Engineers from TU Delft and doctors from Leiden are joining forces to make loose-fitting artificial joints a thing of the past. They are at the forefront in terms of minimally invasive interventions, which make cutting open patients unnecessary. “Nobody else is doing this yet.”

Mr De Groot is sitting cheerfully on the bed that a nurse has wheeled into the radiology department of the Leiden University Medical Center (LUMC). His left elbow is bandaged up, but otherwise there is no sign he has just had an operation that will save him a lot of pain. But in fact he has just come back from an operating table in the CT scanner – a place usually only used to make x-ray images - of blood vessels, organs, or bones. De Groot, however, had an operation there and then on his six-year old artificial elbow, which became loose following a fall. The pain he had suffered since that time made it impossible for him to use his arm.

Mr De Groot is 81 years old and takes medication for heart problems. Orthopaedists at other hospitals generally tell people in poor health that they simply have to learn to live with the pain, because the likelihood of complications from an operation is too great. Over the past few years, however, the LUMC and TU Delft have together developed a technique that makes such a major operation, in which the artificial joint is replaced by a new one, unnecessary, and which is therefore helpful to people like Mr De Groot.

Just two hollow needles go into the bone of Mr De Groot’s elbow, which means it does not have to be completely cut open. As well as reducing the medical risks, it also saves a lot of time and money. The reasons are obvious: no operating theatre is needed, the patient is in and out of the hospital the same day, rather than spending several days there, and only a local anaesthetic is required. Another pleasing benefit is that an artificial joint that is otherwise sound does not have to be wrenched out of the bone (which sometimes has to be broken for the purpose) in order to be replaced by a new one. All in all, if all goes well, an operation of this kind costs 3,500 euros. An operation in which an artificial joint is replaced easily costs 50,000 euros – if there are no complications, that is.

Medical Delta

What is the secret? Injecting polymethylmethacrylate, which is a bit like two-part adhesive, although the doctors refer to it as cement. A small tube is attached to the first needle in the arm, through which the orthopaedist very slowly injects a few millimetres of the ‘adhesive’ into the bone. Moisture from the bone can escape through the second needle, thereby preventing the pressure from getting too high. The cement hardens after around fifteen minutes, leaving the artificial joint firmly in place.

This method has been developed by orthopaedist Rob Nelissen, in collaboration with mechanical engineer Edward Valstar, who was appointed Antoni van Leeuwenhoek professor at TU Delft in the autumn of 2012. Valstar started his career twenty years ago at Leiden University, when he was part of the start of the biomechanics and imaging group in the orthopaedics department. Twelve years ago this was followed by his appointment to the TU Delft faculty of Mechanical, Maritime, Materials Engineering (3mE), in the biomechanical engineering department. Since then he has devoted 50% of his working hours to Leiden and 50% to Delft, all in the framework of the Medical Delta. Valstar forms the link between the engineers in Delft and the physicians in Leiden. There are working partnerships with numerous Dutch and foreign research institutes, and funding is also received from the private sector and research financiers.

In 2007, Valstar obtained a Vidi grant of up to eight hundred thousand euros for his research into the early treatment of loosened artificial joints involving minimally invasive surgery.
Prevention, detection, reparation

A total of thirty people have been treated with a cement injection of the kind given to Mr De Groot, none of whom were considered able to have a major operation. The intention is for every patient to be treated this way in a few years’ time.

Before that stage, however, a technique conceived by mechanical engineer Edward Valstar for removing fibrous tissue using water jet cutting needs to be developed fully. A PhD student at 3mE is going to investigate the optimum water pressure required to cut tissue. If the fibrous tissue can be removed first, the cement injections can be carried out more effectively. Valstar is optimistic about the chances of the treatment method. “This is going to be the new standard.” It is Valstar’s ambition to ensure that artificial joints last a lifetime. Operations, even the minimally invasive kind that the LUMC has just started, should eventually become unnecessary. The steps that Valstar and his colleagues are taking in that direction can be divided into three categories: prevention, detection, and restoration.

On his computer, Valstar speeds through a nearly one-hundred page presentation, which he uses in his lessons. It reveals all kinds of secondary projects, such as a clinical study into the effect of a thin layer of hydroxyapatite, a type of calcium, on the artificial joint. “This makes it possible for the joint to be more securely embedded in the bone.”

Before the operation, Valstar explains that if something goes wrong with artificial joints, it is usually because they work themselves loose in the bone. Every year, 2.5 million artificial knees and hips are fitted all over the world (elbow joints are replaced much less frequently, but they are comparable to the other two). That number will have trebled by 2030 because people are living longer, because of the rise in obesity, which causes joints to wear out more quickly, and because artificial joints are becoming available for people in developing countries.

Something goes wrong with ten per cent of all artificial joints, requiring them to be replaced within ten years. Sometimes this is due to a fracture (seven per cent), as in

Developing countries

Today, Mr De Groot is reaping the rewards from that research. He has to remain completely immobile during the treatment. He is lying on his left side, his left arm bent in front of him, tied down to the treatment table. Orthopaedist Rob Nelinssen and interventional radiologist Arjan van Erkel cover De Groot’s upper body as much as possible after taking a CT scan. Based on the images of the inside of De Groot’s elbow, they first determine very accurately where the needles need to be inserted into the bone. The space around the artificial joint can be clearly seen on the x-ray photographs: this is where the cement will be inserted later.

Valstar is also working on improving and developing surgical instruments that can be adjusted in such a way as to make them ‘patient-specific’. This would make the process of fitting artificial joints more accurate, which is also the aim of using computer assistance. A bloody photograph of a hip operation instantly makes clear how difficult it is for orthopaedic surgeons to see how accurately hip joints are fitted. “At present, a lot of it is down to intuition,” says Valstar. Another factor is that you are dealing with more than just the bone of the joint. Knees also have tendons and muscles, and joints must be able to move as effectively as possible. Further research should make it possible to take all these factors into consideration at the time a new artificial joint is being fitted.

As well as researching preventive aspects, Valstar is also deeply committed to early detection. “It has been shown that if an artificial joint moves slightly during the first year, it is a good indicator that it will fail in the future owing to detachment. We are currently developing RSA, stereo-x-ray technology, which we can use to identify movement and wear-and-tear very accurately.” It works as follows: the patient lies on the x-ray table while two x-ray machines take photographs of the joint, where small particles of tantalum have been added to the bone. Comparing stereo photographs from just after the point when the joints were fitted makes it possible to see the slightest possible divergence. These slight shifts in position can be stabilised with a cement injection of the kind given to Mr De Groot. The method is very new and not yet fully developed. But Valstar is already thinking beyond that stage. He also has a great deal of confidence in a biological approach, as he calls it. He explains within the bone there is a balance between osteoclasts, cells that dissolve bone, and osteoblasts, which produce bone. “If I can put osteoblasts in the fibrous tissue and add certain biological substances to that, it will be possible to convert the quicksand into bone. And just suppose I add a thin layer of this mix to the outside of the artificial joint before it is used, and that I can release these substances by heating up the artificial joint by putting the patient in the MRI – you could regard it as a large microwave oven. The fibrous tissue will then be converted into bone without it being necessary even to inject the patient, never mind cut him open. There is a long way to go, but it is something we are actively exploring in the biomaterials research group in Delft.”

‘This is going to be the new standard’

‘The technique developed by the LUMC and TU Delft eliminates the need for major operations in which artificial joints have to be replaced’
the case of De Groot. Infections are a slightly more common cause (eight per cent), but the main reason to replace artificial joints (72 per cent) is because they work themselves loose after a period of time. Possible reasons for this are that there is too much pressure on them because they have not been positioned right or because the design is not right, or simply because of wear and tear.

Valstar explains what happens when an artificial joint works itself loose. "A fibrous tissue forms around the joint, like a kind of quicksand. The tissue ensures that the joint is no longer securely positioned in the bone, which leads to complaints for the patient. On top of that, the fibrous tissue affects the still-healthy bone, and can even cause holes. Until recently, the only option was to remove both the fibrous tissue and the artificial joint, and to replace it with a new, larger one. You often have to break the bone to get the required access, and then reset the bone so it can heal. In response, the body may start to manufacture new bone in the muscles at the location in question, which can lead to deformities and more pain. In other words, the operation is not without side-effects for the patient – even though the artificial joint itself may well have been perfectly in order."

Strange aroma
Mr De Groot's artificial joint, too, is still perfectly in order. Six years ago, he was given one in each elbow. The right elbow is still working as it should, while the left one probably would be if Mr De Groot had not had his fall.

Orthopaedist Nelissen first anaesthetises the elbow. He then starts to rotate the first needle, which has a razor sharp point, into the bone. He and interventional radiologist Van Erkel keep a constant and close eye on the images from the CT scan to see whether the needle is entering the bone at the correct angle. After some searching, the needle ends up precisely in the fibrous tissue between the bone and the artificial joint. Once the second needle is also in place, the doctors open the packaging of the ‘two-part adhesive’, and mix the powder with the liquid for a few minutes in a special machine. A strange aroma fills the air. Nelissen looks at the mixture and is satisfied. "It is nice and thin, so we can start." He uses a tube to connect the reservoir of cement with the first needle in Mr De Groot's elbow, and very slowly inserts some cement. The images on the CT scan show the polymethylmethacrylate entering the bone. Meanwhile, some moisture is escaping from the second needle. De Groot is now very calm as he lies on the treatment table. Only once does the pressure in his bone cause him so much pain that Nelissen has to stop briefly. Less than five millilitres are inserted into his body, and that is enough. After fourteen minutes, when the cement has hardened, the needles can be removed from the elbow. The doctors are satisfied. Mr De Groot is bandaged up, and is able to return home the same day. <<

The name of the patient has been altered for reasons of privacy. His real name is known to the author.