Prosthetics and Orthotics International, 1985, 9, 100–104

Load bearing and suspension characteristics of airsplint as a temporary prosthesis

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Abstract

Maximum weight bearing observed, using a static weighing scale, in above-knee amputees wearing an airsplint, with a foot, was 10 kg and in below-knee amputees 11 kg with inflation pressures of 40 mmHg. While airsplints with a foot permitted greater weight bearing before deformation occurred, the increase is judged to be of little clinical advantage. Use of an airsplint without a foot would be more efficient for immediate post-operative dressing and for early ambulation in the parallel bars as it is less cumbersome and not subject to toe drag in the swing phase of gait. With the type of airsplints studied inflation pressures above 45 mmHg offered no advantage in terms of weight bearing in the below-knee amputee. In the above-knee amputee similarly, inflation pressures over 40 mmHg offered no advantage and had the effect of reducing the suspension of the prosthesis on the stump.

Introduction

Various authors (Little, 1970, 1971; Kerstein, 1974; Redhead et al, 1978; Bonner & Green, 1982; Monga & Symington, 1984) have reported the use of an airsplint as an immediate post-operative dressing and temporary prosthesis in the management of lower extremity amputees. Airsplints have been found to be effective in reducing post-operative pain, achieving better wound healing, preventing swelling of the stump, allowing early ambulation and aiding stump maturation. Compared with the use of immediate post-operative plaster dressing, this method is more cost effective as a trained prosthetist is not required for its application and the airsplint is reusable. The airsplint is easy to apply and allows ready access to the stump.

A number of problem areas have been indentified and reported by Monga & Symington (1984). Some specific questions were raised following the presentation of results at various scientific meetings. One major observation made was the variability of weight bearing among patients. Another concern was the wide range of inflation pressures and the possibility that excessive pressure applied to the stump could have an adverse effect upon healing of the stump particularly in the avascular amputee. Patients found that the airsplint was very bulky, in particular, the foot of the airsplint created problems in bed mobility. For these reasons, it was decided to carry out a preliminary study of: (1) the load bearing characteristics of the airsplint, with a foot, as a temporary prosthesis, (2) the load bearing characteristics of the airsplint, without a foot, as a temporary prosthesis, (3) the relationship between the inflation pressures and the maximum obtainable weight bearing in order that the therapist could be provided with objective data upon which management could be based, (4) the maximum pressure applied to the stump during weight bearing.

Method

Airsplints*, made of polyethylene, with double walls were evaluated. One airsplint had a terminal foot and the other had none (Fig. I). A front opening zipper permitted easy application and removal. The airsplint was applied directly over a stockinette extending from mid thigh to a

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Fig. 1. Polyethylene, double wall airsplints. Left, without foot, right, with foot.

distance equal to the patient's normal leg. The airsplint was inflated with a Jobst* pump commencing with a pressure of 30 mmHg. The pressure was measured using a gauge which had been calibrated against a mercury column with a range of 0-60 mmHg. The maximum load was measured with the patient standing on a weighing scale by applying increasing weight bearing until deformation of the airsplint occurred. This procedure was repeated using different inflation pressures to a maximum of 55 mmHg. To standardize the procedure, and to define the "deformation load", a marker was placed over the lateral aspect of the airsplint and the patient was asked to stand on the weighing scale and the displacement of the marker, on weight bearing, was measured with a ruler placed by the side of the airsplint. Deformation of the airsplint was defined as occurring when there was a 5 cm displacement of this marker during weight bearing (Fig. 2). This was considered to be an unacceptably large degree of deformation. At the point of deformation, the weight and airsplint pressure were recorded. In below-knee amputees, the testing was carried out twice, first the patients were asked to bear weight through the heel of the airsplint and then, during the second test, weight bearing was transmitted via the forefoot of the airsplint.

Studies were carried out in patients who had recently undergone lower limb amputation for peripheral vascular disease. All the stumps had healed. There were four female and six male patients with an age range of 56 to 79 years. There were seven below-knee amputations in six patients and in four patients the level of amputation was above the knee. Thus a total of 11 legs were studied.

The maximum values of the deformation load and the internal pressure in the airsplint were recorded in relation to the baseline inflation pressure for each subject using different airsplints.

Results

In below knee-amputees with an inflation pressure of 30 mmHg, the mean deformation load was 8.5 kg while at a pressure of 45 mmHg, the mean deformation load was 11 kg. The gain in weight bearing achieved with inflation pressure between 40-55 mmHg was 0.5 kg. The maximum deformation load for an above-knee amputee was approximately 90% of that obtained in a below-knee amputee. Table 1 compares the results obtained in patients with below and above-knee amputation, using an airsplint with a terminal foot.

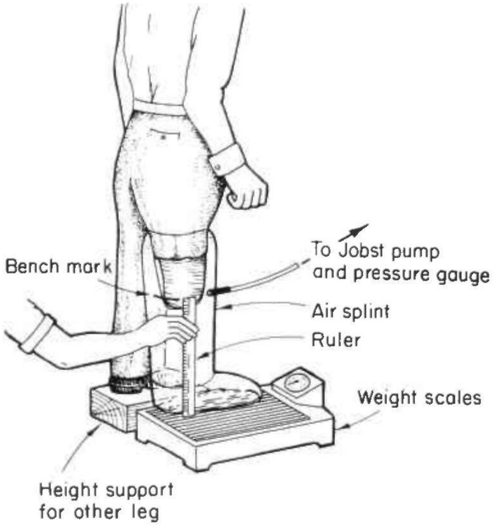

Fig. 2. Measurement of "deformation load" using airsplint with foot.

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Table 1. "Deformation load" in BK and AK amputees at different inflation pressures using airsplint with a terminal foot.

Inflation pressure mmHg	BK Stump (n-7)		AK Stump (n-4)	
	Mean deformation load kg.	Mean pressure on weight bearing mmHg.	Mean deformation load kg.	Mean pressure on weight bearing mmHg.
30	8.5	38	7.5	38
35	10.0	45	9.0	44
40	10.5	48	10.0	49
45	11.0	52	10.0	53
50	11.0	57	10.0	57
55	11.0	64	10.0	63

When airsplints with and without a terminal foot were studied in patients with below-knee amputations, increased weight bearing was possible with a terminal foot. At an inflation pressure of 45 mmHg, the mean deformation load in an airsplint with a foot was 11 kg compared with 6 kg using an airsplint without a foot. Table 2 presents the results obtained using clear plastic airsplints with and without terminal foot and also compares the mean internal pressure in the two airsplints at various deformation loads. At the baseline inflation pressure of 30 mmHg and mean maximum deformation load of 8.5 kg, the mean internal pressure in the airsplint with the foot was 38 mmHg whereas in the airsplint without a foot, 36 mmHg internal airsplint pressure was reached with only 4.5 kg deformation load. Similarly, at a higher baseline inflation pressure of 55 mmHg, the airsplint with the foot allowed 11 kg of mean deformation load and produced 64 mmHg of internal airsplint pressure as compared to a mean deformation load of only 6 kg with 60 mmHg internal pressure in the airsplint without a foot. Thus the airsplint with a foot permitted greater weight bearing at a lower baseline inflation pressure and resultant lesser increase in the internal pressure as compared to the airsplint without a foot.

The mean deformation load in patients with a below-knee amputation during weight bearing over the heel was 11 kg as compared to 8 kg when the weight bearing was over the forefoot of the airsplint. Table 3 shows the mean deformation load in relation to weight bearing on the heel and over the forefoot of the airsplint.

Discussion

Load bearing

The airsplints studied were found to permit weight bearing, in a static position, up to a mean of 11 kg in the below-knee amputees and up to a mean of 10 kg in the above-knee amputees. This level of weight bearing is sufficient to permit earlier partial weight bearing ambulation which the authors have found particularly valuable in the elderly amputee. It is apparent from this study that, when the load bearing was on the

Table 2. "Deformation load" at different inflation pressures in BK amputees using airsplint with and without foot

Inflation pressure mmHg	With foot (n-7)		Without foot (n-7)	
	Mean deformation load kg.	Mean pressure on weight bearing mmHg.	Mean deformation load kg.	Mean pressure on weight bearing mmHg.
30	8.5	38	4.5	36
35	10.0	45	5.5	45
40	9.0	48	6.0	48
45	11.0	52	6.0	55
50	11.0	57	6.0	55
55	11.0	64	6.0	60

Table 3. Weight-bearing characteristics in BK amputees using airsplint with foot.

Inflation pressure mmHg	Weight bearing on heel (n-7)		Weight bearing on forefoot (n-7)	
	Mean weight bearing kg.	Mean pressure on weight bearing mmHg.	Mean weight bearing kg.	Mean pressure on weight bearing mmHg.
30	8.5	38	3.5	36
35	10.0	45	3.5	42
40	10.5	48	4.5	48
45	11.0	52	5.0	51
50	11.0	57	6.5	55
55	11.0	69	8.0	59

forefoot portion of the airsplint, deformation occurred sooner than it did when weight-bearing was initiated through the heel. It would appear, therefore, that a straight tube would be more efficient for an immediate post-operative device and for early ambulation in the parallel bars. During the early stage of stump healing, it is desirable that excessive weight bearing should be avoided and the load bearing characteristics of the airsplint ensure that weight bearing above 11 kg does not occur. As the patient progresses from the parallel bars to a walker, use of an airsplint with a foot may be more advantageous as it allows more weight bearing, however, the disadvantage of dragging the foot component may offset this. Studies of load bearing were not carried out during ambulation, however, during clinical use of the airsplints, our observation is that load bearing during ambulation is less than the maximum static load bearing found during this investigation.

This study further revealed that there was no advantage in terms of weight bearing in relation to the increase in inflation pressure above 45 mmHg in the below-knee amputee. In the above-knee amputee, there was similarly no advantage in increasing the inflation pressure above 40 mmHg and keeping the pressure up to 40 mmHg had the advantage of decreasing problems with suspension.

Suspension

During this study, it also became clear that, as the pressure inside the airsplint increased with weight bearing, this tended to reduce the suspension of the prosthesis particularly in the above-knee amputee. This problem with suspension had also been noted during clinical use of the airsplint. Additional suspension was, therefore, required in the above-knee amputee with a short stump. The authors calculated that the force pushing the airsplint off is equal to the pressure in the airsplint multiplied by the cross-sectional area at the upper part of the thigh, whether the patient is an above or below-knee amputee. The force keeping the airsplint in place is due to the friction between the inner surface of the airsplint and the skin or the stump sock. As the stump gets shorter, the frictional force decreases and, therefore, the splint is more likely to come off. Suspension of the airsplint can theoretically be improved by either increasing the friction between the inner surface of the airsplint and the stump, providing some form of additional suspension, or decreasing the pressure within the splint.

There is a possibility that internal airsplint pressure may cause tissue necrosis, however, no cases have been reported in the literature. The effects of external pressure on blood flow with the use of airsplints have been studied by Campion et al, (1968); and Ashton (1966). Campion et al, (1968) used the 133 Xenon-histamine clearance curve and noted that the blood flow through the calf was greatly reduced at 40 mmHg external pressure. He concluded that, for first-aid purposes, inflation pressure in excess of 30 mmHg should not be used. Ashton (1966) measured the blood flow in the forearm and calf with mercury-in-rubber strain gauges before, during, and after inflation of the airsplints to various pressures for a duration of 10 to 45 minutes. She concluded that a splint inflation pressure of 30 mmHg produces a smaller reduction in blood flow than the splint inflation pressure of 40 mmHg. She recommended that the splints should not be inflated above 30 mmHg.

In our experience, no tissue necrosis was noted with inflation pressures of 30-40 mmHg. The present study shows that there is no advantage in inflation pressures higher than 40 mmHg.

Because of the small group of subjects, these results have not been subjected to statistical analysis. Similar studies in a larger group of subjects are warranted.

Acknowledgements

This study was carried out at the Department of Rehabilitation Medicine, Kingston General Hospital, Kingston, Ontario, and was supported by a Medical Research Council of Canada Grant No. MA4008.

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