

ALBERTO GREGORI

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SUMMARY

Alberto Gregori's trajectory reflects a synthesis of technical precision and humanitarian necessity. From his formative experiences in post-war Zimbabwe to pioneering computer-assisted surgery in Scotland, Gregori has consistently prioritized clinical adaptability. His work with the OrthoPilot and Navio systems established him as a central figure in the evolution of robotic arthroplasty. Today, he balances high-technology surgical practice with a commitment to global health, advocating for sustainable training models that empower local surgeons in resource-limited environments worldwide.

Modesty, eclecticism and commitment characterise Alberto Gregori. His career, which he was willing to evoke for MO Europe, gave him the opportunity to devote himself to navigation, the beginnings of robotics and above all to humanitarian surgery.

Alberto Gregori, what is your background, as an Italian orthopaedic surgeon working far from Italy ?

My grandfather was an Italian immigrant looking for a better life, hoping to go to America but only getting as far as Scotland. He worked in the ice cream and café business. My father was born in Scotland, went back to Italy as a child and eventually took over the family business in Scotland. He married an Italian lady and I was born in Scotland with two Italian parents, speaking Italian at home. It was an Italian microcosm in Scotland: we ate Italian food, we had Italian friends, we spoke Italian, I went to Italian day class to learn Italian.

My friends joke that I have taken the worst of the Italian and the worst of the Scot, but I hope it's actually the other way round! I think like a Scotsman in many ways, but I also have the love of life, of food, of wine of an Italian.

I went to a Jesuit school and was exposed to the concept of the developing, or at that time what was called the third world. Family friends who were African missionaries told me stories about their work and life in the bush. This made a big impression on me. I was given the opportunity to choose medicine as a career, though the expectation had been that I would work in the family business. I qualified in 1982 from Glasgow University. I had a difficult university career, too much "wine, women and song" and at the beginning my knowledge of anatomy was best described as "poor". I enjoyed practical subjects and obtained a merit certificate in orthopaedics. I was fortunate when I qualified that I worked for recognised leaders in their field such as Willie Bisset, one of the first real paediatric surgeons; he did everything: neonatal, cardiac, orthopaedic, neuro and general surgery. He was a great teacher, mentor and human being, teaching us to think out of the box. "if you want to do something, you can"

Where was he working?

The Royal Hospital for Sick Children in Edinburgh. I subsequently worked with people who facilitated my preparation for working in Africa, allowing me time during my busy week to learn

the bare basics of obstetrics, general surgery, and other specialties including anaesthesia. I went to work as a single-handed doctor at St Paul's Mission in Zimbabwe, just after the Zimbabwean civil war. There were many more patients than the 200+ beds. It was a culture shock. We lacked everything: equipment, fuel, money and food. Three people managed it; the mission superior, the matron and myself. I learned a lot about the management of people, and resource prioritization, with a political situation still in flux.

And you were doing general surgery?

I did everything from medicine, obstetrics, general and paediatric surgery and trauma. Obviously it was all very basic. The trauma was all very much splintage, traction, debridement and leaving wounds open. Most trauma presented late, you might see a compound fracture 2-3 weeks down the line. Being at the end of the civil war and with continuing war in Mozambique, there many old gunshot, blast and burns injuries. As a mission hospital we treated everyone. We did as much as we could with a steep learning curve, operating by torchlight, making do with whatever you had, anaesthesia and antibiotics. The two big lessons were learning how to manage things from first principles, and the other which we hadn't ever been taught, was how to do an operation out of a textbook. Read the textbook, look at the anatomy, think it through, and do the surgery. It has subsequently proven a very valuable skill to have.

How much time did you spend there, the first time you went?

Six months in 1985. WHO surveillance and awareness of HTLV3, which was later to become HIV, put us into conflict with Mugabe's regime and we were told to leave in late 1985.

So, you went back to Scotland?

Yes, with no job, no career prospects and not knowing what to do. I enjoyed doing trauma and surgery in Zimbabwe but had gained a lot of obstetrics experience. I started work as an obstetrics registrar but wanted to do some orthopaedics. Most said my time in Africa was career suicide but I got a job in orthopaedics in Norwich and stayed for two years obtaining my FRCS exams then. I worked for John Watson-Farrar, of McKee-Farrar hip replacement fame, Keith Tucker who later was involved with ODEP and Beyond Compliance, Hugh Philips, who became president of the BOA and other people like Malcolm Glasgow an early adopter of arthroscopy in the UK. They were all very supportive and great teachers and visionaries.

Were you exposed to metal-on-metal and with the McKee Farrar implants?

Yes, but remember these were also 1st generation cementing techniques; no pressurization, with variable quality cement and little understanding of what made it work best, we would reduce the hip before the cement had set, there was limited sizes, no different offsets, We saw patients with gross early failure of the metal-on-metal implants, and didn't know why. When you revised them, it was clear that hand finishing of the metal socket on the metal head was of variable quality and survival very much depended on the guy who had finished it. Now in 2021, that an old-fashioned craftsman created a metal-on-metal bearing by hand-polishing seems astonishing. The issue was with the variability of finish. So yes, we saw metallosis and giant cell reactions but we didn't appreciate it for what it was. It led to other solutions appearing and explains why metal-on-metal wasn't popular then. We also did not appreciate the financial implications of patents, education, of controlling the development of implant techniques and technology, and innovation. And again, that was a lesson for later in life.

You mention also arthroscopy?

Yes, it was very difficult to teach then. Malcolm Glasgow was very patient, teaching arthroscopy without a camera. We had no screens and used a double-jointed image splitter, which clipped on to the end of the arthroscope with the teacher standing behind the operating surgeon, directing operations, but usually unsterile, so not able to easily intervene. This required a huge amount of teaching skill, an ability to direct with your voice, to explain what was happening, the anatomy, triangulation, and the offset arthroscope view. The light bulbs were unreliable and were changed frequently. That ability to teach in those circumstances was exceptional and we don't realise how lucky we are now with camera stacks allowing everybody to see what's happening, and the teacher able to supervise and intervene if necessary. It's astounding we managed to train anybody!

That is why it's good to remember where we started from. So in 1988, you finished your two years, and you passed your fellowship exam. What's next?

So, I had a little interlude. Whilst in Norwich, I was asked to deploy to the humanitarian crisis in Lebanon during the Second Camp War with an aid team. There was the siege of Bourj el-Barajneh and other refugee camps and a crisis with high profile hostages; Waite, Anderson and others. The ICRC hamstrung by politics was unable to deploy humanitarian teams to help. Keith Tucker was incredibly supportive "Look, I'd like to do this, is it possible?" and he made a few phone calls, came back and said, "if you really want to go, we can do it" and gave me compassionate leave to go. It was an experience that remains with me forever, seeing pointless death, destruction and war first-hand. It does however provide an experience which molds surgical prioritization and survival skills as well as working in difficult circumstances. I was able to go because I had an Italian passport, going there with a British one would have been a bad idea! I was back working in the UK as if nothing had happened, a surreal experience.

How long did you stay in Beirut?

Just under two months. The plan had been to go for 2 weeks to allow evacuation of the volunteer teams in Bourj el-Barajneh and Shatila. We knew from the past that if there were no international witnesses, such as medical teams in the camps, the potential for a massacre of the camps would be very high, as had happened in Sabra/Shatila in 1985. We hoped to allow time for the ICRC and UN and others to establish an international presence within the camps. Politics and war meant that didn't happen quickly. For Bourj al-Barajneh, we were able to both work and get the team out eventually, with the help of the Italian Ambassador Antonio Mancini, whose quote was; "It's a funny place Lebanon. Everybody wants to be a hero, but nobody wants to be a martyr". He selflessly risked himself and his team to help negotiate and bring aid into the camps, and he did so without taking any credit. He was an inspirational remarkable human being. On my return I passed my fellowship exams and moved to a registrar job up in Edinburgh in April 1988.

How was your practice in Edinburgh?

At that time, training in the UK was still old-fashioned tiered training. Firstly you did general training, then onto registrar orthopaedic training and then a Senior Registrar post to complete training in orthopaedics. It was possible to become a consultant without a senior registrar post just by experience and there still wasn't an exit exam in orthopaedics. There was just an entrance general surgery fellowship exam though by the early 90s, an exit exam became an essential feature of streamlined orthopaedic training. To get a better job in a better unit you had to complete

training and the orthopaedic fellowship examination. It was a time of great change which benefited me in some ways, and it didn't benefit me in others.

Why?

There was huge uncertainty for trainees with different training systems running in parallel as the changes bedded in. General based rotational training was valuable but time consuming encompassing general surgery, orthopaedics, neurosurgery and paediatric surgery. Its removal meant that this time in training would be wasted compared to the new streamlined training starting at the same time. Training in general surgery meant I was okay with an anterior approach to the hip or lumbar spine or draining a thoracic empyema. That's something that's difficult to appreciate now.

You had already had some exposure of image-based navigation ?

In 1989 in neurosurgery I had a chance to do some research with Ian Whittle who was using stereotactic skull frame-based neurosurgery. The concept of triangulation, superimposing the CT scan on a reference frame to coordinate your attack on the tumour was ground breaking. It gave me an understanding that later helped when I saw navigation in Grenoble.

Thereafter in orthopaedics I worked with innovators such as James Christie and Charles Court-Brown who advocated more extensive use of closed nailing techniques and ORIF. James Christie's thoughts as to hip fracture audit and using accurate prospective data collection to determine how hip fractures could be best managed was important for my later work with the Scottish Hip Fracture Audit. I also saw the issues arising from introducing new techniques, thinking and technologies. When I went to Edinburgh it wasn't all perfect, people still did open meniscectomies as then open meniscectomy was still regarded by many as the gold standard meniscal operation as the meniscus was "a vestigial structure of no value". To think that was in our surgical lifetime is quite sobering. Meanwhile Macnicol was a major proponent of arthroscopy, a better understanding of knee function and ligament reconstruction. It was an interesting time of orthopaedic development.

I returned to the West of Scotland and started higher structured orthopaedic training initially as a career grade. I was not certain to gain a senior training post but could eventually get a consultant post after sufficient experience albeit in a smaller hospital. It was a time of rapid change and those caught up in it were anxious. If you wanted a career in a bigger or university hospital, you still had to achieve a senior registrar job and that was where the competition arose..

What was the plan, what were you expecting?

The plan was to become a trauma surgeon, logical with my general training and experience in Africa and Lebanon. In the 90s the United Kingdom decided not to pursue trauma centres, and so I became an Orthopaedic surgeon! I looked at jobs in other parts of the world, Australia and Fiji but they were not the jobs for me. By 1994 I got a senior registrar post in the West of Scotland. I now knew that I could complete my training, sit my exit fellowship in orthopaedics, and would be well placed to apply for a wider choice of jobs.

At that time, you were able to take 6 or 12 months of your training program overseas as a fellowship. I was awarded two fellowships, one the WOCUK/Leverhulme Fellowship; specifically to work in a developing country and I went to work with Professor John Jellis at the University

Teaching Hospital in Zambia. He was a world authority on HIV and bone infection, and ran a flying doctor orthopaedic program, which to me as a pilot was undoubtedly an attraction, the perfect opportunity to combine hobby and orthopaedics together.

In June 1996 I spent six months in Zambia, as a senior registrar/lecturer at the university, working as an orthopaedic surgeon and teaching, and then working on the FlySpec program at the weekends. It was quite an intense time, but interesting and incredible fun as well. John had trained with the great Imrie Loeffler going on to develop the orthopaedic service in Lusaka, and setting up the orthopaedic training program. At that time people were just general surgeons and they had to do everything. John also knew that Zambia was a massive country very poorly served by roads. It was practically impossible for patients who needed orthopaedic care to get to the capital as many were very poor subsistence farmers, and the only time they could travel would be during the rainy season, when they were practically impassable. Essentially rural dwellers who needed orthopaedic care just didn't get it. His solution was to set up a preplanned program of outreach where people would know he would fly out to local hospitals, scattered throughout Zambia. He'd leave on Thursday morning at the end of the fracture clinic and fly for 4-5 hours in his little airplane, land at the mission hospital at 6 o'clock before it got dark, start a clinic, see 200+ patients, and then on Friday start operating those patients that he could safely operate on. On Sunday he'd fly back to Lusaka and go back to work on the Monday.

How did you manage such a busy schedule ?

It was a huge amount of work. He developed a philosophy of doing operations that were safe and achievable using environment appropriate techniques. Some were quite old-fashioned techniques, but they were safe in that environment. So rather than use internal fixation, wires, intermedullary wires, Rush nails would be used. Plaster was extensively used, perhaps with Steinmann pins incorporated into the plaster with a large window cut in to allow wound dressings in open fractures. Appropriate traction techniques, using locally made and available materials and bricks as traction weights were carefully applied. Whilst basic, it worked really well. The programme to train locally-based orthopaedic surgeons eventually allowed the delivery of a network of orthopaedic surgeons in the country. They were trained not just to do the routine operations required at the university, mainly trauma, neglected trauma, infection, paediatric orthopaedics but he took the opportunity to teach them how to do hip replacements, knee replacements and arthroscopy. He used FlySpec to expand the training potential taking trainees out with him. They equipped these local surgeons with the skills to do private practice, probably the most important thing, because it meant these surgeons were able to manage a better income than if they relied on just a government or university salary and so they no longer left the country. That meant that during the Covid Pandemic in Zambia, 85% of the work continued because we have locally-based surgeons to run these missions, whereas in other countries we operate in, that hasn't been the case and little orthopaedic elective work has been done as no teams have been able to go. This was a lesson in capacity building as well, it was incredibly far-sighted of John to do this, because at the time many expatriate doctors would come in, do the work, be a hero and go away again.

You returned after those six month, what happened next ?

I had also been awarded an AO fellowship to work with Professor Hoffmeyer in Geneva but due to an issue there, it was postponed. My expected academic job at the University in Glasgow didn't materialize and luck or serendipity took over. My wife Trish, a partner in crime over these years, but also an Emergency Medicine Consultant and a pilot had travelled to Africa with me teaching

in Lusaka. When we came back from Zambia, she got a job in Hairmyres, a Scottish district hospital, as their first emergency medicine consultant. The next orthopaedic post available was in the same hospital. It was blessed with a management structure that knew they wanted change, innovation and expansion. At this very point AO called to say “There is a fellowship post available in France in a place called Grenoble. The only problem is you have to be able to speak French!”. My new hospital was generous enough to give me leave of absence to go to Grenoble. That was a turning point in my orthopaedic career. I was in Grenoble from June to August 1997. It was a great experience, my first exposure to the French professorial team, completely different to the training model and relationships in departments in the UK. I also saw a different approach to trauma compared to that in the UK. It was an incredibly meticulous approach to the quality of surgery and of soft tissue management, with scrupulous preoperative and postoperative care. It was eye opening to see how low complication rates could go!

Was Dominique Saraglia already the chair of the department?

Yes, Dominique was there, and working with him was absolutely fantastic. I learned that to deliver high standards, you have to engender those high standards throughout the department. It's no use the surgeon having high standards, but the rest of the team not aspiring to having the same high standards. It has to be a departmental approach. My first week there was unforgettable, I was made very welcome, and as we were in France, it meant ensuring I had good food, wine, company and conversation. That's when I met Fred Picard and his family and got involved with his work in Knee Navigation. It was an unusual time as well because I had already worked as a consultant so with Dominique, I had an opinion, which I was willing to argue and I think he enjoyed this. Being open to other ideas was good, it's easy to become fixed in your ways and be resistant to change. My experience in France was mind-boggling, coming with the realisation, of which Seb you are clearly well aware of, that much research that has been done in Europe is buried in their national language journals, but never translated into English, and therefore never referenced in the world literature. There was a huge knowledge base that I was suddenly exposed to. For example with a patient with an unstable ankle following significant trauma, Dominique talked about repair and acute reconstruction of the lateral complex, which at the time was deemed just crazy in Britain. Conservative management ruled with late reconstruction rarely offered even for symptomatic instability. The concept of assessing the degree of ankle instability with stress views at the time of injury was just not on the horizon. Dominique's revelation that the supporting literature was there but in French made me think. He had a cupboard full of articles supporting other for me heretical operations such as ORIF of calcaneal fractures, scarf osteotomies and others. Surgeons in France understood them, but they were weird concepts for English speakers, as we hadn't seen them in an English medium medical journal. We need to be open to other ways of doing things and seek them out.

Did you see already some pilot research about computer assisted surgery?

Yes, very much so. The need to write papers in good English was essential. Fred actually asked me “Look, can you do this? Can you have a look at this lecture and put it into English so that I can present it?” Some of the early documentation had to be written in good English and that was hard for Fred and his team. I was able to help Fred with that at the time, but we went further as we were also brain-storming with Francois Leitner, exploring some of the concepts and how to take navigation forward. That usually involved going to the local restaurant and trying to get Fred not to smoke! It was a time of blue sky thinking, we explored some crazy ideas and at the same time,

the first clinical cases were being done. By the time I arrived in Grenoble, they were at number 7, 8, 9, 10... It was now something that was practical, a real knee replacement done using OrthoPilot. My scottish brain training still thought “why do this?”.

I went back to Scotland and started practice at Hairmyres in September 1997. Dominique was incredibly supportive, helping build links that last to this day. I even had a French fellow come to work with me for six months, Arnaud Huboud-Peron and he brought those same high standards to my unit and helped change people’s minds. They saw a registrar level surgeon who had incredibly good surgical skills, was meticulous in his approach to the whole surgical process yielding better results. People realized it wasn’t just me but others who did the same. When the staff began to see the results, they became converts. Firstly, it was nursing staff and physiotherapists, then gradually my colleagues who realised that we could do better. I was fortunate in that my colleagues generally embraced that change, especially as some were about to retire. The management was also very supportive, appointing new consultants who had been my trainees and we started training registrars. Some techniques such as Scarf osteotomy that I learned in France we published at last in English medium journals. Until 2001 we were still in an old WWII emergency medical service hospital with Nissen huts. I kept in touch with Fred, Yves Tourné and Dominique and we built on these relationships, starting cooperation on orthopaedic research and development. My input often was that of the sceptical anglophone surgeon, as opposed to the enthusiast which in some ways was a good thing.

By 1998 the OrthoPilot was now being supported by Aesculap and I was involved in the discussion as to whether Aesculap should develop it further. I was now able to add a clinical voice saying, “this is a project that will bring value to orthopaedics”. It needed development with an industrial relationship. Aesculap was a much bigger company with a much bigger European portfolio and perhaps a slightly different way of thinking than ICP France the original partner, so the concept of navigation had to be “sold” to them. Within the company, some of the believers struggled to be heard. I know that especially Fred had a major struggle to convince people to invest in navigation research and development, though they fortunately did.

At Hairmyres we had an old operating theatre, which used to leak from the roof on a regular basis and was not big enough to accommodate any kind of navigation system. Navigation was developing rapidly as a practical entity, and was being used in a European multicentre study. We knew it could work, but we didn’t know how well it would work. We didn’t have any randomised prospective work showing that it was worth doing. We agreed in 2001, when we moved to a new build hospital, to bring in an OrthoPilot system to undertake some of the early prospective work.

You really started to use the OrthoPilot system in 2001, when you arrived in the new hospital?

Yes. As an orthopaedic scientific bigot, I was able to say categorically that we could do a perfect knee replacement in 45 minutes with manual instruments and I didn’t need navigation. My starting point was the technology could help surgeons who were below average and as an average orthopaedic surgeon I didn’t need it. I was naïve and stupid enough to believe that. As we had trainees this was a great research project for one of them. We planned a prospective 58 manual knees vs. 50 Search OrthoPilot navigated knees. We expected to show that you didn’t need navigation. I was clearly a very scientific, open-minded orthopaedic surgeon! By the time we had done the first 70-75 knees, with prospectively collected data, it became clear that the OrthoPilot navigated knees were significantly better. The people that recognised it first were the physiotherapists who saw that rising from chair to walking, stairs, and reciprocal stair gait were

all significantly better. Also notable was that patients were going home 2 or 3 days earlier at a time that our average length of stay was 10 days post TKA. The nurses also noted that patients weren't so confused after surgery without that period of postoperative delirium, which we thought was due to analgesic drugs.

At the same time, we were reorganizing rehabilitation and this proved to be a major confounder. We had been involved in the development of the Scottish Hip Fracture Audit and introduced protocol driven surgery and rehab to improve hip fracture care. Surgery was fast tracked, spinal anaesthesia became the norm and we rationalised post operative rehab and analgesia. It followed that we should be able to do the same for our arthroplasty patients so we did. We clearly hadn't planned our research as well as we could have done. With rapid rehab we mobilised both hip fracture and arthroplasty patients on the day of surgery. These confounding factors were concurrent with new young enthusiastic anaesthetic consultants and more physiotherapists appearing, meaning that our data of what was happening with navigation was not as crisp and clear cut as it could have been. Looking back on it, it was a huge mistake.

You mean changing the technique and changing the fast-track protocol?

We introduced too many changes at the same time, without realising the compound effects of these things. By the time we got to 100 patients, the newly appointed hospital ethics committee said, "looking at this data it is not ethical to continue not navigating as just the alignment data supports navigation, let alone the remaining data even though confounded". We had gone from 74-75% mechanical alignment within 3% varus/valgus to 97%. The data told us we had to adopt this better way of doing things. We started navigating all our post traumatic knee replacements and within the space of 2 years, everybody navigated their knee arthroplasties. We also started doing other things, with Fred's new navigation tool as we became very comfortable with it, we used it for the tibial cut on unis and for revision TKA.

When I went to Paris for one of the first OrthoPilot meetings, I presented some revision data and many colleagues thought I was completely off piste! We had thought everybody was doing the same, though not it wasn't in the operating technique and the instruments weren't suitable for navigating revisions. It simply made sense. We also navigated triplanar osteotomies, ACLs and some of my colleagues also used navigation for hip replacements. Navigation simply became part of the surgical armamentarium in the department from 2001.

So that was for navigation, but when did robotics arrive?

In 2012. Interested but not really bothered at first, is probably the best way of putting it. The difficult new ethics infrastructure in the UK meant it wasn't practical to do robotics research properly. Our ethics committee met every 3-6 months, so it could take two years to get approval, and this was along with a lack of a proper research infrastructure. Given this and the solid robotics studies from Cobb at Stanmore and the first Navio clinical case by Bellemans in July 2012 in Belgium, there was just no point in starting research. What we could do was use our track record in teaching navigation to develop teaching of robotic technology and assessing it clinically. We also had access to the laboratory experience at Strathclyde University Bioengineering department where both the Navio and Mako systems were being assessed, suggesting little difference in accuracy but more cost and complexity with the Mako platform.

One of the things we had done with the OrthoPilot system in 2001 was to develop teaching programs, and the first sawbone and cadaveric workshops to explain and teach the technology. It was relatively easy to build on this for teaching the use of robotics.

The other thing about robotics was it could then only do a uni and this along with cost meant the NHS couldn't really justify investing in it. However, BlueBelt recognized our teaching experience and our cooperation with the Golden Jubilee, (remember by this time Fred was now working at the Golden Jubilee) and provided us with a system to look at it's clinical application and development. Things as you know changed elsewhere and we found ourselves performing the first UK Navio implanted uni in October 2012. We now have the longest continuing experience with the system in the world. Our relationship with BlueBelt was symbiotic, there was no extra cost to us as long as we helped with teaching and provided clinical input. We could ask the questions that needed answered without the cost burden being asked of others. We prospectively gathered outcome audit data for all our unis and our surgeons routinely used the system.. It worked well and reduced our early revision rate.

That was for partial knee?

Yes. By 2013 Navio was routinely used for implanting unicompartmental knees in the department. One of our training registrars was the first trainee in the world to perform a Navio Uni, though he is now a limb reconstruction surgeon in Zimbabwe! The registrars understood and used the Navio system routinely, picking it up quickly. We developed a surgical training program for visitors that worked well and could be bidirectional. We would have surgeons come visit us, they'd have an afternoon with Sawbones then see two, maybe three live cases. If they wanted to go on and do this in their own theatre at home, it was open to them that I would go out and operate with them. This allowed a much quicker propagation of the technique that I think would have otherwise happened. We had learned this from teaching navigation years before and a major key factor was to understand Fred's early work about the ergonomics of navigated surgery, applying it to robotics making it quicker and easier, avoiding unnecessary steps or repetition and concurrent rather than sequential steps. It made learning smoother and surgery more logical and faster. Users such as yourself, Jess Lonner and others progressed this further: "how can the tibial prep be quicker?" "Are there better tools?" "Is a cylindrical burr better than a spherical one?" "Can undermining, then a rough saw cut and a burr finish be quicker?" Better techniques appeared as surgeons addressed the issues we all had. Some solutions were better than others. A cylindrical burr, which has a bigger cutting surface is much better than the spherical burr; and we now use that routinely. The undercutting technique that you developed; everybody now thinks "it's so obvious".

You are a pioneer in navigation as well as in robotics. Can you give us some of your thoughts about what are the benefits of robotics compared to navigation?

Whilst there have been some great innovating and scientific orthopaedic surgeons, by and large we are doers, we are hands-on people that are good with our hands and we become very adept at using our instruments and skills in theatre. We learn a technique, develop our skill and a handedness which gives us great confidence in what we do. Only now we are engaging with prospective external quality control through national registries for arthroplasty and hip fracture to name but two. Now an essential part of our professional lives it took a long time but we now know we aren't as good as we think. A good example is arthroplasty where we thought we were good but now see that patient reported outcomes don't match our assessment of our surgery. This

is especially true with knee replacement where our mechanical outcomes are not as good as they could be for many patients. If we plan for a zero mechanical axis, we struggle to achieve it with manual techniques. It also means that if we want to look at kinematic alignment, for example, we can't do that without a measure of where we start and the outcome at the end of the operation and knowing how accurately we placed our components in the six degrees of freedom that we have open to us. If we can't, then how can we know what is best for our patients? We need accurate measures to show us what the best objectives are to achieve both best PROMs and radiological outcomes.

Navigation gives us the tools to measure intraoperatively where we start and finish, and an ability to check that each step of the operation is done as planned, invaluable because we can see that we are doing what we want to be doing. Robotics has taken us one step further, but it has done it a way that perhaps we didn't appreciate: that of planning. Navigating we were doing cuts using an element of planning either in our heads or more in depth on screen. To enable robotics it is essential that a plan is created for execution by the robot. This has forced us to think about a more comprehensive implant positioning plan, but also allows us to visualise what happens dynamically throughout the range of motion in that planning model.

This shows that the balance of a knee prosthesis is not just about flexion and extension but through the whole arc of movement, involving rotation and this three-dimensional understanding shows that you can have a knee that is perfectly balanced in flexion and extension, but is too loose or too tight in the mid-flexion point. That planning and visualisation required by robotics planning before you cut anything I think is a game-changer. I suspect that is why unicompartmental knees can be much better if we get that balance right throughout its range of movement and intuitively, but we don't know yet, why it should also improve the positioning and the balancing of a total knee along with an understanding of how the retained ligaments affect the biomechanics of the prosthetic knee. We hadn't been able to measure this until now, when we can measure, plan, visualize and store it. The concept of storing this big data and then linking it to outcomes is this next exciting step. As we get PROMs outcome measures which are subjective but very valuable we can link these to objective peroperative data; alignment, balance, implant positioning with post operative gait analysis and use Artificial Intelligence algorithms to actually determine what is best for the patient. This ability to have so much data capture available and an analysis at relatively low cost is obviously a game changer. With so much data, it is difficult to understand what matters amongst the clutter and it is easy to make wrong judgements if we use blunter tools such as multiple regression analysis especially if we chose the wrong predictors. To do this analysis was in the past incredibly time consuming...not now with AI algorithms.

That's what is exciting with robotics. We know what we're doing and we have data. Probably the predictive models and all the things thanks to machine learning and artificial intelligence will bring us to the next step

Absolutely. We can't do this without the measurements afforded by navigation and robotics. One of the talks I used to give many years ago when arguing for the wholesale adoption of arthroplasty, hip fracture and other quality control registries, looked at third opinions in my complex knee practice. I used to see patients coming from high-volume respected surgeons, who were unhappy. Looking at those patients with Kelly Vince's structured protocol for revision surgery showed a majority had a technical error in their surgery that had been completely missed. These patients were never failures as they'd never been revised. This difficulty in looking at how well we do what we do is multifactorial. It takes time and money. It's easy to not have the time to look at unhappy

patients in a busy practice and even easier if we lack insight. Unhappy patients may seek help elsewhere so we don't know they've failed, we think they're all happy. Registries are expensive but many healthcare systems are starting to say "we can't afford to do this follow up any more", and are discharging their patients at 6 weeks only telling them come back if there's a problem, which we know doesn't work.

I think the future has to be of quality control. An eye-opener in the Covid era is how we have adopted remote working, can remote sense, measure and follow-up. Many of my patients that are remotely followed up are elsewhere such as Africa or far flung Scottish Islands. We can use phone-based accelerometers, using very simple technology that is within everybody's reach, to capture data that we said we couldn't previously afford. Follow-up data is now more accessible.

This big data will be vital to how we develop Orthopaedics and medicine in general in the future. New financial modelling tools will be able to justify and direct the best use of new costly technologies or interventions that are so attractive to us as surgeons.

What are your main interests and passions outside of work?

Now, my passion is for developing a sustainable model for Global Orthopaedic outreach. I am involved with taking appropriate orthopaedic care to less fortunate environments throughout the world. We spend a lot of money on HIV, malaria prevention but completely neglect what is happening in terms of unmet trauma care. Worldwide, the Lancet Commission and World Bank have shown how significant an issue trauma is worldwide. It would be ideal to avoid trauma, by implementing basic road and work safety projects throughout the world, but that comes at an economic cost which is difficult to implement. When the injury occurs, the financial economic impact of those injuries is catastrophic. A femoral fracture non-union for someone who is a subsistence farmer in rural Zambia, will cause his family to starve. But it's a problem that we can deal with at very low cost, with appropriate technology either traction or simple fixation. Seeing the success of for example John Jellis's work in Zambia, we want to replicate that elsewhere. I am honoured to be elected as chair of World Orthopaedic Concern UK from 2022. Working cooperatively with that organisation and other kindred organisations such as Médecins du Monde, Emergency, Australian Doctors for Africa it has become clear that those projects that have built capacity, and education, have been the most valuable and the most important. Success stories include the work done in Cambodia and Ethiopia where the orthopaedic profession is self sustaining with national training programmes in place. Work is ongoing from Guyana to Zimbabwe both in education and service provision. Education and elevating countries to self sustaining training programmes has to be our goal as an international orthopaedic community. When we get to the end of our professional lives we can make more money and collect possessions but we've been given the wonderful gift of a profession and we can and should give back. I was privileged to be given this opportunity by Willie Bisset, John Watson-Farrar and by others who followed, and I think we can do amazing things for the international orthopaedic community. It's just a matter of working out how we can do that. I still do first world orthopaedics, recently I did four robotic unis, and some complex knee reconstructions, high-tech, expensive but really effective surgery. At the same time, we're supporting providing simple technology to allow orthopaedic care to occur in rural Zambia. Both are equally life changing surgeries, one surgery costs \$120, and the other costs \$12000.

Many colleagues ask me “how can I get involved?” The first step is to join one of the various NGOs such as WOCUK, Emergency! or Australian Doctors for Africa and talk to previous volunteers and prepare by reading and refreshing your general skills. There are some courses that can help. Prepare to be adaptable and forgo some luxuries! I think it should be mandatory that first time visitors buddy up with an experienced hand to support their adapting to these new and difficult environments. We also need to do what is environmentally appropriate and viable. First world orthopaedic techniques are often not valid in Low and Middle Income Countries.

The rewards are however enormous, personal and otherwise.

I invite readers to look at getting involved!