SALTIEL'S DESIGN MODIFICATION : Short-leg Brace for Knee Extensor Weakness

DR. SHIV LAL YADAV*, DR. M.K. MATHUR**, & DR. S.C. KASLIWAL***

A study of an alternative orthosis to prevent hand-to-knee gait is presented. The orthosis in contrast to the standard Knee- Ankle-Foot Orthosis (KAFO) works on the principle of alignment stability by preventing an initial heel contact. Weight bearing on forefoot brings the trochanteric knee ankle line anterior to the knee which stabilizes the knee by pushing it backwards. The orthosis made of polypropylene is fairly rigid and resilient. An attempt has been made in this study to standardize fabrication technique of this orthosis. Weight and cost evaluation of the orthosis has been done. Subjective analysis regarding cosmesis and acceptability of the orthosis along with objective analysis of time motion studies is also presented. Results show its superiority over the conventional KAFO.

In clinical practice, Poliomyelitis is still a major disabling disease in India. A patient of Polio with quadriceps palsy adopts "hand-on-thigh gait" which is quite awkward, ungainly and an energy consuming trick (Fig. No. 1).

Several attempts were made to develop alternate design which would stabilise the knee joint with weak quadriceps. Saltiel1 (1969) designed, a one-piece laminated knee-locking short-leg brace by inducing equinus at the ankle artificially, to stablize knee while shifting TKA line anteriorly. Lehneis2 (1972) modified the original Saltiel design. In 1973, after many modifications, a Kumamoto University Short leg brace (KU-SLB)3 was developed with a single plastic upright on the back of the leg and supracondylar support with a cut-out for the patella. In 1988 Gai-Fu-w. Yang et al4 presented his clinical experience with Floor Reaction Orthosis (FRO) in patients with paraplegia and paraparesis. In this design they have reduced the equinus at the ankle and have used patella and patellar-tendon as reaction point.

The orthosis prepared by Saltiel (1969) was made out of fibre glass, reinforced with resins. It lacked resilience and therefore, developed stress concentration and broke early. In addition, if some minor fault had entered during its fabrication the whole of orthosis had to be rejected. This led us to think of an alternative high strength, low weight-ratio material with some flexibility in one direction. The most easily available material is polypropylene which fills our criterion; it is fairly rigid and resilient. An attempt has been made in this study to standardize fabrication in randomly selected cases with quadriceps paralysis.

MATERIAL & METHODS

The present study was conducted in the Rehabilitation Research Centre, SMS Medical College, Jaipur. The patients having quadriceps paralysis requiring knee orthosis mainly in the antero-posterior plane resulting from poliomyelitis were randomly selected and studied in detail. The present design of orthosis was provided. Patients with flail hip, genu recurvatum and severe calcaneus deformity were excluded.

The present orthosis under study was fitted to 250 patients (age group 6-31 (average) years, Male : Female :: 48:52). Five cases were having bilateral involvement, in these the other side was fitted with conventional caliper. Associated deformities like mild knee flexion, equinus, varus, valgus and cavus of the foot produced no difficulty in fitting of the orthosis as polypropylene can be shaped in any manner. The limb length discrepancy upto 5 cm did not require any additional compensation, as the present design has inbuilt equinus. Thus it automatically increases the limb length. This design stabilises

* Resident, Rehabilitation Research Centre, SMS Medical College & Hospital, Jaipur – 302004.
** Asstt. Professor, Rehabilitation Research Centre, SMS Medical College & Hospital, Jaipur – 302004.
*** Professor, Rehabilitation Research Centre, SMS Medical College & Hospital, Jaipur – 302004.

the ankle fairly well in equinus along with control of quadriceps weakness. In addition, 34% cases in this study those who were using metal/conventional caliper earlier and switched over to this new design. The maximum follow-up was of 18 months in 130 cases while minimum was of 3 months in 11 cases. The average period of follow up was 13 months.

The field trials were carried out to evaluate the efficacy of this design. Present design and performance was judged both by subjective as well as objective evaluation at the time of fitment and during follow up.

Time motion studies of the fabrication procedure, weight and cost evaluation of the present design were also undertaken.

Casting and Fabrication

The patient is comfortably seated with the affected limb exposed upto supra-condylar region. Stockinette is slipped over the foot and leg and all the bony prominences are marked with an indelible pencil. A latex tube is placed on the dorsum of foot and anterior aspect of leg and knee.

Knee is kept in 10^{o} of flexion and ankle is kept in 15^{o} plantar flexion, while foot is kept in neutral rotation. Equinus is maintained with the use of prepared wooden block with the desired gradient.

The wet plaster of paris bandages are applied, starting from the base of the toes and extending upto the lower one-third of thigh. Keeping the limb in desired position, the plaster is allowed to set. The ankle, malleoli and patellar tendon is then outlined.

The negative plaster of paris impression is removed and filled with plaster of paris paste to get a positive mould. Then the positive mould is modified as follows. The infrapatellar & suprapatellar region are scooped out anteriorly. The scoop has to be more generous for a fleshy thigh & less so for a thin thigh. For pressure relief quarter inch thickness of plaster of paris are added over bony prominences like malleoli, patella etc. In addition the foot plate is fully modified for support of the arches snuggly.

The positive mould is then smoothened. A 3 to 5 mm. thickness polypropylene sheet, which is approximately 5 cm. more than the total length of mould and breadth equal to the maximum circumference of the positive mould is taken. The sheet is divided into 2 parts; upper 1/4 and lower 3/4 of the total length. Both the sheets are put alternately in preheated oven at 300^{o}C for 10 minutes. The hot malleable sheets thus obtained, the smaller one is applied anteriorly over supra patellar area. The large sheet is applied posteriorly from upper calf to just distal to the metatarsal heads. These sheets are well moulded by removing all creases and conforming to the sharp contour of the positive mould and allowed to cool for 20-25 minutes. The trim lines are then marked at sole (the distal end of the orthosis) at the level of head of metatarsals, half of the malleoli, anteriorly 1/4th of the leg circumference, upper calf and 5-7 cm. above top of patella.

With a sharp sculpture knife the riddened edges are cut and both the portions of moulded polypropylene sheet are fitted by grub screw on the sides at the level just above the fibular head. Velcro straps are attached at calf region, with this

TABLE NO. 1

SUBJECTIVE EVALUATION AT THE TIME OF FITTING OF OTHROSIS AND FOLLOW UP

Subjective Evaluation at the time of Fitting n = 250					Subjective Evaluation at the time of Follow-up 3-18 Month n = 191							
Stability at Knee			Sitting Cross-Legged/ Squatting		Whether patient Walks Comfortable Fast > 1 Km.		Walking distance without Fatigue		Can Climb Stairs/ Ramp	
1	2	3								
Good	Fair	Unstable	Yes	No	Yes	No	Same	Improved	Yes	No
180	58	12	225	25	156	35	8	183	172	19

Fig–1

Fig–2 (a & b)

Fig–1 : "Hand on thigh gait" body weight acting from above to stabilise knee
Fig–2 (a & b) : Floor-reaction-orthosis (FRO) allows comfortable squatting & cross-legged sitting.

Fig–3 (a & b)

Fig–3 (a & b) : A patient with left FRO ascends & descends the stairs comfortably

orthosis patient can put on the shoes having the sole flat and rigid. The positive model does not require to be broken. So it can be reutilised according to need.

All the patients found the orthosis very light with high acceptability, towards cosmesis and easy to wear and take it off. Only 12 cases felt instability at knee due to a feeling of insecurity because of walking on toes; later with gait training they all improved. 90% cases could sit cross-legged and squat easily (Fig. No. 2).

In the present study, majority of the patients could walk comfortably and fast (82%) and 96% cases showed marked improvement in walking distance. 90% of the patients could negotiate the stairs in the present series (Fig. No. 3).

There was marked improvement in the gait of most of patients (64%). Only 12% of cases did not show expected improvement in the gait; they used to walk with an aid of stick or crutch. All of these cases had bilateral involvement and had to be fitted KAFO/AFO on the opposite side.

Only 14 cases had breakage of their orthosis during the follow up period. Maximum break points were encountered around ankle. No patient showed adverse reaction to skin. There was improvement in the gait pattern, as 76% patients qualified to be labelled as good, which is 12% more in comparison, at the time of fitting. This improvement indicates that the patients have

TABLE NO. 2

OBJECTIVE EVALUATION AT THE TIME OF FITTING OF ORTHOSIS AND FOLLOW UP

Objective Evaluation at the time of Fitting n = 250

S. No.	Gait	No. of Patients
1	Good	160
2	Fair	60
3	Poor	30

Objective Evaluation at the time of Follow-up (3-18) months) n = 191

Break Points			Any Skin Reaction		Gait		
Knee	Ankle	Forefoot	Yes	No	Good	Fair	Poor
NIL	11	3	–	191	145	26	20

TABLE NO. 3

TIME REQUIRED FOR FABRICATION

Sl. No.	STEP	TIME
1.	PREPARATION OF NEGATIVE MOULD WITH PLASTER OF PARIS BANDAGES	20 Min.
2.	DRYING OF P.O.P. SHELL	10 Min.
3.	PREPARATION OF POSITIVE MOULD	20 Min.
4.	DRYING OF POSITIVE MOULD (IN A OVEN AT LOW TEMPERATURE)	30 Min.
5.	FINISHING & RECTIFYING THE MOULD (SHEET IS HEATED DURING THIS PHASE)	30 Min.
6.	APPLYING PREHEATED POLYPROPYLENE SHEET OVER POSITIVE MOULD (INCLUDING COOLING TIME)	30 Min.
7.	TRIMMING/FINISHING & APPLYING VELCRO STRAPS	20 Min.
	TOTAL	160 Min.

THE PRESENT DESIGN TAKES ONLY 2 HRS & 40 MINUTES TO FABRICATE, WHICH IS QUITE LESS.

COST BREAK-UP

Sr. No.	Material	Cost (Rs.)
1.	STOCKINETTE 6 CM X 1 METER	3.00
2.	COTTON BANDAGES 6" X 5 METER – 2	4.00
3.	PLASTER OF PARIS POWDER 5 – 7 Kg.	5.00 – 7.00
4.	VELCRO STRAPS 3/4" 1" X 30 CM.	7.00
5.	GRUBSCREW OF ALIMCO 2 IN NOS. @ Rs. 3.00	6.00
6.	POLYPROPYLENE SHEET 1.5 SQ FEET TO 2.5 SQ FEET @ Rs. 20/SQ. FEET.	30.00 – 50.00
	TOTAL	55.00 – 77.00
	LABOUR CHARGES 2.40 HRS.	15.00
	OVER HEAD CHARGES	3.00
	GRAND TOTAL	73.00 – 95.00

regularly used this orthosis and by sheer practice their gait pattern improved from fair to good and from poor to fair.

The present design has worked out to be of very low cost as compared to other aids. (Rs. 73.00 – 95.00 V/s Rs. 517 – 1029 for KAFO fabricated from ALIMCO components).

Discussion

In poliomyelitis, the most crucially affected level is the knee joint. Any instability at this level severely affects locomotion of the patient and caliper is required for stability.

The present design is more physiological, because it provides opportunity for free knee motion gait and maintains proper swing phase characteristics. Also the patient feels reasonably secure.

Polyprophylene is a low weight and high strength ratio material. The weight of the orthosis is much less (350 gm.) than that of a conventional KAFO (2200 gm.). This design is moulded to provide total contact, thus preventing pressure over bony prominences. On subjective evaluation it is more comfortable, cosmetically highly acceptable, easy for donning and doffing and it allows the user to sit cross-legged and squat, which is not possible with the conventional orthosis. In addition it can fit into a regular shoe and conceals well under normal trousers. It can be cleaned easily with soap and water and requires negligible maintenance as it contains no joints or movable parts.

The present design is very economical, on an average Rs. 84. A conventional KAFO made from ALIMCO components costs Rs. 517-1029. The Orthosis can be fabricated in just 160 mts., which is much less as compared to conventional orthosis. The patient can be fitted with the orthosis on the very day of his arrival.

The only disadvantage with this orthosis is that it does not check mediolateral instability at knee.

Since the orthosis is made of polypropylene, it is fairly resilient, which allows certain amount of dorsiflexion under force. So the patient inspite of equinus at ankle can squat. The amount of inversion at subtalar joints needed for sitting cross- legged is permitted which is not possible with metal or carbon fiber orthosis.

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