No leg to stand on
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SUMMARY AND CONCLUSIONS

6.1 SUMMARY

In chapter 1 the aim of the research is mentioned, trying to find an answer on the question: *Have the developments in amputation surgery and the developments in prostheseology influenced one another?* In this chapter the histories of both amputation surgery and prostheseology are discussed and the answer on the question is given through some conclusions.

In Ancient Times developments in amputation surgery take place. Amputations are at first done in the already dead tissue, through a joint and only with a knife. Later the severance is done on the border of healthy and diseased tissue or even in healthy tissue, through the shank and with knife and saw. Haemostasis is initially done by cauterization, later the surgeons of Ancient Times use ligatures, compression, torsion, vinegar bandages and caustics. Cauterization with a hot iron is then only used as last resort. With the decline of the Roman Empire amputation surgery deteriorates with it. Guillotine amputations are done on the border of healthy and diseased tissue again and only cauterization is used for haemostasis. This technique is written down by Paul of Aegina, an encyclopedist living in Alexandria, and taken over by the Arab surgeons, after they have conquered Alexandria. During the Middle Ages, due to a complete absence of scientific medicine and under the influence of Arabic medicine, developments in amputation surgery hardly occur in Western-Europe. Amputations are not performed by Salernian or university-trained doctores medicinae. These doctores are theoretics, they listen to complaints, perform uroscopy, prescribe medicine and herbs and give advise about practical treatment including amputations. The actual amputations, performed for gangrene, warwounds, leprosy and ergotism, are done by barbers, surgeons and quacks. They mostly have a certain amount of practical experience, but hardly any scientific education and are undoubtedly not familiar with the writings on Ancient surgery, of men like Hippocrates, Celsus, Archigenes, Heliodorus etc. Only a few university-trained physicians, having found out that their education is useless on the battlefield, take the trouble to become physicians-surgeons. However, even these men remain true to the amputation technique described by Abul Quasim, an Arabic surgeon living in Cordoba around 1100 AD, who imitated the inferior technique of Paul of Aegina, except for some details. At the end of the Middle Ages a rise of amputations
follows the invention of the firearms, but initially no development in amputation technique occurs. The severances are, at the end of the Middle Ages, done again in the already dead tissue and haemostasis is done again only by cauterization.

Medical and surgical books from Ancient Times and the Middle Ages do not mention the word prosthesis, but prostheses are mentioned in non-medical books and shown on pottery and pictures. According to these, amputees during Ancient Times and the Middle Ages use either crutches or a simple type of prosthesis, the peg leg. In the Middle Ages a special type of peg leg, the so-called kneewalker peg leg, is used. These peg legs are made of wood and sometimes reinforced with metal sheets. Archeologists even found a peg leg made of wood and reinforced by bronze sheets in a grave near Capua, probably used around 300 BC. The only development in prosthesiology in this period is the refining of the peg leg to the kneewalker peg leg. There is no known design of a leg prosthesis in that period. It is not sure who makes these peg legs. In the Talmud is mentioned that in one occasion a non-trained craftsman made a prosthesis from a log of wood, but in the literature there is no further reference to a limb maker.

After the Middle Ages the scene changes. The invention of firearms gives a rise in amputations, because wounds made by bullets and shells are more severe than wounds made by swords and arrows. Besides in the sixteenth to the nineteenth century there is a succession of wars, fought out with huger and huger armies and with battles, which become more bloody every time. That raises the number of casualties and with it the number of amputations. Up to the First World War the biggest part of the amputations is done by army surgeons. Only a minority of the amputations is performed on civilians. So army surgeons become masters in amputation and for a civilian surgeon an amputation is a rarity, which he infrequently does. Therefore, this period of the history of amputation surgery can be called the era of the army surgeons.

Army surgeons in those days are mostly not the best in surgery. They enter the army for lack of money or education or both. They learn their trade on the job, by trial and error, without any tutor to give them advice or look over their shoulder. As they go along, they get a certain knowledge of first aid and traumatic surgery including amputations. Once they have learned their trade they want to go out of the army and start a civilian practice, which is more profitable and socially more accepted. There is probably always a shortage of these men for Ambroise Paré, who has not enough money to take the examination for master surgeon, can become an army surgeon just like that. Richelieu tries to keep the army surgeons posted by increasing their salary and making them members of the Collège de St. Côme, the famous French surgeons' corporation, in an exclamation of kind. Their attempt was not all of their lack of knowledge, problems are known as Feldscherer (barber) for further education. Frederic the Great, Prussian ones. The Revolution and the French army as a surgeon, cannot be there where his surgeon is so is high that no responsibility beyond stations into slaughter of the finest surgeons themselves, like, among out of it and have further education. As an army surgeon five years of thoroughness only for his lack of perform in servile surgeons and experience amputation surgery, it is the first surgeon that time a below diseased part of the shin, the ankle stump, the ankle joint backwards. The border of sound the site of electric fingers will fit proper ligatures for him most likely the finger he designs a "bois pour les pas prosthesis. This leg prosthesis
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corporation, in an attempt to raise their standard of surgical knowledge. The
exclamation of king Louis XIV, "For my soldiers the amputation knife of my
surgeons is far more dangerous then the enemy's fire", proves that Richelieu's
attempt was not always a successful one. This shortage of army surgeons and
their lack of knowledge are not restricted to the French army. The same
problems are known in the Prussian Army, where most surgeons are just
Feldschere (barbers). In 1716 five promising surgeons have to be sent to Paris
for further education and on the eve of the Second Silesian War (1744),
Frederic the Great has to bring in twelve French army surgeons for lack of
Prussian ones. The shortage of army surgeons remains during the French
Revolution and the Napoleonic wars. Larrey, who comes to Paris to be trained
as a surgeon, cannot find a paid job in a civil hospital, but he can join the navy,
where his surgeon's work is paid for. During the Napoleonic wars the shortage
is so high that nineteen-years-old conscripted surgeons are saddled with a
responsibility beyond their ability. Small wonder they transform their dressing
stations into slaughterhouses. Of course there is wheat among the chaff. Some
of the finest surgeons have started their career as an army surgeon and some of
them, like, among others, Paré, Larrey, Percy and Guthrie even make a career
out of it and have found a place in the history of amputation surgery.

As an army surgeon Paré can be counted among the better ones, for he has had
five years of thorough training on the job in the Hôtel Dieu in Paris, and it is
only for his lack of money that he joins the army. Besides he is not a man to
perform in servile imitation of his tutors, but he acts upon his own observati-
ons and experiences. If necessary he does not shy from experiments. In
amputation surgery Paré reintroduces amputation in healthy tissue and he is
the first surgeon to choose a site of election for a below-knee severance. Up to
that time a below-knee severance is done on the border of the sound and the
diseased part of the shank, or even in the diseased part. Therefore the length of
the shank stump can vary from very short below the knee joint to just above
the ankle joint. The use of a kneewalker peg leg makes the stump protrude
backwards. The longer the stump, the more obvious the result. Paré chooses
the site of election five fingers below the knee joint, with no regard to the
border of sound and diseased tissue, because a stump with a length of five
fingers will fit properly into a kneewalker peg leg. He reintroduces also the use
of ligatures for haemostasis, in favour of the more painful cauterization, and is,
most likely the first surgeon to do a successful above-knee severance. Moreo-
ver he designs a new type of kneewalker peg leg (which he calls "Un jambe de
bois pour les pauvres") and the first known leg prosthesis, an above-knee
prosthesis. This iron prosthesis, weighing about seven kilograms, resembles
the leg of an armour, has a knee joint with a locking device and an ankle joint.
This leg prosthesis is manufactured by an armourer in Paris, who, for his
stature and his origin, is only known by his nickname "Le petit Lorrain". Besides, Paré's name for his kneewalker peg leg design is significant. It shows that only rich people in his days can afford to buy a leg prosthesis. There are not many rich in Paré's days and even less who need a prosthesis, therefore leg prosthetic designs are scarce. Unfortunately Paré is not able to hand on all his knowledge to his contemporaries, pupils and successors, although he is well known and writes several books on surgery. After his death it still takes several decades before hot irons and other cauterization materials finally disappear from the scene, in favour of the ligatures. His site of election is not used commonly, though most surgeons operate in healthy tissue, and it takes more than a century before another surgeon designs a prosthesis.

Up to the end of the seventeenth century the guillotine amputation is the technique of choice, but from then on, owing to the use of a tourniquet and ligatures, new amputation techniques are introduced. These are the dorsal flap technique of Verduyn, the two and the three-cut technique and the double side flap technique of Ravaton. In 1696 Verduyn describes his technique in his book "Dissertatio epistolari de nova artuum decurtandorum ratione". In this new technique for a below-knee severance, a musculo-cutaneous flap of the dorsal part of the leg is created and raised anteriorly to cover the sectioned bones and close the wound. The stump, which Verduyn creates, makes the use of a kneewalker peg leg less suited, because the stump has too much length. Therefore Verduyn designs (and describes in the same book) a new type of below-knee leg prosthesis with a thigh corset, metal sidebars with hinges, a copper socket and a wooden foot. Here amputation surgery influences prosthesology. The same applies to the below-knee amputation technique of Ravaton. He makes a transverse circumferential incision, close to the ankle, up to the bones and then two perpendicular incisions one in the front and one at the back. The bones are sawn through at the top of the perpendicular incisions, leaving two side flaps to cover the wound. This stump is too long for a kneewalker peg leg too. In 1755 Ravaton therefore designs a boot like below-knee leg prosthesis with a leaf spring to imitate the ankle motion. This prosthesis is actually used by the dragon Fray. These designs are, with Paré's leg prosthesis, up to the time of the French Revolution, the only known examples of a prosthetic design made especially after a new amputation technique was described. The description of the other new techniques, the two and the three cut, is not followed by a special new prosthetic design.

Beside the improvement in amputation techniques the problem of the proper time to do a severance in case of a shot wound occupies the surgeons minds. There are three possibilities. Primary amputation, within twenty-four hours after receiving the wound. Intermediate amputation, after a couple of days, when the soldier has recovered from the shock. Secondary amputation, after some time, when the wound is infected.
some weeks when the local inflammation begins to heal. In 1757 the Royal
Academy of Surgery in Paris offers a prize for the best solution of the question
"Should, after a shot wound, be amputated immediately or the amputation be
postponed?" A French army surgeon, Jean Faure, wins the prize. He shows,
by the results of the amputations after the battle of Fountenoy, that secondary
amputation gives the most survivors. This is, incidentally, the first time in the
history of surgery that some sort of statistic is used to prove the value of a
treatment. Unfortunately Faure makes a mistake. He just counts the number of
successfully secondary amputations versus the number of successfully primary
amputations, but does not count the number of casualties that die of the
inflammation of the wound before the secondary amputation can take place.
Taking these in account too, the "outcome" of his statistic shows another
picture. Although he has some opponents, Faure's idea is mostly accepted and
for some decades secondary amputation becomes the treatment of choice.

Amputees in this period commonly use peg legs, because they are easy to
make, mostly weight less than a leg prosthesis and are much cheaper. Only
wealthy people can afford a leg prosthesis and there are not that many wealthy
and even less who need a prosthesis. There are designs of leg prostheses
known in this period though. They are made by limb makers, except the
above-knee leg prosthesis, totally made of wood, designed by the French
surgeon Pierre Dionis in 1707. Dionis' design was not made to meet the
demands of a new amputation technique, but an attempt to make an above-
knee prosthesis, which was not so heavy as Paré's design. The designs made
by limb makers have no connection with a new amputation technique either.
There are only a few designs known and most of them are unique pieces,
probably made for a rich customer. Nevertheless, one of the important devices
in prostheseology, the ischial seat, is designed in this period by the English
limb maker Gavin Wilson. It is possible that this ischial seat, meant to shift
body weight to the prosthesis, is designed under influence of the developments
in amputation surgery. The amputation stumps that surgeons produce in that
period are not end-bearing, so the limb maker has to find an anatomical
convenient spot to shift body weight.

During the time of the French Revolution and the first half of the nineteenth
century, amputation surgery reaches its pre-narcotic zenith. Army surgeons
obtain a tremendous experience in amputation, owing to the enormous number
of casualties they have to take care of. Their amputation speed is unsurpassed,
a thigh or a leg severance is mostly done in about three minutes. Owing to this
experience, sound indications for an amputation and right sites of election can
be set up by some leading army surgeons, notably by Dominique Jean Larrey
and George James Guthrie. They also prove that a primary amputation on the
battlefield gives better results, than a secondary amputation, performed after some weeks. Both prefer the three-cut technique, except in disarticulations and very high thigh severances, because a flap technique is used in those severances. They improve the amputation results, especially by better hygienic measures. Both are successful in amputating through the hip on the battlefield, Larrey is the first in 1803, Guthrie does his first successful hip disarticulation in 1815 on the fields of Mont St. Jean. Moreover both succeed in convincing their army commanders that first aid on the battlefield saves the lives of many soldiers. Larrey is the forerunner in this aspect too. Up to his days it is accustomed to leaving the casualties on the battlefield during the battle, without any aid, and collect them after the battle is over. Due to the bad deployment of the available conveyances it mostly takes more than twenty-four hours before the casualties are brought to the dressing stations. For most of them that is too late. In 1793 Larrey designs his Ambulance volante, a light, well-sprung carriage, for the removal of the casualties. With this carriage the casualties are collected, during the battle, at flying speed and if necessary live saving aid is given. The casualties are then brought to a dressing station, situated on the edge of the battlefield and further taken care of in order of their surgical need, regardless of rank or even nationality. Larrey tries to spread his ideas and techniques among the other surgeons in the French army. Initially he can do so while acting as a teacher at the new training school for army surgeons at Val-de-Grâce. Later, due to the enormous number of surgeons necessary for the French armies and the loss of the experienced surgeons, inexperienced conscripted surgeons are sent on the job right away. Occasionally they make a mess out of it and transform their dressing stations into slaughterhouses. Therefore the few experienced ones have to do most of the major operations and Larrey himself has to do 200 amputations in twenty-four hours during and after the battle of Borodino.

During this period the first partial foot amputations are described, namely the talo-tarsal amputation by Chopart and the tarso-metatarsal amputation by Hey and Lisfranc. The advantages of these type of amputations is that a patient can walk without a prosthesis, the disadvantage that the remainder of the foot does not rest in its normal position, but deforms into a rather painful stump. During the first half of the nineteenth century frequently amputations are done in civilian hospitals, but the death rate after these severances is rather high and that brings some surgeons to think about a cause and a proper solution. James Syme, chief surgeon of the Royal Infirmary of Edinburgh, has the idea that opening and thus inflaming the marrowhole of the long bones might have something to do with it and therefore recommends amputation through the spongy parts of the bone. According to this principle he describes in 1843 the disarticulation through the talo-crural joint. In this operation the shin and the splint of the lower leg is removed on intact on intact, the lower leg prosthe-

Leg prostheses are sold in the first half of the nineteenth century. Due to a high cost of the leg prostheses, the death rate after these severances is rather high. It is hard to get a leg prosthesis for sale in the first half of the nineteenth century. Due to the bad deployment of the available conveyances it mostly takes more than twenty-four hours before the casualties are brought to the dressing stations. For most of them that is too late. In 1793 Larrey designs his Ambulance volante, a light, well-sprung carriage, for the removal of the casualties. With this carriage the casualties are collected, during the battle, at flying speed and if necessary live saving aid is given. The casualties are then brought to a dressing station, situated on the edge of the battlefield and further taken care of in order of their surgical need, regardless of rank or even nationality. Larrey tries to spread his ideas and techniques among the other surgeons in the French army. Initially he can do so while acting as a teacher at the new training school for army surgeons at Val-de-Grâce. Later, due to the enormous number of surgeons necessary for the French armies and the loss of the experienced surgeons, inexperienced conscripted surgeons are sent on the job right away. Occasionally they make a mess out of it and transform their dressing stations into slaughterhouses. Therefore the few experienced ones have to do most of the major operations and Larrey himself has to do 200 amputations in twenty-four hours during and after the battle of Borodino.

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Amputation, performed after a battle, is used in those severance cases where better hygienic measures on the battlefield, such as hip disarticulation, have proven unsuccessful. In those severance cases where it is too late to save the lives of many who come to his days, it is accustomed to the battle, without any bad deployment of the four hours before the battle, that he can do so while casualties are collected, saving aid is given. The reports on the edge of the surgical need, regardless of ideas and techniques, he can do so while surgeons at Val-de-Grace necessary for the patients, inexperienced occasionally they make a cut into slaughterhouses. Of the major operations four hours during and described, namely the amputation by Hey des is that a patient can heaider of the foot does not painful stump. During amputations are done in cases is rather high and proper solution. James Potts, has the idea that bones might have amputation through the shin and the splintbone are horizontally sawn through as low as possible. The anklebone is removed and the heelbone too, but subperiostally, leaving the heelcushion intact. This cushion is then brought forward to form the end-bearing undersurface of the stump.

Leg prostheses are still quiet scarce in this period, most likely because the death rate of a major operation like an amputation is high and to the fact that a leg prosthesis is quite expensive. The above-knee leg prosthesis, designed by the limb maker Peter Baliff of Berlin in 1816, costs ninety Taler and in 1839 an above-knee leg prosthesis, produced by the limb maker William Selpho, is for sale in the USA for 150 US$. This amount of money is more than an unskilled labourer or a common soldier earns in those years, the more so while it is harder to earn a living after losing a leg. There is more proof about the high cost of a leg prosthesis, for Dr Von Rühl, a physician from St. Petersburg designs a below-knee leg prosthesis for his son in 1812. This son has lost his leg during the battle of Borodino. Dr Von Rühl designs this new prosthesis because he finds the existing prostheses, among other things, too expensive. In 1826 Dornblith, the court physician of Mecklenburg, designs new prostheses for the musketeer Drefal, who lost both legs during the fighting around Lille in 1814. In 1830 these prosthetic designs are praised during a meeting of naturalists in Hamburg, among other things because of their low costprice. Nevertheless, developments in prostheseology take place. For the below-knee amputee the kneewalker peg leg is still the prosthesis of choice, but for the above-knee amputee new designs for peg legs are made and leg prostheses are designed for both below and above-knee severed. Up to 1816 the above-knee leg prosthesis has a knee joint, which is locked during walking, giving the user a distinct walking pattern. In that year above-knee leg prostheses are designed with a knee joint, which is movable during walking, giving a more natural walking pattern. This novelty is designed by Peter Baliff and by the limb maker James Potts of Chelsea. Baliff designs an ingenious device that locks the knee joint with heel-strike and unlocks it with toe-off, giving the leg enough stability during the stance phase and the possibility to flex during swingphase. Potts’ design has no lock, so the knee joint is not as stable as Baliff’s, but gets its stability during stancephase from some elastic straps and possibly from the natural friction between the wooden parts the knee joint is made of. Potts’ above-knee prosthesis becomes quiet famously, because a client he makes this prosthesis for, is Henry Bayly, Marquess of Anglesey. At the end of the battle of Mont St. Jean, Anglesey is struck by a grape shot, which Shatters his right knee joint to pieces. He is amputated the same evening. Back in London he obtains a prosthesis from Potts. He is so satisfied with it that he gives Potts permission to use his name in advertising. Therefore the prosthesis becomes known as the Potts-Anglesey prosthesis or simply as the Anglesey prosthesis.
The history of amputation surgery takes a drastic turning during the second part of the nineteenth century. Owing to the introduction of anaesthetics, amputation technique can change from swiftness to thoroughness. Surgeons have ample time to perform more elaborate operations and can try out new techniques, now their patient is temporarily unconscious and feels no pain. The introduction of antiseptic measures lowers the mortality rate, so even more patients survive and need prosthetic supply. Amputation techniques become more designed to meet the demands of prosthesology. This change in attitude of the surgeons is not caused by a sudden interest in their patients, but the result of a turning in the history of prosthesology, which is as drastic and takes place in the same period. Up to 1860 the amputee is accustomed to pay for his own prosthesis. Most amputees cannot produce the costprice of a leg prosthesis and have to be content with a peg leg. With the start of the American Civil War (1861 - 1865) this changes for the better. In both the "North" and the "South" committees are founded, which devote themselves to raising money for the financing of leg prostheses for the soldiers, who have lost a leg serving their country. As soon as the hostilities suspend, the American government makes an official regulation about this item and about 28,000 soldiers get a leg prosthesis paid for by the government. In the same time the Prussian government sets rules about financing leg prostheses for amputated soldiers and some years later Her Majesties government does the same for the British amputated military men. Considering the fact that most amputations still take place in wartime, this means that the bulk of the amputees can afford to "buy" and use a leg prosthesis. The fitting of a leg prosthesis requires more of a stump than the fitting of a peg leg and so the surgeon has to meet these demands.

Having the time to do more elaborate operations gives the surgeons the opportunity to find solutions for some of these demands. One of them is the transfer of bodyweight to the prosthesis. The easiest way to do this is by creating an end-bearing stump. If the amputee can put his total bodyweight on the end of his stump and lean on it, the substitute of the lost part of the leg can be a simple peg leg, attached under the end of the stump. If the amputee cannot put his total bodyweight on the end of the stump, or even any weight at all, anatomical convenient spots must be found to transfer bodyweight. This makes the prosthetic appliance more complicated. It is found out that bones with an intact periostal or cartilagenous lower surface can bear weight, but sawn through bones, of which the lower surface consists of a marrow hole, surrounded by a bony ring, cannot. Therefore operation techniques are devised to make the weight bearing surface of the bone consist of either periost or cartilage. So, for example, Pirogoff, a Russian surgeon, uses the intact dorsal surface of the heelbone as weight-bearing surface for his amputation technique.
during the second introduction of anaesthetics roughness. Surgeons and can try out new techniques become more accustomed to pay the costprice of a leg and feels no pain. A higher rate, so ever more amputations become popular. This change in attitude by their patients, but the risk is as drastic and requires more of a costprice as the surgeons the one of them is the way to do this is by total bodyweight on the stump. The amputee cannot carry any weight at all, except the weight of the stump. This makes it impossible that bones with an weight, but sawn through the ankle, which he describes in 1854. In 1857 the Italian surgeon Gritti describes an above-knee severance in which he uses the knee cap as weight-bearing bone. Both the Russian surgeons Sabanejeff and Abrashanoff describe a modification on the Gritti technique, in which they use either the anterior or the posterior surface of the upper part of the shinbone as weight-bearing surface. Even at places where normally no osteoplasty is possible, like in the middle of the shank, surgeons try to make an end-bearing stump by closing the opened marrow hole somehow. The French surgeons Laborie and Duvalle use the Achilles tendon for this purpose in 1869. In 1882 the German surgeon Levy creates a bony bridge between shin and splintbone as weight-bearing end of the stump. Another German surgeon, August Bier, uses the dorsal surface of the shinbone as weight-bearing end in his so-called "window" technique, described in 1892. He makes an oval hole in the soft tissue of a long shank stump (the window), removes a conical piece of the two bones and turns the lower part of the two bones ninety degrees to the front, thus creating something like a small foot. The skin of the back of the shank becomes the "sole" of this small foot and the dorsal, periostal, surface of the bones makes the amputation end-bearing. In the first half of the twentieth century osteoplasty is still used in Germany, even for midthigh severances. M. Kirschner closes the marrow hole with pieces of bone and Loeffler does the same in the thirties. Other surgeons, like Blencke and zur Verth do not believe in end-bearing midthigh stumps, though they believe in the end-bearing capacity of the Gritti operation and even try to find a solution for the greatest problem of this technique. This problem is the slipping away of the kneecap from under the thighbone. To avoid this zur Verth scoops the kneecap and shoves it, as a lid, on the thighbone end. For the same problem Oehlecker, another German surgeon, remodels the kneecap into a press stud and pushes it into the marrow hole.

The form of the midthigh stump changes in this period due to prosthetic influences. According to Larrey and Guthrie a midthigh severance is done with the three-cut technique, which produces a rather cylindrical stump. The limb makers prefer a more conical stump, which will slide more easily into a plug-fit socket. Therefore the muscles in the three-cut technique are cut away or allowed to retract as much as possible. In 1913 the American surgeon Jackson uses another technique. He sutures the opponent thigh muscles over the bone end, so that part of the muscle strength remains and the stump can act as a good lever for the prosthesis. Although the imbedded bone stump is less vulnerable, it takes more time before the stump is ready for prosthetic supply and the shape of the stump is rather cylindrical. This technique becomes afterwards known as the myoplastic technique. Of course there are opponents to this technique, who, influenced by the prosthetists, remain true to the old
The limitations of prostheseology are responsible for two other developments in amputation surgery, the cineplasty and the turnover operations. Cineplasty is created by Vanghetti and Ceci, two Italian surgeons. It is a plastic operation on the thigh stump, performed to use the contraction power of the remaining muscles, to control a movable part of the prosthesis. Muscle tunnels are made in the stump. Through these tunnels a metal axis is placed and a tow-line is connected with the axis. Muscle contraction moves the axis and the tow-line with it and by connecting the tow-line to the knee or ankle joint the movement of this joint can be controlled. Rotation operations are designed in cases where a hip disarticulation is due for a tumour or trauma high on the thigh, although shank and foot are uninvolved. Walking with a hip disarticulation prosthesis is less unobtrusive and costs more energy than walking with an above-knee prosthesis. Therefore special techniques are designed, in which the shank bones are used as a substitute for the thighbone. The use of the remaining muscle power in an above-knee stump is furthermore preserved in the tendoplastic amputation technique, which is quiet popular in the thirties of the twentieth century, but it takes till well after the Second World War before the importance of the muscles in an above-knee stump is fully understood and used in techniques like myoplasty and myodesis.

During the first half of the twentieth century the amputation level is determined with the so-called amputation schemes. These schemes are set up, in Germany by zur Verth, Kreuz, Lange and Watermann, in England by Aldredge and in the USA by Thomas & Haddan. In this schemes the leg bones are divided in parts, which are classified as valuable, less valuable, unimportant and annoying. By using these schemes, according to their makers, the surgeon can always choose the right level to amputate, being sure that the stump will have the proper length for a prosthesis. By strict obedience of these schemes more trans-femoral than trans-tibial amputations are performed because the trans-femoral stump shows a better healing tendency. Therefore, many knee joints will unfortunately have been sacrificed without necessity. The knee disarticulation is almost totally neglected, for the knee and its surroundings are in the schemes classified as unimportant or annoying. This is probably because it is not easy to fit the knee disarticulation stump, though end-bearing, in those days with a proper prosthesis, for lack of a good prosthetic knee joint. The schemes remain in vogue till in the Second World War.

After the Second World War the indication for an amputation changes drastically, from accident and infection towards vascular diseases. Initially this brings no change in the amputation level, for still more trans-femoral than trans-tibial severances are performed, due to the fact that the trans-tibial technique was more profitably be done when the disarticulation takes place between two important bones, whereas the trans-tibial amputation technique initially heals nicely and is not a danger to the muscle mass. As the prosthetic knee joint is not a perfect factory product yet, it is not always possible to fit this stump at an amputated knee joint and a rather multiple knee disarticulation stump will be seen. Also, when sitting, the leg bones are together and a disarticulation stump will not lock and remain in a position. The knee disarticulation shows a very good healing tendency as it is a sort of a pivot of the knee, but requires a longer stump length being supplied with a vascular system.

The drawback of the multiple amputations is that the factory prosthetic knee joint is not always the right one for the stump, for the prosthesis is always a little too small or too big, so it means that the prosthetist has to fit the prosthesis multiple times to get a proper fit. In any case, things tend to get better and the use of the prosthesis is more known among the amputees and more patients receive a proper prosthesis which can be used by the patient in his everyday life.
World War the developments continued. Cineplasty is a plastic operation on the remaining tunnels are made and a tow-line is pulled in the movement in cases where the thigh, although an above-knee prosthesis is useful in the tend- rers, the surgeon of the remaining ars are set up, in unimportant s, the surgeon it the stump will if these schemes f the knee joint shifts to the back of the thigh, making the difference in length between the two thighs more acceptable. With this better prosthetic supply the knee disarticulation becomes more popular among the surgeons.

The drastic turning that the history of prosthesology takes in the second half of the nineteenth century, means a change for the limb maker. His shop or factory is flourishing. Instead of a few wealthy customers he has to provide prostheses for many military amputees and mostly against a fixed price. That means that every prosthetic design can no longer be a unique piece but is multiple produced. On the other hand it means that limb making becomes a profitable business and with it competition sets in. The limb maker can do two things to fight his competition, one is to protect his products by patents, the other to simply deliver better products. The last thing is possible by gaining more knowledge about the way a prosthesis functions and about the materials.
he is using. So limb making becomes a real profession and the limb maker is no longer the local carpenter or blacksmith, but a trained craftsman. Gradually he becomes better trained for the job and develops into a prosthetist. The technical development of prosthesiology in this period is above all a matter of inventions in the shops and factories with hardly any influence by amputation surgery, though the limitations in this development have their influence on amputation surgery. Up to the First World War mostly small factories can come up to the demands of prosthetic supply, but during that war the number of amputees, which have to be provided with prostheses, grows enormously. Therefore special hospitals, with limb factories attached to it, are set up in various countries. In the factories mass production of prostheses is done. For example in Budapest where General Stabarzt (brigadier-surgeon) Dollinger commands a hospital of 600 beds and a factory with 230 employees. There his design, the "Arbeitsprothese", a rather crude temporary prosthesis, consisting of two metal sidebars with in between a leather thigh and shank corset and ending in a wooden or iron foot without ankle joint, is made. This prosthesis is available at short notice and fitted by the prosthetist under supervision of a surgeon or physician. If the fitting is proper, the amputee is sent to a walking school, also attached to the hospital. The same set up is made in England in Roehampton, where Queen Mary's hospital for the limbless is founded in 1915, with limb factories attached to it, and in some places in Germany. In these hospitals and factories surgeons and prosthetists meet and gradually become aware of each others possibilities and problems. That does not mean that all surgeons and prosthetists come and remain on speaking terms once and for all, for it takes until well after the Second World War before mutual contacts become normal.

Between the First and the Second World War the technical development of prosthesiology goes on. New materials are introduced, like cast iron, aluminium alloys and the first synthetics. The prosthesis is divided in three components, the socket, the knee joint-with-shank and the foot-with-ankle joint. These components can be aligned and a certain standardization is initiated. Factories start a mass production of components, which lowers the costs. Further research makes the components more sophisticated over the years. The suction socket, originally designed in 1863, but with a low success, is produced again and tried out, on an experimental base in England and on a commercial base in Germany.

The Second World War gives a new impulse for prosthetic research. A new socket design, the quadrilateral socket, is introduced, both as normal and as suction socket. New materials, plastics, are used to produce sockets and components. Further technical research brings innovations, like new hip, knee and ankle joints, onto the market. Knee joints are provided with a stancephase control and for below knee amputation (PTB) prostheses, Tibiale à profil médial (KBM) and the quadrilateral socket. Plastics (6.2) play an important part in the components, allowing mass manufacture.

6.2 Control

To begin with, amputation surgery at the time was not based on any indication of the development of the disease. It was considered that amputation was necessary to save the limb, that afterwards the amputee could be treated and that the limb could be replaced later. In the Reconstructive Surgery level, his age, physical fitness, etc. decides the type of amputation and joint. This type of amputation, especially during his lifetime, was done by a surgeon who thought it was necessary to remove the diseased limb, to save the patient's life. The evidence shows that some surgeons, even some who lived through both wars, intended to remove the arm and amputate the leg.
totally new designs for below-knee prostheses are made, resulting in the Patella Tendon Bearing (PTB) prosthesis. Later this design is modified in Europe into the Prothèse Tibiale à emboîtage Supracondylien (PTS) and the Kondylen Bettung Münster (KBM) prostheses. Another novelty, which enters the market in the seventies, is the endoskeletal or modular prosthesis, with its tubular frame and soft plastic cover. In the eighties new materials like Carbon Fibre Reinforced Plastics (CFRP's) and titaniun make their way into prostheseology and finally the computer enters the world of prostheseology, both as aid in designing and manufacturing and as device in a new generation of modular knee joints.

6.2 CONCLUSIONS

To begin with, there is no trace any mutual influence between amputation surgery and prostheseology in Ancient Times and the Middle Ages. There is no indication that prostheseology or limb makers have any influence on the developments in amputation surgery or on the deterioration of these developments. It is doubtful that the limb maker as a profession even exists, because except for the citation in the Talmud, about one occasion when a non-trained craftsman makes a prosthesis from a log of wood, no limb maker is ever mentioned. There is also no indication that amputation surgery or any surgeon have any influence on the developments in prostheseology. There is no evidence about any surgeon who cares whether his patients can walk again after the amputation, except the mythical twins Cosmas and Damian. But even they do not provide their patient with a prosthesis.

In the Renaissance there is a change for the better. Paré chooses an amputation level, his site of election, which is influenced by prostheseology; for he decides to make the length of a trans-tibial stump five fingers below the knee joint. That gives the stump the ideal length for the prosthesis that is most used during his times, the kneewalker peg leg. His leg prosthetic design is influenced by amputation surgery, for the design of an above-knee prosthesis is only necessary if there is a patient who needs such a prosthesis, i.e. a patient who survived an above-knee severance. So Paré can be considered as the mutual influence incarnate. Moreover he is the first known surgeon who has contact with a limb maker, Le petit Lorrain. It is almost certain that they have discussed the manufacturing of Paré's design, but it is not to our knowledge if the limb maker has any influence on the final product, though the fact that he is an armourer and the prosthesis resembles the leg of an armour, might indicate some influence. Unfortunately Paré is far ahead of his time, for there is no evidence of any further influence from either side for more than a century and
the only influence that can be found before the French Revolution is in the
designs of Verduyn's and Ravaton's prostheses, who are influenced by their
own new amputation techniques. No other amputation technique has any
influence on developments in prostheseology and no development in prostheseology has any influence on amputation surgery.

During the French Revolution and the first half of the nineteenth century the picture is essentially the same. Some surgeons choose a site of election, influenced by the then used prostheses. It is possible that a prosthesis has been made for a hip disarticulation amputee, for that is the new amputation level, which is successfully explored, but no evidence of such a prosthesis still exists.

From the second half of the nineteenth century on the scene changes. Owing to the introduction of anaesthetics and antisepsis surgeons have ample time to do elaborate operations and the mortality rate is lowered. On the other hand the number of potential amputees rises, due to the increasingly huger armies, which are brought into the field during the almost continuous wars. So the number of surviving amputees rises and with it the demand of prosthetic supply. In the same period the possession of a leg prosthesis comes within reach of the common soldier, the bulk of the amputees, because their prosthetic supply is paid for by a third party. So the production of leg prostheses changes from a singularity into a profitable business, and from the manufacturing of a unique device into mass production of prostheses and later of prosthetic components. The use of a leg prosthesis requires more of an amputation stump, in the field of fitting, than the use of a peg leg, so surgeons are obliged to improve their amputation technique and reckon more with the possibilities and limitations of prostheseology. That generates the new amputation techniques like osteoplasty, myoplasty, cineplasty and turnover operations. On the other hand it is also responsible for the strict use of amputation schemes, the way a midthigh severance is usually handled and the aversion to the knee disarticulation. The surgeon's knowledge of possibilities and limitations of prostheseology supposes a certain contact between surgeons and prosthetists. This contact originates from the military (amputation) hospitals, annex limb fitting centres who are set up during the First World War in Austria, Germany and the United Kingdom. In these hospitals surgeons and prosthetists meet and gradually become aware of each others possibilities and problems. Before the Second World War these contacts are not generally established, but some contacts remain, like in Queen Mary's hospital for the limbless in Roehampton and in Germany between Schede and Habermann and between Görlach and Franke. After the Second World War the research in human physiology and kinesiology benefits both amputation surgery and prostheseology. In amputation surgery new techniques as osteomyoplasty and myodesis are developed and

in prostheseology on material and physiological material.

Amputee's level of development is due to the momentaneous level of development owing to the contact between surgeons and prosthetists.

So it can be said that prostheseology on the one hand and has influenced.

From the introduction of anaesthetics and antisepsis surgeons have ample time to do elaborate operations and the mortality rate is lowered. On the other hand the number of potential amputees rises, due to the increasingly huger armies, which are brought into the field during the almost continuous wars. So the number of surviving amputees rises and with it the demand of prosthetic supply. In the same period the possession of a leg prosthesis comes within reach of the common soldier, the bulk of the amputees, because their prosthetic supply is paid for by a third party. So the production of leg prostheses changes from a singularity into a profitable business, and from the manufacturing of a unique device into mass production of prostheses and later of prosthetic components. The use of a leg prosthesis requires more of an amputation stump, in the field of fitting, than the use of a peg leg, so surgeons are obliged to improve their amputation technique and reckon more with the possibilities and limitations of prostheseology. That generates the new amputation techniques like osteoplasty, myoplasty, cineplasty and turnover operations. On the other hand it is also responsible for the strict use of amputation schemes, the way a midthigh severance is usually handled and the aversion to the knee disarticulation. The surgeon's knowledge of possibilities and limitations of prostheseology supposes a certain contact between surgeons and prosthetists. This contact originates from the military (amputation) hospitals, annex limb fitting centres who are set up during the First World War in Austria, Germany and the United Kingdom. In these hospitals surgeons and prosthetists meet and gradually become aware of each others possibilities and problems. Before the Second World War these contacts are not generally established, but some contacts remain, like in Queen Mary's hospital for the limbless in Roehampton and in Germany between Schede and Habermann and between Görlach and Franke. After the Second World War the research in human physiology and kinesiology benefits both amputation surgery and prostheseology. In amputation surgery new techniques as osteomyoplasty and myodesis are developed and
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eveloping in prostheseology components are made who meet the requirements for a
physiological walking pattern ever more. Moreover the developments in new
materials like plastics and CFRP's and the research in small hydraulic and
umatic devices makes components smaller, lighter and more sophisticated.
putation surgery develops after the seventies further as a part of the total
development in medicine and special attention is given to choose the right
level of amputation by several very advanced medical techniques. Up to this
moment no technique, which gives a 100% certainty about the right ampu-
tion level, has been found. Prostheseology develops further after the seventies
owing to technical research, the use of new materials and the introduction of
the computer.

So it can be concluded that the influence of amputation surgery and prosthese-
ology on one another, has been non-existent up to the end of the Middle Ages
and has been scarce from then on to the second half of the nineteenth century.
From the second half of the nineteenth century on, the development of ampu-
tation surgery is influenced by the possibilities and limitations of prosthese-
ogy, as can be seen by the development of osteoplasty and by the idea to give
the stump a more cylindrical than conical shape. The fact that a knee disartic-
ulation was hardly performed, was influenced by the inability of the prosthetist
to produce a decent prosthesis for this severance. The development of prosth-
eseology went on without any influence by amputation surgery, except for the
fact that a new amputation level (hip disarticulation, trans-pelvic amputation)
demanded a new prosthetic design. Development in prostheseology is determi-
ned by technical improvement and economical measures. A closer look at the
development of prostheses shows that, between the Renaissance and the
second half of the nineteenth century, they were only made for a few rich
mputees, although they show some technical ingenuity from time to time.
From the moment a third party paid for a prosthesis, that is from the moment
the majority of the amputees could afford a leg prosthesis, the real develop-
ment in prostheseology started. More and more new materials, new technical
devices and technical knowledge were used.

6.3 CLOSING REMARKS

The history of amputation surgery and prostheseology of the lower extremity
has finished in this thesis, but it is not the end of the history. In both fields not
everything has been investigated yet and many improvements can still be
made. In amputation surgery the research for the proper test to determine the
amputation level and for a better way to heal amputation wounds continues.
In prosthesology there is still much research left, on the best socket design and on the working and usefulness of components. The connection between functional and technical characteristics of components is hardly known, even by the manufacturer. Most statements on the working of prosthetic components are not scientifically proven. The prescribing physician must know more about the connection between functional and technical characteristics to be able to serve his patient the best way possible.

Moreover it is time to combine the knowledge of amputation surgeons and physicians for rehabilitation medicine more than is done today. In the Netherlands amputations are performed in almost every hospital by almost every surgeon. In view of the number of amputations performed yearly and the number of surgeons available, it means that most surgeons do only a few amputations per year. Too few to know and use the refined technique an amputation requires. Therefore physicians for rehabilitation medicine see many unfavourable amputation stumps, of which the prosthetic supply is extremely difficult. It is about time that a few specialized amputation clinics are founded in the Netherlands, where all the amputations of a certain region can be performed by a few highly specialized surgeons, in close cooperation with physicians for rehabilitation medicine and their rehabilitation team, who take care of the prosthetic management. Only this way the amputee will have the assurance that the very traumatic operation of the severance of a part of his leg and the rehabilitation are done in an optimal way.