technology system, can introduce advanced training methods, collaboration, and technology transfer to India. Such North-South academic partnerships have the potential to drive up the quality and quantity of P&O education. Indigenous innovation, engineering integration. As seen in the KADAM knee joint program and the SCMS-NIPMR partnership, the potential of indigenous innovation in the creation of new devices is large, as mechanical engineering and clinical P&O work side-by-side. investments in formal research collaborations between P&O training institutions and engineering colleges to create locally available, affordable assistive devices for India. Policy and insurance While the Rights of Persons with Disabilities (RPWD) Act 2016 sets the policy framework, provisions for assistive technology in the Act must be better implemented. Accessibility would increase by much if P&O devices were covered by health insurance schemes like Ayushman Bharat.

IX. CONCLUSION

India's prosthetics and orthotics industry is in a precarious position; it has a long history, is expanding in its clinical capabilities, but still lacks the size necessary to meet the needs of the millions of Indians who want its services. A similarly interdisciplinary approach to teaching and innovation is required due to the profession's inherent interdisciplinary character, which bridges engineering and medicine.

An excellent example of what cross-disciplinary cooperation can accomplish is the partnership between SCMS School of Engineering and Technology and NIPMR's BPO program in Kerala. Two years in a row, BPO students have gone into a mechanical engineering lab and come out with a more comprehensive, hands-on grasp of the materials and structural concepts that support the devices they will design and manufacture during their careers. This is not an activity for peripheral enrichment.

It directly affects the standard of treatment that patients in the future will receive. It is impossible to overestimate the significance of P&O specialists. They play a crucial role in the rehabilitation of millions of Indians who have physical disabilities rather than being incidental to the healthcare system. Each qualified orthotist and prosthetist symbolizes not only a medical professional but also the restoration of

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their patients' autonomy, dignity, and involvement. It is both a healthcare priority and a social justice need to strengthen this profession through increased training, improved policies, engineering partnerships, and international engagement.

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