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Precision grip function after hand replantation and digital nerve injury☆

M. Schenker[a,b,c,*], M.K.O. Burstedt[a], M. Wiberg[b,d], R.S. Johansson[a]

[a] *Department of Integrative Medical Biology, Physiology and Anatomy Sections, Umeå University, Umeå, Sweden*
[b] *Department of Plastic, Reconstructive and Hand Surgery, St James's University Hospital, Leeds, UK*
[c] *Department of Plastic, Reconstructive and Hand Surgery, South Manchester University Hospitals, Manchester, UK*
[d] *Department of Hand and Plastic Surgery, University Hospital of Northern Sweden, Umeå, Sweden*

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Summary Understanding how the loss of digital sensibility affects manual dexterity could have important implications for rehabilitation after hand injury. We investigated precision grip function during lifting tasks in seven patients after hand replantation, in five after single digital nerve injury and in four volunteers subjected to digital anaesthesia. Using their affected hand, all participants could successfully lift test objects with parallel and vertical grip surfaces and they all reliably increased the grip force with increasing object weight (0.11–0.55 kg). However, the grip forces used were frequently significantly higher than those applied by the unaffected hand. This was partly due to participants compensating for loss of sensibility with high grip force safety margins against slips, and partly related to misalignments of the fingertips on the grasp surfaces. The latter was most prominent after hand replantation. In a second series of lifting experiments we changed the shape of the grip surfaces in order to investigate the participants' ability to adapt grip forces based on tactile recognition of object shape. An important finding from this series was that in patients with poor clinical outcomes, the contralateral unaffected hand tended to mirror the abnormal grasp patterns of the injured hand. This suggests that control strategies developed for the impaired hand can influence the control of the contralateral uninjured hand.

It is common knowledge that the loss of digital sensibility after hand injuries can severely affect manual dexterity, especially when handling small objects requiring a precision grip. This effect may vary according to whether the loss of sensibility is

☆ This is the first of a series of two publications on fingertip force co-ordination in precision grip and describes the effects of traumatic loss of digital sensibility on grasp.

* Corresponding author. Address: 5 Hesketh Road, Sale, Cheshire M33 5AA, UK. Tel.: +44 161 972 5780; fax: +44 161 972 5781.
E-mail address: michael.schenker@dial.pipex.com (M. Schenker).

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caused by isolated injuries to digital sensory nerves, to mixed nerves to the hand and forearm, or is part of major hand trauma affecting nerves, bones and soft tissues.

Understanding the mechanisms that affect precision grip in the presence of reduced fingertip sensibility may facilitate the rehabilitation of such injuries. Some patients with abnormal sensibility after peripheral nerve injury seem to grasp objects with more force than normal or necessary. Clinical and experimental studies have demonstrated high grip forces—fingertip forces applied perpendicular to the grip surfaces of an object—with reduced fingertip sensibility.[1-10] Taking these findings further we investigated how peripheral nerve lesions affect the co-ordination of fingertip actions in a simple hand function; i.e. to grip and lift objects between the tips of the thumb and a finger.

For a stable grasp, to prevent accidental slips, healthy people automatically apply grip forces that are strong enough to deal with the destabilising forces (tangential forces) that come into play whenever an object is manipulated. These are largely based on object weight.[1] At the same time, excessive grip forces that might cause unnecessary fatigue, crush fragile objects or injure the hand are avoided. In one of the two test series in our study, we assessed the fingertip forces generated by the participants for control of grasp stability and their ability to adapt grip forces to changes in object weight.

Grasp stability also requires adjustments of fingertip forces to the surface properties of objects. Based on tactile afferent signals from the fingertips, healthy individuals adapt the ratio between the grip and tangential forces to the current friction between the hand and the grasped surfaces.[1,2] For any given tangential force applied during lifting and further manipulating an object, a greater grip force is applied with a more slippery grasp and a similar adaptation of force co-ordination takes place for variations in object shape. These variations in shape are easier to control experimentally than variations in friction. A greater grip force is applied when the grip surfaces

Table 1 Clinical results after hand replantation (HR)

Patient	Age (op)	FU (years)	Injury (side/level)	Reported use of replanted hand	Thumb opposition	S2PD (mm)	Intrinsic atrophy uln/med	MRC flex/ext
HR1 (m)	11	9	RD/dist forearm	Full	LF MCPJ	5	−/+	5/5-5/5
HR2 (m)	15	4	RD/dist forearm	Restrictions at work	RF tip	7	++/−	5/5-5/5
HR3 (f)	8	4	LnD/prox wrist	Reluctant to show and use hand	MF tip	7	−/+	5/5-5/5
HR4 (m)	49	7	LnD/mid wrist	Some restrictions (same job)	MF tip	>10	−/++	5/5-4/5
HR5 (m)	41	5	RD/dist wrist	Restrictions forced change of job	LF tip	>10	++/++	5/5-4/5
HR6 (m)	47	4	LnD/dist forearm	Little useful function (same job)	IF DIPJ	>10	+++/-+++	4/5-3/5
HR7 (m)	67	4	LnD/dist wrist	Little useful function (retired)	IF DIPJ	>10	++/−	5/5-4/5

The patients are listed according to declining clinical outcome at the follow up (HR1–HR7). 'm' (male) and 'f' (female) indicate the sex of the patient. Patient age refers to that at operation (op); 'FU' indicates the follow-up period. The injured side is coded as right (R) or left (L), dominant (D) or nondominant (nD). Patients were asked about the use of their replanted hand at work and at home ('reported use'). The thumb opposition follows a modified version of Kapandji's system[29] and refers to the maximum reach of the thumb towards the tip or a joint of index (IF), middle (MF), ring (RF) or little finger (LF). Static 2-point discrimination (S2PD) is given in mm and strength obtained for the finger flexors and extensors were examined according to the MRC scale. Atrophy of intrinsic hand muscles innervated by the ulnar and median nerve ('uln/med'), respectively, was graded according to a 4-grade scale as minimal (−), some (+), considerable (++), and complete (+++).