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Computer and Robotic Assisted Orthopaedic Knee Arthroplasty Surgery Who drives innovations?

David Wallace[**], Fahd Mahmood[*1], Angela Helen Deakin[*†],

Philip E Riches[§2], Kamal Deep[*2], Joseph Baines[*2] and Frederic Picard[*‡]

Golden Jubilee National Hospital
Agamemnon Street, Clydebank, Scotland
University of Strathclyde
16 Richmond St, Glasgow G1 1XQ

1 Introduction:

Computer assisted and Robotic technology in orthopaedic surgery is still not commonplace compared to un-assisted, conventional orthopaedic surgery.

It may be considered somewhat surprising therefore, at a time of incredible technological progress that the computer still struggles nowadays to make its way in all orthopaedic theatres of the world. [1,2]

In June 2016, Dalton et al. [3] reviewed all patents and papers published between 1980 and 2014 related to knee surgery and sorted them into four clusters of innovations, which could be used to link patents and publications: Unicompartmental Knee Arthroplasty (UKA), Patient Specific Instrumentation (PSI), Navigation and Robotics. Three of these are part of the CAOS technology "family". Since 2004, the ratio between patents and publications increased from approximately 1:10 in 2004 to almost 1:3 in 2014 showing industry-driven innovation on technology introduction in the field of knee arthroplasty.

[*] Preparation of Manuscript
[†] Preparation of Manuscript, data collection
[‡] Preparation of Manuscript, data collection, original idea

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Using the same methodology as Dalton et al. up to 2018, we analysed the relationship between patents and publications trend every year and question whether we could recognise a pattern which would confirm their conclusion on industry-driven innovation.

2 Material and methods:

Using the same methodology as Dalton et al. we reproduced their figures extending them to 2018. Search terms in Pubmed with date range set to 1980/01/01 to 2018/12/31. Publication numbers were normalised to 2014 using the following formula as per Dalton et al.

$$\mathrm{II_i}^{\mathrm{normalised}} = \frac{\mathrm{II_i}^{\mathrm{original}}}{\mathrm{c_i}}$$

$$\text{where } \mathrm{c_i} = \frac{\mathrm{t_i}}{\mathrm{t_{2014}}}$$

where II is the innovation index (number of patents or publications in area), i is year, t is total number of patents granted or paper published, and c is the innovation constant. Data was then plotted using a 4-period moving average as per Dalton et al's method.

3 Results:

Between 2001 and 2004, the number of publications regarding navigation multiplied by 20 (Figure 1). At the time, most of the large global multinational orthopaedic companies had little expertise with CAOS systems other than maybe Stryker and Medtronics. Most of the systems commercialised at the time were from smaller orthopaedic allied companies, e.g. Brainlab/ München, Germany; Aesculap/ BBraun Tuttlingen Germany; OrthoSoft, Montreal, Canada

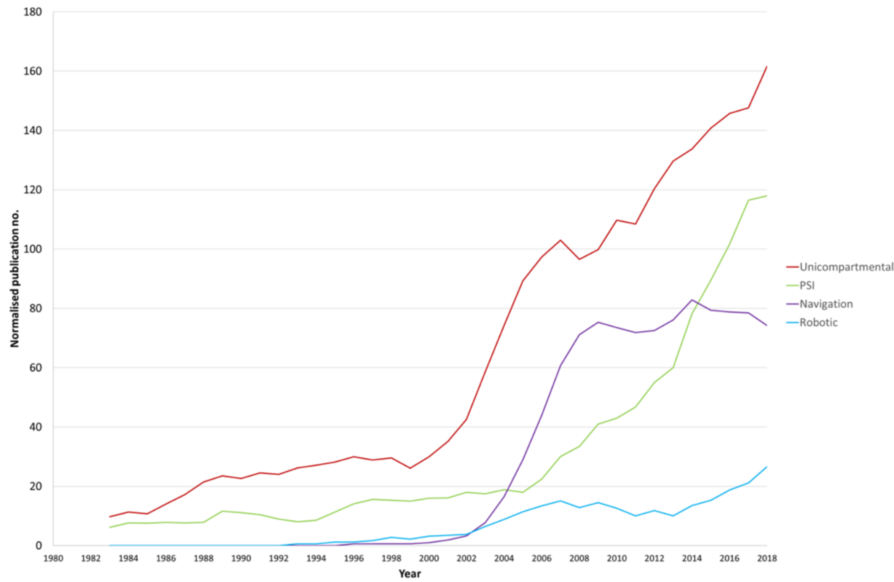

Figure 1: Graph of the normalized publication growth curve of the individual technology clusters and the overall knee arthroplasty publication curve. X axis referred to time between 1980 and 2014, Y axis referred to number of publications.

Whether this sudden interest in CAOS made the larger companies react vigorously or not is difficult to confirm due to their strategic secrecy. However, it is clear that from 2003 onwards a wave of publications, supported by the large corporations, promoted Minimally Invasive Surgery (MIS) for both hip and knee arthroplasty, which created a temporary diversion from the adoption of CAOS technology.[4]

From 2004 until 2008, the number of patents registered under the “knee replacement” or “knee arthroplasty” label by industry grew steeply (Figure 2). We could deduce, therefore, that the orthopaedic industry responded to the demand for CAOS and invested in new and better designed systems to match surgeons’ expectations. The number of publications rocketed during this period showing solid evidence of interest in the technology but also genuine vigilance from orthopaedic community in order to avoid worrying past experiences.

The number of patents dedicated to navigation after 2008 reduced, whereas more investments focussed on PSI and then two years later to robotic technologies (Figure 2). By 2008, the number of publications for navigation declined whereas they increased for PSI. It can be postulated, therefore, that the industry felt that investing more into PSI may, on the one hand, solve the ergonomic issues surgeons complained about but also, on the other hand, may solve their economic problems related to navigation. Despite, in 2007, Novack [5] concluding that CAOS navigation was potentially a cost-effective or cost-saving addition to TKA, economics was found to be one of the main issues limiting CAOS adoption, not only due to the high capital cost of the systems themselves, but also due to the overall overhead cost related to increased length of surgery and increased operating expenses with regards to inventory and surgical assistances.

After 2010, the orthopaedic industry had invested a lot in robotic-assisted technology despite unsuccessful past market introduction and less in navigation certainly to offset implant price reduction and the lack of instalments for the costly surgical trays/instrumentations. Selling at a very high price, robots became suddenly appealing to the industry but on the other hand remained an obvious and significant restraining factor of use of this technology due to the high capital cost for users. Investment grew more abruptly by 2012 onwards where industry tried to change the paradigm from computer aided to robotic aided technology. The Mako® robot was one of the drivers of robotics in orthopaedics in reviving UKA market which was clearly noticeable on Dalton et al. figures with growing number of publications in UKA but also patents related to UKA.

Mako® attracted Stryker®, one of the leading orthopaedic majors in the world who acquired Mako® for $1.6 billion between 2012 and 2013 launching the "robot war" between competitors. Smith & Nephew bought the Navio®/BlueBelt Technology today CORI® for $275 million in 2016, Zimmer bought the ROSA® robotic system for at least $132 million, and more recently Johnson & Johnson invested in a new robot named Velys® for an unclosed amount, while the first active Robodoc® system product of the Think® company is still in use.

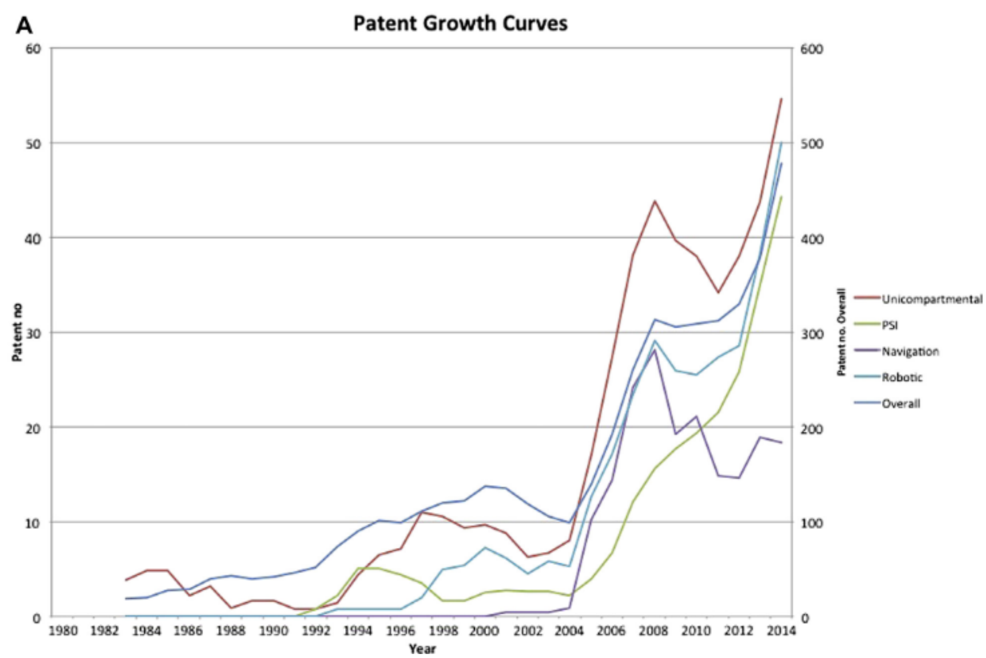

Figure 2: Graph of the normalized patent growth curve of the individual technology clusters and the overall knee arthroplasty patent curve. X axis referred to time between 1980 and 2014, Y axis referred to number of patents.

After 2014 while the number of publications increased for PSI, navigation and robotic publication numbers went to opposite direction in favour of the later to the former. This would confirm our previous statement about the “robot-war” between companies and their driving force in innovations.

4 Discussion/ Conclusion:

In joint replacement the technology is being used to more accurately replicate conventional surgery, as opposed to opening up new surgical possibilities. Therefore, in essence, to have a wider adoption of CAS in arthroplasty as in oncology [3], spine applications [6] or difficult cases in arthroplasty [7], surgeons must admit, individually and as a community, that their conventional arthroplasty surgery could be performed “better” with computer-assistance and with increased cost-effectiveness.

However, the industry seems to have finally found a lucrative economical model after many years of trial and errors and sustained driving innovations.

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