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Local Innovation Systems Project

University - Industry Collaboration in Medical Devices Development  
A Case Study of the Oulu Region in Finland

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# **University – Industry Collaboration in Medical Devices Development**

## **A Case Study of the Oulu Region in Finland**

### **LIS Project Case Study Working Paper**

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## 1. Introduction

This study focuses on university - industry collaboration in medical devices development in the Oulu region in Finland. The study describes collaboration both at the organizational and the individual level. Active university-industry collaboration increases local innovativeness (Cooke 1998, Powell 1990) and characterizes an innovative milieu (Camagni 1991). Here the Oulu region is defined as an innovative milieu according to Camagni's definition (1991 p. 8): "*An innovative 'milieu' may be defined as the set, or the complex of networks of mainly informal social relationships on a limited geographical area, often determining a specific external 'image' and a specific internal 'representation' and a sense of belonging, which enhance the local innovative capability through synergetic and collective learning processes*".

Earlier studies have also shown the significance of university-industry collaboration especially in medical research (Gelijns, Zivin and Nelson 2001, Gelijns and Their 2002). Medical innovations require extensive interaction between universities and industry and fluent knowledge and technology transfer flowing to both directions. According to Koivukangas (1996) the Oulu region has been especially successful in promoting medicine, natural and engineering science related knowledge exchange in the region. One of the key actors here has of course been the University of Oulu with its faculties of medicine and technology. The most important channels for information flow between public research institutions and industrial R&D units seem to be relatively decentralized, meaning that information flows do not typically follow formal institutional links (Cohen, Nelson and Walsh 2002). Informal interaction, in addition to formal institutional links, plays an important role in university-industry collaboration (Gelijns, Zivin and Nelson 2001, Gelijns and Their 2002, Cohen, Nelson and Walsh 2002). Informal collaboration is usually based on trust, voluntary and open communication among the network members and has no formal, designated roles or power relationships within the network (e.g. Freeman 1991, Owen-Smith and Powell 2004).

Medical devices are complex products that utilize several technologies, e.g. wireless and electromagnetic technology. During the development process of these products one of the key challenges is to sustain fruitful cross-disciplinary and cross-institutional exchange of knowledge. Cross-disciplinary knowledge acquisition and transfer requires effective collaboration practices in the research and development process. This study aims to describe these forms of university-industry collaboration in medical devices development in the Oulu region.

### 1.1. Oulu region as an innovative environment

The Oulu region, with over 200,000 people, is one of the growing regions in Finland. Oulu is the sixth biggest Finnish city and the commercial and industrial center of northern Finland. The population of the city is over 130,000 and about 10% of the inhabitants are employed in the high-tech sector.

In the late 1970s the city of Oulu was struggling against economic decline. This struggle promoted a sense of solidarity and trust among the local people. According to Kulju (2002) the sense of solidarity and trust at the individual level has increased

formal collaboration between organizations, and informal collaboration between individuals. The economic and technological development of the region has been a success story and is often described as the “Oulu Phenomenon” (Kulju 2002, Ojala 2001, Männistö 2002, Tervo 2004, Tunkelo 1988, Sotarauta and Linnamaa 1997).

The “Oulu Phenomenon” has been based on several factors including serendipity (Tunkelo 1988). Without strategic investments by the city of Oulu, the Finnish government and local companies as well as the efforts of key individuals the “Oulu Phenomenon” would not have happened (Kulju 2002). One important investment was the foundation of the first science park of Europe in Oulu in 1982. The seed funding for the science park came from the city of Oulu, the University of Oulu and about 20 local companies.

Nowadays the Oulu region is well-known for its information and communication technology (ICT) companies. The growth of the ICT sector has improved the image of Oulu as a high-tech city. Besides the information and mobile technology sectors, medical device technology has been one of the focus areas in the Oulu region (the strategy of Oulu 2002, Koivukangas and Valtonen 1997). Extensive knowledge flows within industrial sectors and also between industry and the university are considered as strengths of the region (Kulju 2002, Ojala 2001, Männistö 2002, Tervo 2004). Moreover, geographical proximity eases the arrangement of informal and formal face to face meetings. In Oulu, the medical department of the University of Oulu, the University Hospital, the Oulu Polytechnic, the science park and companies of business parks are side by side in the same small geographical area.

## **1.2. Medical devices industry and technology**

In this study, medical device technology refers to hospital technology, telemedicine, health care technology and wellness devices. Hospital technology covers treatment devices used by trained personnel (Kivisaari et al. 2001). Telemedicine is medical treatment through telecommunication (Alasaarela 2003), such as a radiograph sent from a health center for consultation to the Oulu University Hospital. Digital patient archives are also a part of telemedicine. According to the National Research and Development Centre for Welfare and Health (Stakes), the category of health care technology covers pharmaceuticals, devices and procedures in public and private health care.

The term ‘wellness’ came into use in the USA in the late 1980s. Traditionally the focus of health care has been on medical treatment, while wellness is more focused on comprehensive well-being. The wellness industry is based on the advancement of medical devices technology and on products and services built on this technology. The Finnish wellness industry has developed and supplied products and services for medical treatment and for rehabilitation (Kivisaari et al. 2001). Wellness devices include all devices from basic health monitoring to athletics condition measurement. Medical device technology has been one of the growing technologies in the Oulu region. According to Alasaarela (2003), medical device technology is a globally fast growing industry sector, and the global medical device market is growing on average by 10 percent each year. The western health care system has quickly adopted new medical technologies, both devices and pharmaceuticals, and in the coming decade there will be a significant increase in the number of new technologies available, such

as new imaging technologies, computer based drug design and miniaturized devices (Amara et al. 2003). In the '90s, the R&D intensity of Finnish medical devices companies was over 8.5% and export rates were high -- for some companies over 95% of production (Viik and Malmivuo 1998). The export of Finnish health care technology increased by about 40% to 640 million euro between 1999 and 2002 (Alasaarela 2003).

The medical devices industry is a small company intensive industry sector. According to Savage, Blair and Fottler (2002) most of the European and U.S. medical technology companies have fewer than 50 employees. Fewer than 10% of companies around the world in this sector have over 500 employees (Savage, Blair and Fottler 2002, Goodman and Gelijns 1996). Two of the three biggest international companies in 2004, GE Healthcare and Philips Medical Systems, have considered Finland as an appropriate environment for medical device R&D and manufacturing functions (Lilius 2004). In Finland, there are over 300 medical technology producers (Yritystele 2005) employing over 10,000 employees (Ihme 2004).

Some of the devices developed in the Oulu region have become global market leaders. The best known device is the heart rate monitor of Polar Electro. According to earlier studies, the development of successful products is usually based on university-industry and inter-company collaboration in general (Kulju 2002, Tunkelo 1988, Salo 2003, Alatossava 1997) and especially in the ICT sector (Männistö 2002, Tervo 2004). Local university-industry collaboration in medical devices development has also included the University Hospital and Oulu Polytechnic (Tunkelo 1988, Salo 2003). Accordingly, in this study university-industry collaboration refers to collaboration between universities, university hospitals, polytechnics and the medical devices related industry.

In Biemans' (1992) study of medical devices development, three-quarters of the medical devices were developed within networks which consisted of manufacturers and potential user organizations like hospitals, but also various kinds of third parties such as distributors, universities, research institutes, government agencies, scientific foundations, competitors and consultants (Biemans 1992). Efficient networking provides companies with competitive advantage (Shaw 1993). The speed, flexibility and success of a medical device innovation process depend on knowledge sharing in these organizational networks (Shaw 1993).

### **1.3. Organizational and social networks of an innovative milieu**

The institutional setup in a region and the structure of organizational networks are important for technology transfer (Kautonen, Kolehmainen and Koski 2001). Companies aim to reduce technical and economical uncertainty and to create and share new knowledge efficiently by interacting with other organizations (Kautonen, Kolehmainen and Koski 2001). Collaboration between companies and universities, including knowledge sharing, increases the companies' innovativeness and characterizes an innovative milieu. So if the company does not have collaboration with other companies and organizations, the innovativeness of the company and the innovativeness of the milieu can decrease.

According to Camagni (1991) an innovative milieu consists of different kinds of organizational and social networks called innovation networks. These innovation

networks aim to increase the innovative capacity of the milieu. The organizational and social networks vary by origin, size, structure and purpose of the network. Innovation networks are defined as networks where different types of actors are connected with each other in terms of innovation and mutual learning (Camagni 1991). According to Powell, Koput and Smith-Doerr (1996) innovation networks provide entry to the relevant knowledge which is widely distributed and not easily produced inside one firm or gained through market transactions.

In organizational networks, organizations are linked together through formal ties, whereas a social network is operationalized in terms of informal ties among individuals (Granovetter 1985, Uzzi 1990). An organizational network can be defined as a cluster of organizations in one industry sector or in one region, as a cluster of organizations around a university or research center (Paija 1998), and as a cluster of companies driven by market mechanisms and as a source of knowledge (Owen-Smith and Powell 2004, Powell 1990). The location of an actor in a network is important. Centrally located companies usually have richer protocols for collaboration (Powell, Koput and Smith-Doerr 1996).

In innovation networks formal ties between organizations are important because these ties provide access to social networks of academic and industrial scientists. Owen-Smith and Powell (2004) found that companies of a local organization network of technology developers have contacts with academic and industrial scientists through company representatives' social networks.

According to Nahapiet and Ghoshal (1998) social relations, or ties, are channels for information and resource flows. Tie strength describes how much time individuals spend together and what is the level of emotional intensity and intimacy as well as what is the amount of reciprocal services exchanged between the individuals (Granovetter 1973). Through social interactions, an individual may gain access to the resources of other individuals. Such an access enables innovators to cross organization borders in order to find the knowledge they need.

Trust can act as a governance mechanism in relationships (Uzzi 1996). When two parties begin to trust each other, they become more willing to share knowledge related to their core competence without worrying that they will be taken advantage of by the other party (Tsai and Ghoshal 1998, Powell 1990). A common language, a shared educational background, regional loyalties and shared experiences play an important role in networking (Freeman 1991, Lundvall and Borras 1999).

#### **1.4. University - industry collaboration**

Researchers in the USA and Finland have stated that one of the main tasks of a university is to be a source of new knowledge based on scientific research (Gelijns, Zivin and Nelson 2001, Gelijns and Their 2002, Cohen, Nelson and Walsh 2002, Lester and Piore 2004, Salo 2003). The industry gets access to this useful information and knowledge through patent data, informal information exchange, publications and reports, public meetings and conferences, recently hired graduates, licenses, joint or cooperative ventures, contract research, consulting, and temporary personnel exchanges (Cohen, Nelson and Walsh 2002). Naturally, geographical proximity of companies and universities, other research institutions and science parks is beneficial

for university-industry collaboration (Lindelof and Löfsten 2004). University-industry collaboration is also important for sustaining high quality education that responds to the needs of industry (Koivukangas 1996). Finnish universities are more flexible than North American universities in introducing education programmes designed to respond to the needs of industry (Chakrabarti and Lester 2002).

Chakrabarti and Santoro (2004) explored how networking, trust, and problem-solving patterns affected technology development and commercialization in university-industry collaboration. They found that when a company is developing its core technologies in university-company collaboration, a high level of trust between the university and the company is needed. When a company is searching for possibilities to solve more generic problems in a university-industry network, trust is not so much emphasized.

Companies developing medical devices have emphasized the importance of interaction both at the organizational and the individual level in university-industry collaboration (Lampelo 2000). Scientists from many disciplines interacting and working together promote technology transfer between Oulu University and local industries (Koivukangas 1996). According to Gelijns and Their (2002), the scientific and practical problem solving in medical devices development is usually based on cross-disciplinary research.

Medical device innovation requires integration of innovations from healthcare, engineering and materials science, and may combine pharmaceutical or biotechnology knowledge (Hanna et al. 2001). University-industry collaboration in medical devices development usually leads to patenting (Gelijns and Their 2002; Koivukangas 1996). When this is the case intellectual property rights (IPR) of all the collaboration parties including the university need to be agreed upon. Intellectual property rights (IPR) such as patents, copyrights, designs and utility models are rights to protect innovations.

### **1.5. Research questions**

The aim of this study was to explore the role of university-industry collaboration in medical device development in the Oulu region and how this collaboration is perceived.

The research questions of this study are as follows:

1. Is there university-industry collaboration in medical device development in the Oulu region?
  - i. Which are the active companies and organizations in medical device development collaboration?
  - ii. Which people are active in medical device development collaboration and what are their roles in the collaboration?
2. What are the forms of collaboration in medical devices development?
3. What is the role of the university in medical devices development?

## 2. Material and methods

A qualitative case study approach was selected for this study. The case study method is suitable when describing organizational and social phenomena without having control over the events (Yin 1994). The aim of this study is to gain more understanding about networking in medical device development in the Oulu region. According to Yin (1994) a research design of one case with more than one unit of analysis is called an embedded single case design. In this case study, university-industry collaboration roles and forms were studied both at the organizational and the individual level.

According to Eisenhardt (1989) case study research is especially appropriate for a type of exploratory research, with a focus on documenting a phenomenon within its context and integrating information from multiple sources. In this study, data were collected from different sources such as public documents, presentation materials, web pages and through thematic interviews. Due to the small amount of published material concerning the development of medical devices in the Oulu region, the main focus of the data collection was on interviews.

A snowball sampling method was selected to identify the focal people in medical devices development in the Oulu region, because standard sampling methods are inefficient when locating people involved in informal activities (Frank and Snijders 1994). The snowball sampling begins with an interview of a focal actor or actors (Scott 1998, Wasserman and Faust 1994). We used five people as a starting point for identifying other relevant people in medical devices development in the Oulu region. The selection of the first five people was based on documented information, mainly from the web pages of Tekes, the Finnish Funding Agency for Technology and Innovation, and the University of Oulu, concerning medical devices technology development in the Oulu region.

The five focal actors were two professors and one researcher from the University of Oulu, one manager from the science park Technopolis Ltd, and one manager from the Oulu Polytechnic. The snowball sampling was started by asking “who are the active people in the medical devices development network”, and the outcome was that 68 people were identified. Professors and innovation managers of the University of Oulu, the president, administrators, physicians and doctors of the University Hospital and managers and researchers of the Oulu Polytechnic were mentioned. Moreover, vice presidents and/or R&D managers of small and medium size enterprises (SMEs<sup>1</sup>) were also mentioned. The people from the big companies were typically R&D and strategy managers.

Interviews were done in two phases. The first phase was conducted in 2002 and the second phase in 2003. In the first phase, 28 people were interviewed using a semi-structured interview. In the second phase, the interviews were completed with 16 interviewees. Four of the interviewees were interviewed twice so the total number of interviewees was 40. In the first phase, the interviews focused on collaboration

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<sup>1</sup> According to “*Definition of micro, small and medium-sized enterprises*” of the European Commission (<http://europa.eu.int/scadplus/leg/en/lvb/n26026.htm> 1.3.2005) small size companies have less than 50 employees and medium size companies have less than 250 employees

partners and forms of collaboration. In the second phase interviews had the same themes as in the first phase, but they were more focused on the content of collaboration. The four interviewees who were interviewed twice were seen to be important people in providing information about collaboration partners but also about the content of the collaboration.

Interviews were conducted during four time periods. Each of these periods lasted about two weeks. Because of time constraints of interviewees and interviewers, it was not possible to settle interview times with all of the named people. Five people were interviewed in Helsinki instead of Oulu. Most of the 28 people who were not interviewed were from the Oulu Polytechnic, the University of Oulu and the University Hospital. However, interviews were conducted at all these organizations. In the end, the only organizations at which no interviews were conducted were two small companies.

Most of the interviews were conducted by two interviewers. The interviews lasted from one hour to two and a half hours. In the first phase interviews, interviewers made notes during the interviews and afterwards the notes were combined. The second phase interviews were recorded and then transcribed word by word.

A total of 40 people out of the 68 focal people were interviewed. The interviewees from the University of Oulu were four professors, two managers and one researcher. From the University Hospital two doctors, one physicist and one manager were interviewed. From the Oulu Polytechnic, the interviewees were two managers and one researcher. The company interviewees were seven managers from big companies and fifteen managers from SMEs. In addition, two managers of the city of Oulu, one manager in the Technical Research Centre of Finland (VTT) and one manager in Oulu TE-Centre were interviewed. The four who were interviewed twice were managers of small companies including two managers of the Wellness Forum project. Table 1 shows the sample and interviewed people and their organizations in different phases of the research process.

Table 1. The amount of focal people in the phases of the research process

| Organization        | Snowball Sampling / Focal People | Interviewees    |                  |                | Total      | Not interviewed | Interviews of focal people by type of organization |
|---------------------|----------------------------------|-----------------|------------------|----------------|------------|-----------------|--|
|                     |                                  | in Phase I 2002 | in Phase II 2003 | in both phases |            |                 |  |
| University          | 10<br>15%                        | 5               | 1                |                | 6<br>15%   | 4               | 6/10<br>60%  |
| University Hospital | 14<br>21%                        | 4               | 1                |                | 5<br>13%   | 9               | 5/14<br>36%  |
| Polytechnic         | 6<br>9%                          | 2               | 1                |                | 3<br>8%    | 3               | 3/6<br>50%   |
| Big company         | 11<br>16%                        | 6               | 1                |                | 7<br>18%   | 4               | 7/11<br>64%  |
| SME                 | 21<br>31%                        | 9               | 10               | 4              | 15<br>38%  | 6               | 15/21<br>71%                                       |
| Other               | 6<br>9%                          | 2               | 2                |                | 4<br>10%   | 2               | 4/6<br>67%   |
| Total               | 68<br>100%                       | 28              | 16               | 4              | 40<br>100% | 28              | 40/68<br>59%                                       |

The sample had a fair balance between university (36%) and industry (47%) people. However, in the interviews company representatives were slightly over represented. After 44 interviews the collected data was considered sufficient for a final analysis.

## **2.1. Data analysis**

The interview data was analyzed using deductive content analysis. In the first phase of analysis, collaboration partners and forms of collaboration were analyzed. These were also the themes of the first phase interviews. The aim of the analysis was to illustrate the collaboration networks and the forms of collaboration between the university and the industry. The data analysis in the second phase was based on an inductive content analysis and the aim was to define the content of collaboration within the organizational and interpersonal networks. When possible, other documented data was used to validate the interviews. The preliminary results were also validated before the final analysis by presenting the results to the local medical devices developers in their Wellness Forum meeting.

Based on the content analysis of the interviews, collaboration networks and how the University of Oulu is linked to these networks were illustrated and the forms of collaboration were described. The organizations and active individuals were named. Based on the descriptions of the collaboration within the organization and social networks, the forms of collaboration within the organizational and social networks were described. The role of the University of Oulu was described according to interviewees' perceptions.

## **3. Collaboration in medical devices development in Oulu region**

The "technology positive atmosphere" in the Oulu region has facilitated local technology development. An interviewee from the science park Technopolis described Oulu as a high-tech testing ground and often the first market for the developed products. According to the manager, the local companies get feedback from technology users very easily because people in Oulu are technologically enthusiastic.

Almost all interviewees emphasized that networked collaboration was a typical characteristic of the Oulu region. They pointed out that social networks among individuals are as important as organizational networks. One company manager reported that the efficient collaboration in the Oulu region was based on shared vision and trust between collaboration partners. However, collaboration must be profitable and beneficial for the collaboration partners. In 1995 the "Welfare Cluster" project that aimed at developing a network of health care authorities, social and health research, and the medical technology industry in the Oulu region was launched. One of the professors said that after the local organizations in the "Welfare Cluster" were mapped out, it was easier to increase and coordinate the activities between these organizations.

The most important aim of the "Welfare Cluster" project was to get all the local medical device developers involved in a collaboration network. Some company

managers and university professors said that there was also an aim to establish an institute for the medical device sector. This institute gathers together local researchers and offers a testing environment for the new medical devices developed in the companies. According to company managers, the first project focused on establishing the Wellness Institute was the Center of Wellness Technology project in 1996-1997. The aim of the project was to integrate regional academic research, clinical excellence and local business in medical device technology. The technological basis of the project was in telemedicine and digital patient records. One of the professors was convinced that this particular project had nation-wide impact on how healthcare is organized today.

According to company managers, the next step was the launch of the project named Wellness Forum, coordinated by the incubator Technopolis. The manager of the Wellness Forum emphasized that the strategy of Oulu, named the Oulu Growth Agreement 2006, showed the strong commitment of the city to the development of medical device technology.

The interviewees reported that in medical device development companies collaborate mainly locally although they have national and international collaboration partners as well. The clearest exception to this was a company called Polar Electro which has global collaboration with research institutes in several countries around the world.

Most of the interviewees mentioned that public funding is vital for collaboration projects. Tekes and the Academy of Finland, the national level policy makers, have funded projects and promoted information sharing between projects through national level research and technology programmes.

### **3.1. Main actors in medical devices development**

The organizations in medical device technology development in the Oulu region were categorized as scientific knowledge and information providers, medical device developers, medical device development supporters and local users of developed medical devices. The organizations providing scientific knowledge and information are the University of Oulu, the Oulu University Hospital and the Oulu Polytechnic, while the main medical device developers are the local companies, but also the University of Oulu with the Oulu University Hospital and the private hospital Oulu Deaconess Institute. Medical device development supporters are companies such as venture capital firms and the incubators Oulutech, Technopolis and Medipolis, the Oulu University Hospital, Oulu Deaconess Institute, the city of Oulu, TE-centre and other regional policy makers. The local users of developed medical devices are the Oulu University Hospital, Oulu Deaconess Institute, local private rehabilitation centers and the city of Oulu.

At the University of Oulu, the Faculty of Medicine is integrated into the University Hospital as a part of the medical entity. The University of Oulu is the only university in Finland which includes Medicine, Science, and Engineering in the same university. The interviewed professors and managers of the companies saw information technology and biotechnology as important for medical device development. At the province level, the Oulu University Hospital is responsible for organizing specialized medical care for the whole of northern Finland. At the province level collaboration is

focused mainly on collaboration between the Oulu University Hospital and the local healthcare centers. Also different activities in telemedicine are becoming more common, for example remote consulting regarding x-ray images, digital patient archives etc.

The Oulu Polytechnic collaborates with the University of Oulu in education and research. The Oulu Polytechnic provides education in healthcare, partly together with the University of Oulu. The interviewed company managers perceived the Oulu Polytechnic to be in some cases more important for medical device development than the University of Oulu. Flexibility in the planning of research projects and a greater focus on applied rather than basic research were said to make the Oulu Polytechnic more cost-effective for companies.

The perceived importance of the organizations varied according to who was interviewed. The university professors defined the small and medium size research and development oriented companies as key organizations. The managers of the companies saw the global companies like Nokia and Polar Electro to be important channels to international markets for local small and medium size development companies.

Although the big ICT companies like CCC and TietoEnator also operate abroad, the managers described these companies' business in the Oulu region as more local rather than global. They said that local collaboration has been important when they have tailored their products to respond to the requirements of local customers. The managers of the software companies said that hospitals have different kinds of information systems, so a lot of customization is needed. Also knowledge about the local regulations and how the doctors work was needed.

Some of the small companies such as Innokas Medical, Newtest, Onesys and Tracker are selling their innovative products to global markets. The managers of these companies said that the efficiency in networking and resource sharing can be seen in the launches of new innovative products. Organizational networking has made it possible to share resources between the companies and research institutes and that has helped the companies to develop ideas for products.

Technopolis Plc and Medipolis Ltd were both engaged in the Oulu Region Centre of Expertise programme for promoting business. The programme started in 1993. This programme has been regularly evaluated to be the best of its kind in Finland. The aim of the programme coordinated by Technopolis is to promote the success of information technology, medical technology and biotechnology companies. The aim is to combine top-level expertise in different fields to create new, globally competitive products and services. The programme was implemented in close cooperation with training and research organizations. The current phase of the programme (2003-2006) has two main focus areas: information technology and well-being.

Company managers saw the growth of the wellness industry to be important for their own companies and offering better possibilities for collaboration. They found it also necessary to have organizations that support spin-offs and company growth. According to the interviewed company managers, the local key companies in the wellness sector were technology companies, venture capitalists, incubators and private

hospitals. Some of the big technology companies were also acting as venture capitalists, funding medical device technology spin-offs. However, technology companies in the wellness sector were mostly SMEs.

### **3.2. Organizational collaboration in medical devices development**

The interviewees recognized three important networks in the Oulu region, the Wellness Forum, Oulu Wellness Business Board and Revontuliryhmä (Northern Light Association). Company managers saw the Northern Light Association as an important strategic level institution, which expresses the companies' interests to regional and national level policy makers. Wellness Forum has been the most important public arena for medical device developers. Oulu Wellness Business Board is smaller, more company oriented and it is a more closed community compared to the Wellness Forum.

#### **3.2.1. Collaboration within the Northern Light Association**

Revontuliryhmä (the Northern Light Association) was founded in 1986. It links different industry sectors together and shares information between organizations in the Oulu region but also in northern Finland more generally. The impact of the association is based on its members' individual activity. Its members are managers of high-tech companies and organizations like the University of Oulu, VTT, the Oulu Polytechnic, the Oulu Chamber office and the city of Oulu.

The mission of the Revontuliryhmä group is to develop a favorable enterprise climate and to consult companies on managerial questions. Company managers in Revontuliryhmä stated that a favorable enterprise climate can be built on the efficient collaboration between the industry, research centers and the University of Oulu. One of the concerns of Revontuliryhmä was to ensure competent recruits for the future.

Interviewed company managers stated that Revontuliryhmä facilitates interaction between company managers across different industry sectors. Because electronic and software technologies play an important role in the medical devices sector, managers of the ICT companies were important know-how providers for managers of the local medical device companies. One of the aims of Revontuliryhmä from the beginning was to increase national level collaboration between companies.

#### **3.2.2. Collaboration within Wellness Forum**

The Wellness Forum was set up during the year 2000. The Wellness Forum started as a publicly funded project with a focus on gathering the local medical device developers together. One of the aims of the Wellness Forum from the beginning has been to increase the number of projects which combine different high technology fields and create successful products or product concepts for the wellness technology market. According to the managers of local companies, the Wellness Forum has been important in the creation of networks within the wellness industry. According to the interviewed company managers, other important communities besides the Wellness Forum are Software Forum, Mobile Forum and Bio Forum. The manager of Technopolis mentioned that the Wellness Forum was linked with the Software Forum

to increase the synergy between the companies in both forums and provide the possibility to link different technologies.

Information sharing within the Wellness Forum is organized in different ways, e.g. through web pages, company presentations and visits and monthly meetings. All the research institutes, medical device companies and customers were brought together to assess needs and to give feedback to each other concerning medical device development. Although the collaboration has been mostly local, the Wellness Forum has a joint construction project with the city of Sendai in Japan at the Well-being Centre in Sendai.

Managers of the companies said that the university was loosely linked to the Wellness Forum. According to company managers, the companies in Wellness Forum tried to get the university more tightly linked to the research by financing a biomedical engineering professorship for the University of Oulu. Although they pointed out the lack of university involvement in the Wellness Forum, they mentioned that some innovative projects by the University of Oulu and the industry together, such as the Wireless Hospital and the prevention of osteoporosis projects, have taken place.

The professors of the University of Oulu said that the Wellness Forum makes collaboration with companies and research institutes easier. The university professors described the Wellness Forum as an industry-driven collaboration network and they saw it more as a forum where industry dictates what will be done. The professors saw some of the activities in the Wellness Forum as so focused on applied research that the university's involvement would not benefit either of them. The professors mentioned that their research funding depended on the type of their research. The professors stated that if the research was too applied, they would have difficulties getting funding from the Academy of Finland.

### **3.2.3. Collaboration within Oulu Wellness Business Board**

Oulu Wellness Business Board (OWBB) is a consortium of companies inside the Wellness Forum. The consortium is an open discussion forum where companies act independently. One reason why the active companies founded OWBB was the growth of the Wellness Forum into a community too big and too open for discussion focused on the companies' core business. One company manager said that "the problem in a big loose consortium is that there will be participants who take without giving". So the need for a tight, trustful small consortium where the companies can share information and ideas concerning their core business was the main reason for the founding of OWBB. Another reason the managers mentioned was the aim to create a broader selection of locally manufactured wellness products.

OWBB is expected to increase companies' productivity by helping them with their business plans and by benchmarking their processes. The company managers said that the vision of the OWBB is to collaboratively develop new innovative products and service concepts for global markets. One of the tasks of the OWBB is to steer the activities of the Oulu Center of Expertise in a more business-oriented direction. Sometimes OWBB can play the role of executor for the issues raised in the Wellness Forum.

The managers of the companies described OWBB as an open, informal community of local company managers who participate in the development of the local wellness industry. Collaboration in OWBB covers strategic planning, technology development and the resourcing of product development, company growth and spin-offs. The high-tech boom made some of the local company managers millionaires and these managers are now acting as business angels and venture capitalists. Nowadays these venture capitalists and business angels finance companies which strengthen the local wellness industry.

### 3.2.4. Collaboration networks in medical devices development

Figure 1 illustrates the companies and organizations of medical devices development and how they were networked. Most of the interviewees were involved in the two main networks, the Wellness Forum and Oulu Wellness Business Board. The participants in these two networks described the information sharing and formal organizational collaboration as extensive and open.

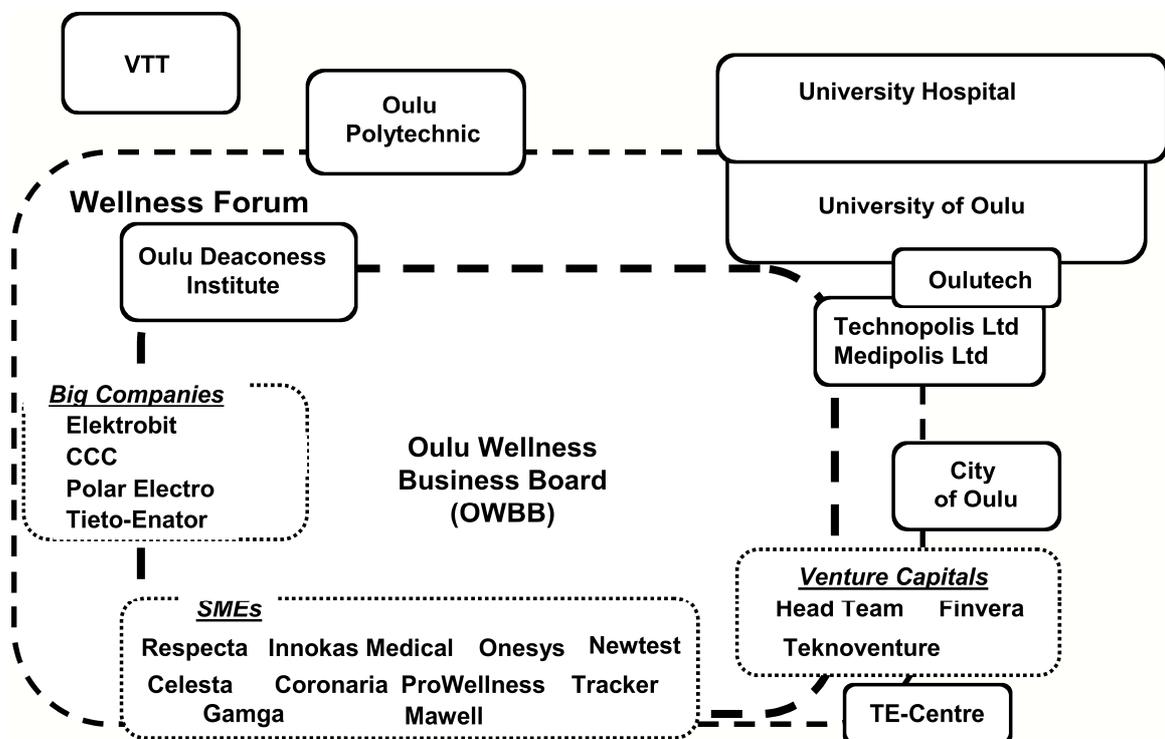


Figure 1. Organizational networks of medical devices technology development in the Oulu region

The Northern Light Association is not shown in Figure 1. However, it affects local medical devices development through its members' participation in the Wellness Forum and Oulu Wellness Business Board, but not directly as an association or formal network. The University of Oulu, the University Hospital and the Oulu Polytechnic collaborate with companies in the Wellness Forum. Most of the companies in the Wellness Forum are also participants of Oulu Wellness Business Board where the collaboration is most active. VTT is an important research institute in Oulu and people from VTT were included in the snowball sampling. However, the interviewee

from VTT and other interviewees stated that VTT is focusing more on bioscience and is not actively linked to the medical devices development.

### 3.3. Key individuals and their roles in medical devices development

The university professors said that from the perspective of knowledge and information sharing, the key individuals for local medical devices development are their colleagues, especially professors in the Biomedical Engineering Program at the University of Oulu, and company managers and from a funding and administration perspective the deans of the faculties.

Interviewees from the Oulu University Hospital named as key individuals the manager of the Oulu University Hospital and the heads of the departments of the Oulu University Hospital. They were important because of their strategic position as resource allocators.

From the company managers' perspective, the key individuals were other company managers, a few professors in the University of Oulu and the University Hospital doctors and physicists who offered the test environment for products or were involved in collaboration projects.

Interviewees identified different roles among the people developing medical devices, such as that of network builder, inventor and executor. The most frequently mentioned role was that of network builder, referring to the person's activity in building formal and informal networks between organizations and individuals.

*“The managers of the Wellness Forum have been essential for keeping the network active. Managers of the Wellness Forum, having ten contacts in each finger, have been crucial for linking organizations and people together.”*  
(Manager of SME)

The second role that came out in the interviews was that of an inventor. Some people were mentioned to be innovative idea providers linking different technologies together. These individuals, who brought some of their new ideas to the public arena, were said to have a good sense of when the technology and markets are mature for these inventions.

*Some of the ideas have come up years ago but the time has not been right at that time. So the idea generators, like NN, have developed these ideas during the years and pushed these for products when the time was right.* (University Professor)

The third mentioned role was that of executor. This person pushes the ideas for products in collaboration with other individuals or organizations. An executor finds, evaluates and contacts qualified partners. They know actors within a network and their competence and resources. They have the ability to motivate these people to be involved in the projects.

*“The company managers have a different time scale compared to university professors. When they have an idea, they search the needed resources and suitable collaboration partners in a very short time and start the co-project.”  
(University Professor)*

The company managers stated that at the organizational level collaboration with the University of Oulu was inflexible. However, there was no difference between university professors and company managers in the collaboration activity at the individual level. Although company managers stated that it has sometimes been hard to get the University of Oulu involved in collaboration projects, some of the professors were defined as active collaborators and network builders.

In some cases individuals' roles differ from the role of their organization. For example, a university professor can act like a company manager developing new products and a company manager may start scientific basic research in collaboration with the University of Oulu and the University Hospital. These kinds of boundary crossings from traditional roles were seen as strengths of the Oulu region in the field of medical devices. The key individuals named “the well-being of people living in the Oulu region” and “being at the forefront of medical devices technology development” as the most frequent objectives of collaboration.

#### **4. Forms of collaboration**

Three different forms of collaboration in medical devices technology development were found. These were collaboration in research, information and knowledge sharing, and training of researchers and product developers.

##### **4.1. Research collaboration**

Research collaboration was mainly based on personal relations between company managers and university professors. Even if company managers thought that research collaboration between companies and the University of Oulu could still be more active, they perceived that collaboration has increased during the last twenty years. According to them, the reasons for this have been the growing amount of public funding and the increased amount of cross-disciplinary research.

In many cases collaboration between the University of Oulu and industry was focused on research or testing new devices in a hospital context. Companies collaborated with the University of Oulu when they needed theoretical knowledge or when they needed testing opportunities for a newly developed medical device. The time span of company-university research collaboration projects was longer than company-polytechnic collaboration. When collaboration outcomes were expected to be practical and easily applied, companies preferred Oulu Polytechnic over the University of Oulu.

According to company managers, the lack of university-industry collaboration restrains medical devices development. This was especially the case if the companies needed scientific validation of the new device or method. According to company managers, small companies usually need help in solving their immediate problems. The university can help them if the problem is near the university's own research

interest. For big companies universities can be a good source of new ideas. According to company managers, it is very important for them to be on the leading edge of new technologies and to be able to be differentiated from their competitors.

Some of the university professors also do consulting, which was mentioned as a significant form of collaboration. Consulting contracts are made between the company and the professor, not with the University of Oulu. University personnel are allowed to have a secondary occupation with the permission of the university's administration. Working hours for consulting are capped at 50 hours per month. Some of the professors have their own companies through which they can do consulting, some professors do consulting only informally without compensation and some do not engage in consulting at all.

#### **4.1.1. Managing Intellectual Property Rights in collaboration projects**

Some companies divide collaboration projects into research projects in which the University of Oulu is involved and product development projects where only companies are involved. Some company managers said that patents and licensing agreements were easier to arrange between companies than with the University of Oulu. However, company managers said that it is easy to make publishing agreements with the university personnel. When required, university research personnel do not publish research results until the new product is ready for the market.

The intellectual property (IP) agreements made in university-industry collaboration projects vary between companies. Some company managers said that when there is something to protect, the project participants negotiate an IP agreement. Another company manager said that they make agreements in every project and that because of the complexity of the IP issues, the agreements are usually negotiated by lawyers. Another company manager said that in collaboration projects the university researchers are rewarded the same way as employees of companies when there is something to patent. However, all company interviewees said that confidence has not been a problem in the projects because of the personal contacts and trust between the professors and the managers of the companies.

The Research and Services unit of the University of Oulu and Oulutech offer the services of IPR protection and commercial exploitation of research results for University of Oulu personnel. The Research and Services unit and Oulutech managers stated that their work is becoming more and more important from the university's perspective because the companies' interest in owning IP has increased recently. The Research and Services unit manager assists in patent financing while the Oulutech manager assists in commercialization. According to managers, it usually takes 10 years to get basic research results to market and five years to get applied research to market.

#### **4.2. Information and knowledge sharing**

The University of Oulu together with local companies and the city of Oulu has arranged symposiums and conferences on medical devices technology development as public knowledge exchange forums. These forums have provided a place for discussion between university researchers and company R&D personnel.

The Biomedical Engineering Program at the University of Oulu arranged a symposium on “Technology Transfer between Research Institutes and Industry” in 1996. The presentations in this international symposium varied from innovation management in the medical engineering industry to how to promote the welfare cluster in the Oulu region. The Biomedical Engineering Program has also arranged the “To be or Well be” seminars. The seminars were arranged together with local industry and Oulu Polytechnic. In addition to the seminars, the Biomedical Engineering Program has arranged “Biomedical Engineering Meetings”. Also the Faculty of Medicine has arranged congresses and seminars and the annual “Faculty of Medicine Science day” for researchers and practitioners interested in research work and students of the faculty.

The interviewees described these meetings as important for knowledge sharing and for seeking new collaboration partners. Company managers stated that in these meetings it is possible to present ideas concerning new devices to other developers as well as possible users and to get feedback for their ideas. According to the professors, these meetings provide opportunities to present their current research and to find possible industry collaboration partners.

#### **4.3. Education and training of researchers and product developers**

According to the professors, education in medical devices technology at the University of Oulu is cross-disciplinary. The interviewed professors described collaboration in medical devices education between the different faculties of the University of Oulu as extensive and well-working. The professors divided education into undergraduate teaching, postgraduate supervising, supplementary education and technology developers’ training.

Master’s theses by students participating in university-industry collaboration projects are important for the University of Oulu and also for companies. These projects are funded by companies and Tekes or the Academy of Finland. The projects offer companies access to university research and new knowledge and the possibility to employ R&D personnel. For the university professors, master’s theses made in these projects increase external funding for university research and link university research to the product development processes of the companies.

According to the professors, postgraduates working for companies have more independent positions and more challenging research tasks than do other research personnel in companies. Postgraduates can exchange knowledge with other researchers quite freely. Professors stated that the postgraduates’ research is based on formal and informal collaboration between the University of Oulu and companies. Usually, the collaboration between professors and postgraduates continues after graduation. Some of the former postgraduates working in companies have very active collaboration with the professors.

The increasing need for cross-disciplinary collaboration in education has generated new education programmes at the University of Oulu, the Oulu University Hospital and the Oulu Polytechnic. The Oulu Polytechnic and the University of Oulu have

tailored courses and a supplementary education programme for the employees of Oulu region companies and local unemployed people.

According to the professors, one form of collaboration was training companies' technology developers. Professors and University Hospital physicists showed the developers how a device could be used in a clinical environment while they did clinical testing and gave feedback concerning the usability of the device. They showed the companies' technology developers how other devices that were used simultaneously affected the tested device and how they acted on the patient. According to professors and physicists, with this feedback companies can improve the developed device, and the knowledge transfer in the training also helps them develop new devices.

## **5. Role of the university in medical devices development**

The interviewees considered the role of the University of Oulu important for local medical devices development. However, some interviewees stated that the University of Oulu could have an even more active role in local university-industry collaboration. Collaboration activity and the role of the University of Oulu vary depending on the form of collaboration.

The interviewees mentioned three roles played by the University of Oulu. The first role is that of promoter of academic research in university-industry research projects. The second role is as knowledge sharer, and the third role is as a trainer of specialists.

### **5.1. University's role in promoting research**

In university-industry research collaboration, the content of the collaboration affects the university's activity. According to company managers, collaboration in medical devices development was mainly industry driven. Most of the interviewees said that the company managers were usually the initiators of university-industry collaboration. However, the University of Oulu had an important role in transferring new knowledge to the companies.

From the company managers' perspective, getting new ideas and knowledge and the possibility to solve problems have been important reasons for the collaboration with the University of Oulu. The interviewed professors described university research as mostly basic research. Company managers said that university-industry collaboration makes it possible to commercialize the results of basic research. Company managers wanted to shorten the development time from an idea to a product in university-industry projects and therefore they would have liked to accelerate the progress of the collaboration projects.

While local company managers were mainly the initiators for university-industry research projects, the University of Oulu has a more active role in the development and clinical testing of new medical devices. Medical devices have to go through strict clinical testing and the University Hospital and the Deaconess Institute have offered a testing site. The doctors and physicists in the hospital have tested e.g. ear implants, a laser scalpel and wireless monitoring systems developed in Oulu region companies.

## **5.2. University's role in knowledge providing**

The University of Oulu actively organizes public conferences and seminars together with companies. The University of Oulu and the Wellness Forum organize international and local conferences and annual meetings, in which medical device developers and the professors and researchers of the University of Oulu have presented innovative medical devices.

These conferences and annual meetings are information and knowledge sources for practitioners and researchers concerning the latest university research and development in medical devices. According to company managers, these forums stimulate social interaction between the University of Oulu and the industry.

The professors stated that the university's role in the first symposiums was to present new technologies and ideas concerning local healthcare and medical devices technology development. According to company managers, the role of the university in these symposiums and meetings is to be an academic contributor by sharing international scientific knowledge for local technology developers.

## **5.3. University's role as a trainer of development specialists**

According to the professors, the role of the University of Oulu in education is to increase the number of people educated in medical devices technology and to provide a workforce for the growing industry. Master's theses carried out for companies have been a common way to transfer knowledge between the industry and the university.

There have also been some postgraduate students working for companies. One doctor at the Oulu University Hospital stated that one of the main mechanisms of university research is through doctoral dissertations. The professors said that university-industry collaboration benefits both collaboration partners and the collaboration has extended university research to new technology and research areas.

Supplementary education is designed to meet the requirements of companies and is offered together with Oulu Polytechnic. However, the University of Oulu manages the education program. The practical training part of the education is done in the local companies, in the Oulu Deaconess Institute or in the University Hospital. Professors stated that the education is tailored based on feedback from companies.

## **6. Discussion**

The aim of this study was to increase the understanding of university-industry collaboration in medical device technology development. Collaboration was studied at the organizational and the individual level. The data was collected in interviews and the interviewees were selected using snowball sampling.

To increase the understanding of university-industry collaboration, collaboration participants and the different forms of collaboration were defined and the role of the university in medical devices development was described. In addition, the roles of individuals and other organizations were explored.

## 6.1. Collaboration in medical devices development

Networking characterizes medical devices development in the Oulu region. Although most of the organizations in the network had both national and international collaboration partners, the interviewees stated that in medical devices development they collaborated mainly with local partners. For example, lack of resources was mentioned as one reason for collaborating only at the local level. Company managers said that local networking is easier and requires less resources than networking at the national or international level.

In the Oulu region one important aim of the companies has been to increase collaboration between the university and industry and to get all the local medical device developers involved in the collaboration network. Research and development funding organizations like Tekes and the Academy of Finland have also promoted this collaboration. According to company managers, technology and research programmes have linked new collaboration partners in information and communication technology as well as in mobile technology with medical device developers.

In this study we found that collaboration networks operated at different levels. Key organizations collaborated within the Wellness Forum, Oulu Wellness Business Board and Revontuliryhmä. In the medical devices industry, key organizations within these networks were the companies, the Oulu Deaconess Institution, the Oulu Polytechnic, the University Hospital and the University of Oulu.

The Northern Light Association operates at the strategic level and represents companies' interests to policy makers at the regional and national level. Oulu Wellness Business Board is a small, company-oriented network, a closed community for medical device developers. It focuses more on the operational level. The Wellness Forum is the most open network and it forms a platform for formal networking and informal discussions for all medical device developers in the Oulu region. All interviewees mentioned the importance of social interactions within the medical devices development network. Effective collaboration within the Wellness Forum, with a strong sense of solidarity among local people and companies, supporting instead of competing with each other were the reasons for efficient knowledge sharing among medical device developers.

From the company managers' perspective local organizational networks have been important especially for small companies, helping them to develop innovative products for the global market. From the perspective of the University of Oulu, the local networks offer professors collaboration partners and the researchers and students employment possibilities.

The company managers stated that informal collaboration in social networks was as important as formal collaboration in organizational networks. This finding supports previous findings (Gelijns, Zivin and Nelson 2001, Gelijns and Their 2002 and Cohen, Nelson and Walsh 2002) that informal interaction, in addition to formal institutional links, plays an important role in university-industry collaboration. According to local company managers, efficient collaboration in the Oulu region was based on shared vision and trust between collaboration partners.

Descriptions by the interviewees concerning the most active people within the network were more extensive than was expected. The interviewees mentioned individuals who were important for the collaboration, but also described their roles within the network and in the innovation processes. The roles cited - network builder, inventor and executor - were similar to the role categories identified by Chakrabarti and O'Keefe (1977), Rogers (1995), and Chakrabarti and Hauschildt (1989).

## **6.2. Collaboration forms in medical devices development**

The forms of university-industry collaboration in medical devices development varied. Big companies seem to develop their core technologies mainly in-house. When collaborating, they focus on acquiring knowledge for more generic technology development. SMEs, on the other hand, develop their core technologies more often in direct collaboration with the university. Also, social networks seemed to be more important for small companies in terms of sharing innovative ideas.

The University of Oulu and local companies organized seminars, conferences and annual meetings together to promote information and knowledge sharing in medical devices development. In education, the University of Oulu and the Oulu Polytechnic have collaboration with local companies. Professors supervised students carrying out their master's and doctorate theses in local companies. Also students from the Polytechnic carried out their theses in companies. Based on the requirements of local companies, the University of Oulu and the Oulu Polytechnic tailored updated training both for employees in local companies and for local unemployed people.

According to Gelijns and Their (2002), scientific practical problem solving in the medical devices development is usually based on cross-disciplinary research. The company managers also mentioned that cross-disciplinary research was a strength of the University of Oulu and collaboration with professors, researchers and hospital physicists makes it possible to implement applications from basic research. Because medical devices combine different technologies, cross-disciplinary collaboration in the university-industry interaction has also increased the innovativeness of the companies. According to company managers, companies have successfully combined different technologies in new products in university-industry collaboration projects.

The interviewees appreciated the scientific knowledge accumulated in the research and they especially valued it when there was a possibility for patenting. This was in line with the findings of Koivukangas (1996) and Gelijns and Their (2002) regarding the potential for commercialization of research outputs in medical devices. Also the representatives of Oulutech and the Research and Services unit of the University of Oulu commented that companies' interests in IP have increased in recent years and that in some cases IPR agreements are made by lawyers. According to the interviewees, publications like masters' theses and dissertations were more important than university-owned patents and licenses as a source of new knowledge for medical device developers.

Collaboration relationships in medical device development between universities and companies are usually long. Clinical testing also lengthens the collaboration time. The University Hospital and the Deaconess Institute have provided a test environment for the new devices and methods.

The interviewed company managers emphasized that the formal and informal collaboration was built on professional skills and a spirit of solidarity. The spirit of solidarity does not break even if professors and company managers move away. The people who have moved, have “opened the doors in their new home district” for Oulu people. Also Freeman (1991) and Lundvall and Borrás (1999) have stated that common language, educational background, regional loyalties and shared ideologies and experiences play an important role in formal and informal collaboration.

### **6.3. University’s role in medical device development**

The University of Oulu was the most important academic partner for most of the company managers interviewed. Only a few companies also collaborated with other universities. According to the company managers, collaboration with the university has shortened new products’ time to market. Also communication, knowledge sharing and co-operation with the university have increased companies’ competitiveness and promoted innovations.

Although the importance of university-industry collaboration was mentioned many times, company managers also stated that the university could still do more to collaborate with the industry. However, the managers added that collaboration with the university has increased recently. Besides the University of Oulu, the Oulu Polytechnic had an important role in the medical devices development network.

According to Lester and Piore (2004), universities provide a forum for discussion and public spaces for knowledge exchange. The University of Oulu together with the local organizations organizes international and local seminars, conferences and annual meetings for discussion between university researchers and R&D personnel from companies. These meetings focusing on medical device technology development have been an information source for companies and researchers and have stimulated social interaction between the university and industry people.

Even if university-industry collaboration in medical devices development was mainly industry driven, the University of Oulu had an important role in transferring new knowledge to the companies. Both the professors and the managers of the companies mentioned that the most important task of the university is training skilled undergraduates and graduates. Also the finding by Chakrabarti and Lester (2002) that in Finland the universities generally show flexibility in introducing curricular reforms designed to respond to the needs of the industry is supported in Oulu as well. In Oulu, the increasing need for cross-disciplinary collaboration in medical devices development has generated new education programmes between the University of Oulu, the Oulu University Hospital and the Oulu Polytechnic.

### **6.4. Limitations of the study**

The case study method used in this research was appropriate for this study. However, the case study approach and the qualitative research methodology limit the generalizability of the results. The results provide only a sketch of the kind of collaboration that exists between companies and universities and the role of the University of Oulu in medical device technology development in the Oulu region.

Because of the small size of the Oulu region, different methods of finding interviewees could be used. However, the snowball method using a set of focal people instead of a single individual seemed to be the best and fastest way to have all the key participants involved in this study. The interviewees confirmed that the important individuals developing medical devices were the people who had been identified in the snowball sampling. However, if a different method for finding the key people had been used, the sample might have been different. This could affect the results of the study. Also, with a different set of focal actors, the sampling of key people could be slightly different.

In the set of focal actors many people at the University of Oulu, the University Hospital and the Polytechnic were mentioned who were supporting and managing technology development. However, the interviewees in these organizations were more involved in technology development than in supporting and offering resources for development. Therefore the managerial side of the development process is not as strongly represented as it could be based on sample selection by snowball sampling. With more data from the managerial side included, different issues might have been emphasized.

In the first phase the interviewers made notes during the interviews while in the second phase the interviews were recorded which increased the amount of collected data. However, the recording affected some interviewees. Although the interviewing sessions seemed to be open and confidential, some of the interviewees stressed important issues only when the recording had ended. Interviewees stated that these issues were too confidential to record although permission was asked from the interviewees for recording.

The interviews were conducted between 2001 and 2004 when public funding growth was strong and the companies' economic situation was generally good. If the amount of public funding had been smaller and the economic climate different, university-industry collaboration might have been less active than it was during these years.

### **6.5. Scientific contribution**

The results of the study emphasized the informal social networks sharing knowledge between individuals. The study shows that informal interaction in medical devices development has increased idea sharing among companies, and some of these ideas were developed to products as collaborations between companies, the university and other local organizations.

Informal interaction between individuals seems to be at least as important as formal interaction between organizations. Since medical devices are complex systems, one of the key issues has been how to have cross-disciplinary and cross-institutional knowledge exchange between universities and companies (Powell 1990, Gelijns, Zivin and Nelson 2001, Gelijns and Their 2002, Cohen, Nelson and Walsh 2002, Lester and Piore 2004, Siegel, Waldman, Atwater and Link 2004) and how different roles in collaboration promote innovativeness (Chakrabarti and O'Keefe 1977, Rogers 1995, and Chakrabarti and Hauschildt 1989).

However, the roles of the individuals promoting innovativeness in the development of medical devices were different from those of the organizations they work for. The roles of the University of Oulu, the University Hospital, companies and other organizations at the organizational level in medical devices development were clear. The roles of the individuals were more interesting. Some of the focal individuals have the same roles as their organizations in formal collaboration but different roles in informal collaboration. This role discrepancy promotes collaboration between organizations and brings new innovative ideas to the discussion.

#### **6.6. Suggestions for further research**

The interviewees described collaborations in medical devices to be more local than national or international. Even in those cases where the new products were launched directly onto global markets, the interviewees described the collaboration during the innovation process as local. Analyzing how the sense of solidarity in the Oulu region on the one hand increases local collaboration, knowledge transfer and promotes innovativeness, but on the other hand decreases external collaboration and blocks external knowledge transfer could give a different view. The small geographical size of the region and the small size of the population have made it possible to build tight collaboration networks and technology forums covering the different technology areas. The tight collaboration within the networks has been the basis for open collaboration, but it could also block the participation of innovative new individuals and idea generators.

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Information about the National Research and Development Centre for Welfare and Health, STAKES <http://www.stakes.fi/english/>

<http://web.mit.edu/lis/>

