Assessment of marker fixation in prospective motion correction using a multiple marker approach.

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Introduction: Optical tracking of external markers for prospective motion correction (PMC) has been demonstrated to achieve high accuracy [1]. However, the underlying assumption that the motion of the marker is coupled to that of the object of interest remains to be quantified. In neurological applications, markers are often adhered to the bridge of the nose or to the forehead. Although these offer simplicity and subject comfort, skin motion due to changes in facial expression (squinting), or due to changes in the adhesive properties, will cause changes in the position of the marker relative to the brain, causing erroneous updates of the slice position during PMC. In this study, a multi-marker tracking approach is taken [2]. Marker fixation on the forehead is assessed by simultaneously tracking another marker fixated to a subject specific dental-grade mouthpiece worn by the subject. By calculating the relative position of the markers, non-coupled marker motion, such as drifts and susceptibility to squinting can be evaluated.

Methods: All experiments were conducted using a Siemens 3T Trio (Siemens Healthcare, Germany) and an in-bore optical camera with moiré phase tracking (MPT) (Metria Innovation, WI, USA). A single subject was imaged. Two markers were attached to the head of the subject: The first was fixated to a mouthpiece fitted to the upper jaw of the subject (reference marker). This marker was assumed to have perfect coupling to the motion of the skull. The second marker was attached to the face of the subject, at locations between the eyes, over the eyebrow and onto the bridge of the nose. Different adhesives were investigated: putty, adhesive tape (Powerstrips, Tesa) and a clip for the nose bridge. Over an imaging period of 4 minutes, both markers were simultaneously tracked at a temporal resolution of TR=15ms, and the difference between the marker poses was logged. After two minutes, approximately 5 seconds of squinting was performed. Offline, marker drifts pre- and post-squinting, and susceptibility to squinting was evaluated from the difference between the marker positions. To demonstrate the effect on the non-coupled motion of the facial marker, in a phantom study, the relative change was used as an input source for a PMC scan, thus updating slice position with this relative change, producing the potential artefacts caused [3].

Results: Traces of the change in the facial marker pose relative to the reference marker can be seen in figure 1. Table 1 summarises the differences in marker pose pre/post squinting; peak values during squinting; and marker drifting pre and post squinting. Figure 2 shows the motion artefacts caused by typical non-coupled marker motion (from a marker positioned on the forehead) in a phantom. From Table 1, it can be seen that drifting occurred in all experiments, often drift direction changed after squinting occurred. Marker pose was found to change after squinting, with markers positioned on the forehead being the most effected. All marker positions showed large susceptibility to non-coupled motion during squinting.

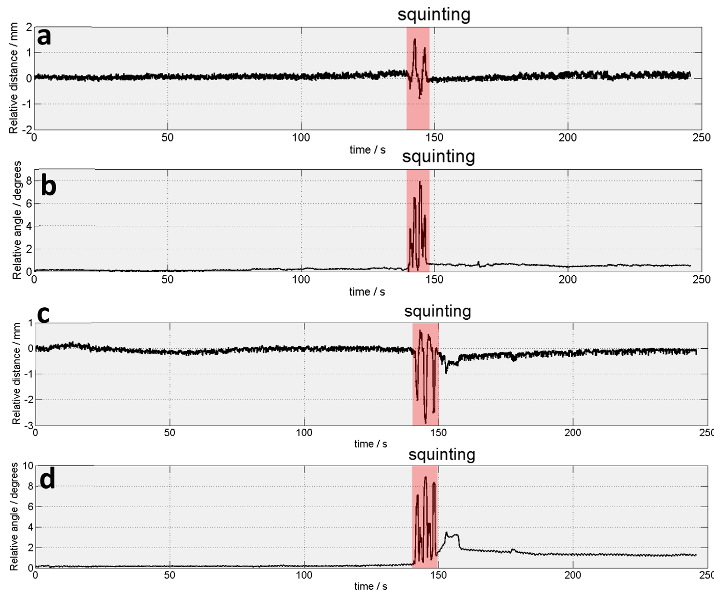

Figure 1: Traces of the face marker pose relative to the reference marker for marker locations between the eyes(a-b) and on the forehead (c-d). Measurements from these traces include marker drifts pre- and post- squinting; difference in marker pose pre-and post-squinting; and peak pose deviation during squinting.

Discussion: In all experiments, drifts in the relative angle between the markers were observed. The impact of these drifts however, will be dependent on the duration of scan. Most drifts observed would remain under 1mm or 1deg for a 5min imaging protocol. The effect of squinting on marker position is however, noteworthy. From figure 2, in two out of five measurements (40%), substantial drifting occurred, however, a larger sample size is required to draw conclusions on the frequency of this occurrence. All fixation methods showed susceptibility to squinting and in all measurements, slight image degradation occurred, although k-space ordering was low-high, and squinting occurred halfway during the scan. This was reproduced in Figure 2. It is also important to note that the squints performed were exaggerated, and would not be expected under normal conditions. In general, markers positioned between the eyes showed most robustness towards marker drifts and exhibited small pre- and post-squint pose difference. One of the limitations to this study lies in the assumption that the marker fixated to the mouthpiece perfectly describes the rigid motion of the head. As these mouthpieces are custom-fitted to the subject by a dentist, they are known to fixate very tightly to the upper jaw and non-coupled motion is minimal.

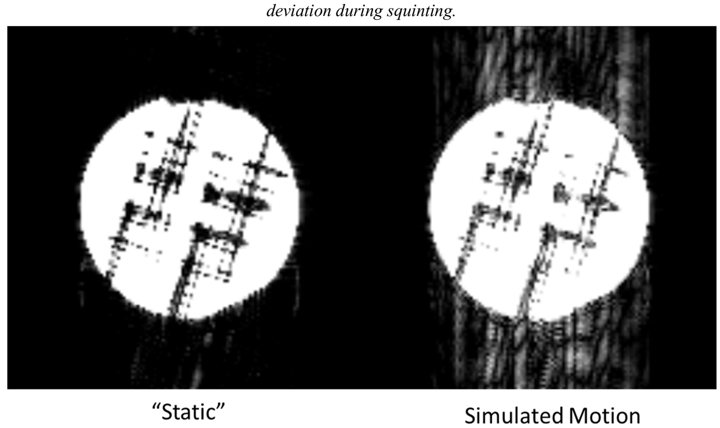

Figure 2: Static phantom (left) and scan repeated with simulated marker drifts and squinting. Images are scaled so that artefacts can be seen.

Conclusion: Dual marker tracking in PMC allows for the assessment of marker fixation. In most measurements, marker drifts were found to be small, but it was occasionally noted that post squinting, relatively large deviations in marker pose compared to pre squinting and drifts occurred. Overall, it was determined that using an adhesive tape between the eyes provides the most robust marker motion coupling to the skull. However in general, this study highlights the need for the detection of squints in neurological imaging with PMC, and for an approach to handle any occurrences of marker drift.

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References: [1] Maclaren et al., PLoS One 2012; 7:e48088. [2] Singh et al. ISMRM 2014 #891. [3] Herbst et al. MRM 2014; 71(1)

Table 1: Table of face marker pose value relative to reference marker. The first column show the difference in marker pose pre and post squinting. The second column shows peak marker deviation during squinting. The third column shows the measured drifts pre and post squinting

	Pre/Post Squint Difference		Peak Squint Pose		Marker Drifts			
	Angle (deg)	Translation (mm)	Angle (deg)	Translation (mm	Pre-Squint (mm/min)	Post squint (mm/min)	Pre squint (deg/min)	Post squint (deg/min)
Forehead (Putty)	1.2	-0.11	9.0	-2.9	0.057	-0.51	-0.0029	0.024
Between eyes (Putty)	0.35	-0.11	8.0	1.5	0.12	-0.15	0.056	0.16
Forehead (Tape)	0.75	-0.72	10.0	-6.7	0.30	0.00	-0.11	0.25
Between eyes (Tape)	0.13	-0.13	4.4	-1.85	0.16	0.14	0.040	0.019
Nose Clip	0.24	0.21	4.2	-0.5	0.22	0.22	-0.071	-0.11