Summary of Key Journal Papers: AlignRT®

General System Validation
Bert et al [1] carried out a phantom evaluation of the AlignRT® system. This study investigated the surface measurement reproducibility, surface model accuracy, accuracy of recommended patient realignment and dynamic surface measurement. They concluded that the system performed well within clinically required accuracy (errors < 1 mm for alignment and surface matching; motion in concordance with RPM) and that operation and setup was convenient, and daily clinical use should be possible.

Further work to evaluate the system accuracy was carried out by Schöeffel et al [2]. Positioning accuracy was measured on both phantom and volunteers. This study reported high system stability and detected pre-defined shifts of phantoms and healthy volunteers with errors of 0.40 +/- 0.26 mm and 1.02 +/- 0.51 mm, for spatial deviation between pre-defined shift and suggested correction, respectively. The accuracy of the suggested rotational correction around the vertical axis was always better than 0.3 degrees in phantom measurements and 0.8 degrees in volunteers.

Breast Treatments
Bert et al [3] reported their clinical experience of AlignRT® for alignment of partial-breast irradiation patients. This study compared the breast surface alignment, for a group of 9 patients, when using tattoos and lasers, portal imaging and AlignRT®. The authors concluded that surface imaging for PBI setup appears promising. Moreover, they concluded that the alignment of the 3D breast surface, achieved by stereophotogrammetry, shows greater breast topology congruence than when patients are set up by lasers or portal imaging. The authors noted that a correlation of breast surface and CTV must be quantitatively established.

Work to investigate the correlation of breast surface and CTV was initially carried out at MGH by Gierga et al [4]. A group of 12 patients undergoing external beam accelerated patient breast irradiation was studied. Target Registration Errors (TRE) were quantified for four methods of image guidance: standard laser-based setup, kilovoltage imaging of the chest wall, kilovoltage imaging of surgically implanted clips, and three-dimensional surface imaging of the breast. The uses of a reference surface created from a free-breathing computed tomography scan and a reference surface directly captured with three-dimensional video imaging were compared. The effects of respiratory motion were also considered, and gating was used for 8 of 12 patients. This paper concluded that the TRE of surface imaging using a reference surface directly captured with three-dimensional video and the TRE for clip-based setup were within 1 mm. Moreover, they concluded that gated capture was important for surface imaging to reduce the effects of respiratory motion in accelerated partial breast irradiation.

Further to the above study, Chang et al [5] compared the accuracy of isocentre placement, using various positioning methods, on a group of 23 PBI patients. Clips were placed within all patients at the time of surgery. Patients underwent computed tomographic simulation and surface contours were used to reconstruct a reference surface map. At the treatment machine, patients were initially positioned by laser alignment to tattoos. Orthogonal kilovoltage imaging of the chest wall, followed by video surface imaging of the breast, were performed. The 3D video surface was matched to the reference CT surface to adjust the couch position. Verification orthogonal chest wall imaging and video surface mapping were again performed. The accuracies of setup by laser, orthogonal imaging of the chest wall, and surface alignment were retrospectively compared using the centroid clip position as the reference standard. The impact of setup error by surface alignment and by orthogonal kilovoltage imaging on planning target volume coverage was then calculated. This study concluded that video surface mapping of the breast (with AlignRT®) is a more accurate method for isocentre placement in comparison to conventional laser-based alignment or orthogonal kilovoltage imaging of the chest wall, with mean setup errors < 2 mm in each orthogonal axis.

Gierga et al [6] describe a surface imaging technique developed for accurate patient setup and reproducible real-time breath-hold (BH) positioning used for 20 patients with unfavourable cardiac anatomy. Surface imaging was used to correct the daily setup for each patient. Initial setup data were recorded for 443 fractions and were analysed to assess random and systematic errors. Real time monitoring was used to verify surface placement during BH. The radiation beam was not turned on if the BH position difference was greater than 5mm. Real-time surface data were analysed for 2398 BHs and 363 treatment fractions. The mean and maximum differences were calculated. The percentage of BHs greater than tolerance was 22%. Mean differences of 2mm between the treated and planned breath-hold positions were calculated. This study concluded that daily real-time surface imaging ensures accurate and reproducible positioning for BH treatment of left-sided breast cancer patients with unfavourable cardiac anatomy.

Frameless Stereotactic Radiosurgery
Cerviño et al [7] carried out a study to investigate whether it is feasible to use less rigid immobilisation for SRS if the patient is tracked using the AlignRT® system. Initial accuracy tests were carried out using an anthropomorphic head phantom. Volunteers were used to study patient motion inside a new type of head mold that was used for minimal immobilization. Results showed that for different couch angles, the difference between the phantom positions recorded by the surface imaging system and by an infrared optical tracking system was within 1mm in displacements and 1 degree rotation. The motion detected by both systems during couch shifts was within 1 mm agreement. The average maximum volunteer head motion in the head mold during the 20 minute interval in any direction was 0.7 mm (range: 0.4–1.1 mm). Patient motion due to couch motion was always less than 0.2 mm.
The authors concluded that motion inside the minimally immobilizing head mold was small and could be detected accurately by real-time surface imaging.

Peng et al [8] characterised the AlignRT® system for stereotactic positioning by carrying out a study which validated the system accuracy through comparison with the Elekta kV CBCT system (XVI) and the Varian frameless SonArray (FSA) optical tracking system. Surface-image data sets were acquired daily, with the AlignRT® system, for the evaluation of pre-treatment and inter-fractional and intra-fractional motion for each patient. Results for two different reference image sets, planning CT surface contours and previously recorded AlignRT® surfaces, were reported. The authors concluded that AlignRT® can be used as a non-ionizing IGSPS with accuracy comparable to current image/marker-based systems. IGSPS and CBCT can be combined for high-precision positioning without the need for patient-attached localization devices.

Li et al [9] established a new clinical procedure in frameless stereotactic radiosurgery (SRS) for patient setup verification at treatment couch angles as well as for head-motion monitoring during treatment using video-based optical surface imaging (OSI). They concluded that the OSI system is capable of detecting 0.1 +/- 0.1 mm 1D spatial displacement of a phantom in near real time and useful in head-motion monitoring. The authors highlighted that this is necessary for frameless SRS in case of unexpected head motion that exceeds a set tolerance.

Cerviño et al [10] present their initial clinical experience using AlignRT® for frame-less and mask-less stereotactic radiosurgery treatments on their first 23 patients treated with this technique.

Pan et al [11] report the clinical outcomes using the above [10] real-time, frameless, surface imaging-guided radiosurgery (SIG-RS) technique to treat brain metastases. Data were prospectively gathered for 44 consecutive patients totalling 115 intracranial metastases treated with SIG-RS in a median of 1 fraction (range, 1-5) to a median dose of 20 Gy (range, 15-30 Gy). Local control, regional control, and overall survival were estimated by the Kaplan-Meier method. These results were then compared with data previously reported. This study concluded that SIG-RS for treating intracranial metastases can produce clinical outcomes comparable to those with conventional frame-based and frameless stereotactic radiosurgery techniques while providing greater patient comfort with an open-faced mask and fast treatment times.

**References**

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