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Experimental fittings of sockets for below-knee amputees using computer aided design and manufacturing techniques

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Introduction

A number of experimental fittings of below-knee amputees was carried out in Britain and Canada using Computer Aided Design (CAD) and Computer Aided Manufacturing (CAM) systems. The CAD system was developed at the Medical Engineering Resource Unit (MERU), University of British Columbia, Vancouver, Canada. A dedicated CAM system was developed at University College London (UCL), England. These systems, along with the West Park Research Centre's Shape Sensing system were demonstrated at the ISPO World Congress in London during September 1983. The experimental fittings carried out in London, Glasgow, Dundee and Vancouver are reported here.

Procedure

Two approaches to fitting the amputees were taken (a) a very systematic procedure was followed by an inexperienced person to fit three amputees at the MERU. (b) An intuitive procedure based on experience was used to fit 14 amputees in Britain. The operator who had no previous experience of fitting prostheses would show what level of success could be achieved through an iterative process. The fittings carried out by the experienced people would show if a direct transfer of skills could be made from general practice to the CASD system. It was also hoped to see how experience compared to the systematic approach.

The same steps were used by all operators in the preparation of the sockets for the prostheses.

1. Measurements—calipers were used to make AP and ML measurements at specified locations on the stump.
2. Modifications—Computer Aided Socket Design (CASD) programs were used to modify the model socket in the computer to comform to the requirements of each amputee based on his measurements.
3. Replication—a model over which the socket could be made was carved on a numerically controlled carver.
4. Socket fabrication—a polypropylene socket was vacuum formed on the "Rapidform" machine.
5. Checking—the prosthetist compared the CASD socket against the patient's stump and, if necessary, made modifications on the computer.
6. Components—modular components acceptable to the amputee were used for construction of the prosthesis.

Discussion

None of the sockets were completely comfortable. However, there were amputees who wore their prosthetic CASD sockets for extended periods.

Sample cases

1. The prosthesis was worn for a one week period using two socks. On removal of one sock to reduce tightness, an antero-distal tibial abrasion developed. The socket was not total contact but had a soft liner.
2. This amputee wore his prosthesis for three days without difficulty. He was

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Table — clinical results

*Location of CASD/CAM equipment	Location of patients	Number of trials	Number of amputees	**Rating I	II	III	IV	V
UCL	UCL	14	12	2	5	4	3	0
UCL	Strathclyde	3	1	0	0	2	1	0
UCL	Dundee	2	1	0	0	1	0	1
MERU	MERU	17	3	0	6	8	3	0
	Totals	36	17	2	11	15	7	1

* UCL—University College London, Bioengineering Centre.
Strathclyde—University of Strathclyde, National Centre for Training and Education in Prosthetics and Orthotics.
Dundee—Dundee Limb Fitting Centre
MERU—University of British Columbia, Medical Engineering Resource Unit.

**The sockets were rated according to the following scale.

Class I Unable to enter socket.
Class II Able to stand but not walk for half hour.
Class III Able to walk for half hour but uncomfortable.
Class IV Able to walk for over half hour with minor discomfort.
Class V Comfortable, normal use.

advised to discontinue use of the tighter experimental limb because it might affect the shape of his stump so that comfort in his original prosthesis, on which he was dependent, might be affected. The socket was not total contact and did not have a liner.

3. The third amputee, a bilateral fitted on one side only with a CASD socket, wore his prosthesis intermittently because of problems with the suspension, but indicated satisfaction with the fit of the socket. The socket was not total contact nor did it have a liner.

Summary

The experiments showed that it is possible to successfully design a socket using a computer based socket model. Variability of results, however indicates the existence of shortcomings. These were identified as (a) inadequacies in the caliper method used to measure the stumps; (b) inability to make the sockets total contact; (c) lack of flexibility of the design process in the Round #1 computer CASD system.

It was shown by results of the MERU fittings that an iterative procedure in the hands of an inexperienced person would lead to a degree of success comparable to that achieved by experienced persons using judgement. Also indicated was that experienced prosthetists were able to transfer their skills to the CASD system. This is indicated by the fact that they achieved 5 Class IV results with 8 sockets as compared to 2 Class IV results with 10 sockets achieved by the inexperienced operator.

Recommendations

1. A consistent method of measuring the stump needs to be established.
2. The capability for enclosing the distal end of the stump in the socket is required.
3. Round #2 CASD system should include the capabilities for dealing with needed shape changes anywhere on the model as well as in specified regions.

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