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Knowledge sharing in temporary teams: Exploring the use of 3D printing in orthopaedic surgery

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ABSTRACT

This study explores knowledge sharing in temporary teams which use 3D printing technology to support surgical interventions. We focus on the planning phase of orthopaedic surgeries when senior surgeons organise a temporary team to create personalised treatment using 3D printing technology. We conduct in-depth interviews with 25 surgeons and their teams in one of the leading orthopaedic research hospitals in Italy. Based on our qualitative evidence, we find that when the technology provides a basis for the surgical planning, knowledge sharing in teams mostly occurs through two-way – dyadic – relationships between team participants. Our findings also demonstrate that hierarchy within teams is important to support the formation of dyads thereby facilitating knowledge sharing practices within temporary teams. This study is novel in highlighting how temporary teams deal with knowledge sharing challenges due to the continuous changes in team composition in healthcare.

1. Introduction

Today's organisations are embedded in a complex environment that includes many unexpected events which make continuous changes in work procedures necessary (Edmondson, 2012). In response to this changing environment, organisations arrange temporary teams around projects or tasks, and the teams disband once the projects or tasks are performed. While organisations isolate the changes to smaller parts of the organisation, define tasks, and allocate additional resources on a small scale (Jacobsson and Hällgren, 2016), the temporary nature of relationships among team members can jeopardise work process and knowledge sharing within teams. As the relationships are temporary, team participants do not have enough time to build trust, interact, and share relevant knowledge to fulfil complex tasks (Edmondson, 2012). Therefore, a lack of stable relationships within the teams hampers knowledge sharing practices (Carmeli et al., 2009; Nguyen et al., 2022).

The challenge of temporary relationships is more pronounced due to the use of new technologies that temporarily adds more participants to the teams. Although new participants provide new sources of knowledge and information (Nahapiet and Ghoshal, 1998), they increase the fluidity of the teams (Mortensen and Haas, 2018) and their temporary relationships. In environments where teams create innovative personalised solutions, team participants must exchange and recombine complex knowledge into work practices. The innovative outcome depends on social process, relational strength, and appropriate interactions that result in knowledge sharing (Rouse, 2020; Tzabbar and Vestal, 2015). In turn, a new challenge comes to light when technology adds more complexity to the tasks inviting more team participants, yet demanding more innovative work and knowledge exchange among participants.

Prior studies on team knowledge sharing highlighted that knowledge sharing does not happen spontaneously in teams; rather, team characteristics and processes influence team participants' knowledge exchange practices (Haas et al., 2015; Hansen, 1999). In the same line, team diversity and more agreeableness in communication style of the teams lead to willingness for knowledge sharing among the team participants (Thomas-Hunt et al., 2003; Vries et al., 2006). The studies addressed that longer life span of the team can result in effective knowledge sharing among team participants (Bakker et al., 2006; Sawng et al., 2006). Yet, less attention has been paid to the process of knowledge sharing through temporary relationships embedded in temporary teams.

Our study explores knowledge sharing process within healthcare temporary teams. Healthcare organisations increasingly organise

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temporary teams to achieve desired outcomes (Lemieux-Charles and McGuire, 2006). The complexity of health problems, the pressure of deadlines and the unpredictability of events amplify the use of temporary teams as an integrated part of caregiving practices (Heinemann and Zeiss, 2002). In addition, caregivers do not simply rely on their knowledge but use new technologies to improve the quality of caregiving process. Studies focusing on healthcare settings addressed that the use of new technologies reshapes work relations in complex and unexpected ways (Barley, 1986; Beane and Orlikowski, 2015; Kellogg, 2021; Sergeeva et al., 2020); because new members are invited to contribute the team tasks, provide the relevant knowledge, and use their skills to better handle the technologies (Nembhard and Edmondson, 2006). We focus on teams of orthopaedic surgeons who aim to provide customised treatments using 3D printing technology. Our main research question is: How does knowledge sharing occur in teams in which team membership is fluid and work relationships are temporary? We gathered data in the Rizzoli Orthopaedic Institute, one of the leading orthopaedic research hospitals in Italy, using observations and interviews to qualitatively explore our research question.

Our work offers a threefold contribution to the extant literature on knowledge sharing in teams. The first contribution links to our clarification of how knowledge sharing occurs in the context of temporary teams. Prior research on knowledge sharing has recognised the close relationship between team interactions and knowledge sharing process. Yet, little is known about how the absence of stable relationships among team members can affect knowledge sharing process within teams. As teams become more and more fluid and overlapping, understanding the conditions that enhance knowledge sharing among team members becomes of quintessential importance (Mortensen and Haas, 2018). Moreover, knowledge sharing predicts team learning, innovation, and performance (Vashdi et al., 2013). Understanding the ways through which knowledge is exchanged in teams with fluid members and unstable relationships can have implications for success and outcomes of temporary teams. We also contribute to the role of hierarchy through the exchange of knowledge within teams. There is an open debate in the organisational literature about the role of hierarchy in team dynamics, documenting its positive impact (Bendersky and Pai, 2018; Sanner and Bunderson, 2018; Zaccaro et al., 2020). In some instances, also negative impact of hierarchy has been supported (Gray et al., 2022; Park et al., 2018). Building on the temporary nature of teams, our study contributes to the positive line of research by demonstrating the conditions under which hierarchy generates benefits for knowledge sharing in teams. Knowing the role and the potential benefits of hierarchy can support the formation of teams in which knowledge sharing is more effective. A third contribution we offer is related to clarifying how teams can sustain the use of 3D printing technology in organisations to provide customised treatments. In many industries, nowadays, 3D printing technology offers an enabling occasion for innovative work, but at the same time it requires teamwork and an effective interaction among highly specialised professionals. We unpack how innovative work evolves in orthopaedic teams when 3D printing technology mediates team interactions. This brings insights into theorising the usefulness and drawbacks of the technology at the team level and how influential the technology can be in stimulating innovative work.

2. Theoretical background

2.1. Temporary teams with fluid members

As the nature of work becomes more complex, many organisations tend to use temporary teams to ensure effective functioning in changing environments. Temporary teams are short-lived organisational units that assemble on demand to accomplish very complex tasks, and the teams disband once their tasks have been fulfilled (Valentine, 2018). Typically, participants in temporary teams come together from various organisational units and larger workforce (Kim et al., 2021). Moreover, temporary teams tend to focus on the ongoing tasks, face time pressure, and are not configured for future interactions or long-term efficiency in team processes (Saunders and Ahuja, 2006; Sydow and Braun, 2018). Given the complexity of the tasks temporary teams deal with, many of them are necessarily fluid, with employees moving quickly from one team to another (Dibble and Gibson, 2018; Mortensen and Haas, 2018; Summers et al., 2012).

Although the use of temporary teams helps managers to isolate the changes to smaller parts of an organisation, define tasks, and allocate additional resources on a small scale (Jacobsson and Hällgren, 2016), it also involves considerable fluidity of team participants. The teams experience various compositions over time as they shift from one task to another on weekly basis (Valentine and Edmondson, 2015). While members of the stable teams have the opportunity to interact and work together for a long period of time, temporary teams don't have the possibility to rely on stable relationships due to the fluidity of actors' membership. Yet, participants have to engage in multidisciplinary knowledge, share their skills, connect and socialise, and optimise knowledge sharing activities to perform complex tasks successfully.

Given the specialised nature of teams where complex tasks must be done through intense knowledge work in a short period of time, interdependency of the tasks requires interactions among team participants to facilitate knowledge sharing activities (Kim, 2020; Thommes and Uitdewilligen, 2019). Yet, the fluidity of temporary teams does not allow participants to have enough time to build trust, interact and communicate appropriately about the tasks (Edmondson, 2012). Consequently, knowledge sharing activities become a vulnerable factor and team participants are not able to translate knowledge into teamwork practices (Thommes and Uitdewilligen, 2019). Therefore, the key ingredient of knowledge sharing is the trust that team participants progressively build over time through repetitive interaction and familiarity (Levin et al., 2002), which is instead missing in temporary teams.

2.2. Knowledge sharing in teams

Knowledge sharing is defined as the process intended "either to create new knowledge by differently combining existing knowledge or to become better at exploiting existing knowledge" (Christensen, 2007: 37). Knowledge sharing is important for the success of teamwork for several reasons; it creates access to diverse sets of knowledge, expands the scope of available knowledge, and facilitates innovative work (Carnabuci and Operti, 2013; Fong et al., 2018; Hargadon and Sutton, 1997). The importance has led scholars to take various viewpoints through knowledge sharing within teams.

One critical stream of research sheds light on the link between knowledge sharing and team outcomes by considering knowledge sharing as an input, and investigates its impact on team innovation, effectiveness, and performance. Prior research demonstrated that knowledge-sharing occurs as a type of social-exchange behaviour (Wu and Lee, 2017) and social processing and impacts team outcomes (Imran et al., 2018; Neeley and Leonardi, 2018). Furthermore, knowledge sharing behaviours can create enabling environment for innovative work and successful performance in teams (Mura et al., 2013).

Other studies have instead considered knowledge sharing as an outcome of team process. This literature heavily relayed on the impact of expertise, creative-thinking skills, diversity, rewards and intrinsic task motivation as the main building blocks of innovative work and knowledge sharing behaviours (Amabile, 1988, 1996; Bodla et al., 2018; Wang et al., 2021). Inclusive environment can promote social inclusion, therefore impacting on knowledge sharing (Nishii, 2013). This argument suggests that the formal structure of teams is a relevant antecedent for knowledge sharing (Bresman and Zellmer-Bruhn, 2013), and that the formal team structure can promote innovative work by increasing knowledge sharing among team members (Valentine and Edmondson, 2015).

A third argument has conceptualised knowledge sharing as a team process. Taken together, these studies have characterised the process as a set of observable individual behaviours (e.g., attention, detection, assessment) emerging within teams. Knowledge sharing at the team level is the result of individual collaborative behaviours among team members (Klimoski and Mohammed, 1994; Wildman et al., 2012; Zheng et al., 2019). Collaborative behaviours include interactions among members, but also conversations, communication, and coordination aimed at helping team members to meet overarching team goals (Mathieu et al., 2005).

The link between knowledge sharing and team interactions has been documented in prior research. Less knowledge is available about how the temporal characteristics of interactions and relationships among team members are relevant for knowledge sharing in teams. Recent studies suggest that also technological tools and procedures used to support tasks predict knowledge sharing and creation in teams (Choo et al., 2007). When participants work in a knowledge-intensive environment the use of new methods likely influences team members' judgment, motivation, level of stress, which in turn will affect knowledge sharing efficacy (Cui et al., 2019; Edmondson, 1999; Edmondson et al., 2003).

2.3. Emerging technologies and knowledge sharing

The introduction of emerging technologies as an element of social context reshapes the organisation of work (Barley, 1986; Orlikowski and Barley, 2001). It first challenges the existing patterns of work and then re-formulates work procedures (Barley, 1986). Recently, the use of emerging technologies such as artificial intelligence, digital platforms, robotics, social media, blockchain, and 3D printing is continuously reshaping human action and interaction at the different levels in organisations (Bailey et al., 2022; Massaro, 2021; Sergeeva et al., 2020; Spanò et al., 2021). The technologies are called "emerging" since they are still changing in the wat they're adopted, yet there is no stable pattern for their utilisation (Bailey et al., 2022). The link between knowledge sharing, emerging technologies and innovative work has been investigated in prior research, which has documented that technologies enable individuals to engage in innovative work, recombine knowledge, and generate new ideas (Bailey et al., 2022; Edmondson et al., 2001; Manley and Williams, 2022; Silva et al., 2021).

A growing body of literature has started to investigate the impact of emerging technologies on communication and knowledge exchange ties among individuals (Cascio and Montealegre, 2016; Leonardi and Barley, 2010; Orlikowski, 2007; Orlikowski and Scott, 2008). Evidence suggests that the use of emerging technologies brings significant changes to individual work including the reconfiguration of job tasks, the need of knowledge codification, as well as the reduction of experience-based skills (Massaro, 2021; Sergeeva et al., 2020). At the same time, new technologies likely interrupt existing behaviours requiring refinement and change of established routines (Narayanamurthy, 2022). Moreover, the adoption and use of emerging technologies often require the creation of new knowledge, including "social knowledge about who knows what" (Edmondson et al., 2001). This requires new behaviours aimed at seeking alternatives through the implementation of the technology. In this regard, the more or less stability of ties among users affects innovation and change (Beane and Orlikowski, 2015; Edmondson et al., 2003).

Although the adoption of the emerging technologies has made organisations more mature (Shaygan and Daim, 2021), concerns about the challenges imposed by emerging technologies on the team based structures are increasing. Evidence from existing literature confirms that emerging technologies affect the existing patterns of relationships, coordination and knowledge sharing within teams, therefore affecting team success. With the potential for such changes in relations and scope, new questions about the interplay between emerging technologies and temporary work groups were arisen (Bailey et al., 2022). In this paper, we explore knowledge sharing processes occurring in temporary teams that rely on a new emergent but still scantly explored technology - i.e., 3D printing technology - to perform surgical tasks.

3. Methods

Given the exploratory nature of our research question, we conducted a qualitative field study to explore temporary teams' dynamics. Hence, the single case study methodology was well suited to our goal. The method allows a deeper exploration of team interactions and knowledge sharing within this specific type of teams where team participants do not have enough space and time to build stable relationships.

We were interested in retaining real-life characteristics of the context such as individual behaviour, team interactions, and membership change which frequently occur in temporary teams. Moreover, context is an important component in our study that cannot be neglected. Thus, hospital setting was selected as the setting where temporary teams are increasingly organised to make decisions on complex tasks. In addition, the single case study approach constitutes the context in which real-life phenomena are embedded (Yin, 1994). Building on this, our units of analysis were teams formed at the planning phase of orthopaedic surgery where the orthopaedic surgeons decide to provide a personalised treatment for the patients using 3D printing. The technology is important since it enables orthopaedic surgeons to personalise the treatment for a unique patient, on the other hand it brings complexity to the work of teams by adding more participants with different specialities (engineers, biologists etc.).

3.1. The case of 3D printing technology in Orthopaedic surgery

The fundamental idea of 3D printing technology is to create a part by adding material layer by layer, each layer on top of the previous layer (Ventola, 2014), which is a quicker and cheaper mechanism to design and create highly personalised products to meet patient needs. The technology started to play an inevitable role in producing custom-made implants and improving personalised treatments, proving its full potential in orthopaedic surgery.

The reason that leads us to consider 3D printing technology as a complex technology derives from the characteristics of the technology and its applications in orthopaedic surgery. First, it demands more innovative work (Chaudhuri et al., 2022) as the outcome of the technology should be a customised implant characterised by every patient. Fig. 1 shows the different steps adopted for customised implants using the case of the vertebral column as an illustrative example. Spinal tumour extension is depicted with the circle in picture A, meaning that the single vertebra has been destroyed by the tumour and should be removed to protect the whole vertebral column. After removing the damaged vertebra, the empty space should be replaced by an object similar in design to the vertebra. Picture B shows the simulated object made by 3D printing technology to replace the damaged vertebra (affected by the growing tumour). The object should find the best fit with the whole vertebral column and the best connection to the vertebral column from the top and bottom (labels 1 and 2 indicate the linking points). A superior view of the open surgery in picture C depicts the position of the implant within the vertebral column. Picture D implies MRI illustration of the final reconstruction of the vertebral column. The procedure reveals that there is a lot of innovative work in the surgical planning phase, which differs from one body part to another. Surgical tasks are quite complex requiring different knowledge and expertise among team participants in orthopaedic teams.

Secondly, starting from picture A moving to pictures B and C, and then reaching picture D, the surgeons confront several limitations which cannot be solved with their medical/clinical knowledge. The skills and knowledge of computer designers, bioengineers and external partners are required to produce the implant represented in picture B. Surgeons go to the operating rooms due to their collaborative work with engineers at the planning phase. The procedure heavily relies on image

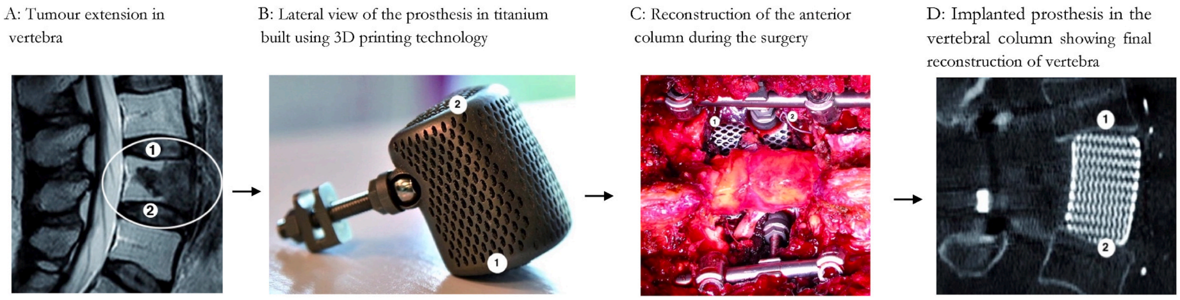

Fig. 1. Process of vertebral body reconstruction (Girolami et al., 2018).

acquisition, segmentation, file optimisation and material selection; beyond all these procedures, shared understanding and consultation among surgical teams and engineers are clearly required. This is a complex procedure that requires a considerable number of back-and-forth practices and knowledge sharing to create personalised implants. Apart from all the complexities brought to the work of surgeons, the technology enables orthopaedic surgeons to rapidly create customised implants at low cost (Ballard et al., 2020). Therefore, the entire process presents an ideal context to explore knowledge sharing at the team level.

3.2. Research setting

Our study was performed at the Rizzoli hospital in Bologna, a highly specialised research hospital in the field of orthopaedics and traumatology in the Italian national health system. A distinctive feature of this hospital is the close integration between research activities and patient treatment services, which are carried out by nine translational research laboratories and six industrial research laboratories that overall employ about 250 people, including doctors, biologists, engineers, and other professionals. Every year, it counts more than 150,000 admissions and carries out more than 20,000 hospitalisations, most of which are of the surgical type.

Engineers, physiatrists and surgeons synergistically work together in the Laboratory of Movement Analysis. The laboratory uses state-of-the-art instruments to make objective measurements of human movement, such as stereophotogrammetry or inertial sensors, and the internal and external forces generated during movement through force and pressure platforms and surface electromyographic systems as well as 3D printing technology.

The surgical teams consist of three levels of hierarchy: 1) the head of the unit (HU), that is a surgeon who makes the final decision and is primarily responsible for patient health. The HU is a highly specialised orthopaedic surgeon and decides upon the use of 3D printing, prostheses compatibility and the external participants who manufacture the final implant; 2) the team leader (TL), who holds the middle level of hierarchy and contributes to the decision-making procedures and is responsible for supporting activities; and 3) the team members (TM), doctors who are in close contact with the patients, conducting daily checks and follow-up controls, and are only partially involved in the decision-making process.

Each caregiving practice starts with an orthopaedic problem stated by a patient. The patient is hospitalised in one of the clinics based on the anatomical area of the problem. After a problem has been presented to the team, the HU recognises the potential utilisation of 3D printing technology for the specific clinical case by assessing its potential benefits for the patient. Then the HU starts forming the team by inviting colleagues specialised in the field, bioengineers (from the Laboratory of Movement Analysis) who are experts in the application of 3D printing, as well as experts in other internal labs and hospital divisions, such as biology and radiology. In addition, people from companies and manufacturers (external participants) join the teams to ensure the supply and quality of the material, the manufacturing process and the creation of the final implant. The whole process including patient hospitalisation, team staffing, and utilisation of 3D printing is illustrated in Fig. 2.

The Rizzoli hospital is among the first institutions to realise the potential of 3D printing technology to provide customised treatments for rare diseases in the Italian National Health Service. In our setting, the anatomical area of the clinical cases treated with the support of 3D printing technology involved knee, pelvis and hip, ankle, elbow, spine and thorax. However, the majority belonged to Pelvis and hip surgery (Table 1; Appendix). In terms of pathologies, the application of 3D printing is highly beneficial in cases in which the patient suffers from tumours and bone loss (Table 2; Appendix). 3D printing technology supports surgeons in finding the best position for osseointegration and the best fit between the bones and the implants.

The adoption of a single case design with a single unit of analysis was deemed appropriate in our study (Yin, 1994). Our setting includes three main clinics, each specialised on a particular anatomical area. We focused on teams staffed in the three clinics who are responsible for the treatment of clinical cases belonging to their area of specialisation to provide customised treatments to patients with the support of 3D printing technology.

3.3. Data source

Our fieldwork started in June 2019 by contacting the laboratory of movement analysis and moved forward after receiving official permission to enter the field and start data collection over a period of 22 months. The sources of data include group interviews, focused observations, and individual semi-structural interviews. During this period, six group interviews with 25 overall participants were conducted, followed by observation of team meetings (of the same teams) at the end of each interview session. Each group interview included one HU (Orthopaedic surgeon), one TL (Orthopaedic surgeon) and a bioengineer, although in some cases, team members participated in the meetings. Decisions on the participants were based on the real workflow in the hospitals, and the authors involved in data collection did not make any choices about team meeting participants. Details related to the participants and composition of the group interviews are reported in Table 1.

We used group interviews as the main tool to gather data for two main reasons. First, our respondents were surgeons who are extremely engaged with their responsibilities. Due to their busy lives, they are always occupied and unavailable to participate in the interviews. Therefore, group interviews were an excellent mechanism to bring us closer to more respondents within a shorter timeframe (Frey and Fontana, 1991). Second, as this study focuses on medical teams, we arranged the group interviews so that clinicians from the same teams could come together and be kept at the same level of hierarchy. Therefore, we had the opportunity to observe the real teamwork environment as well as to capture actual interactions, behaviours and team dynamics.

Our semi-structural interview protocol was designed after preliminary-individual interviews with the director of the laboratory of movement analysis. The questions were categorised into three parts: the first part included general questions about decisions on choosing 3D

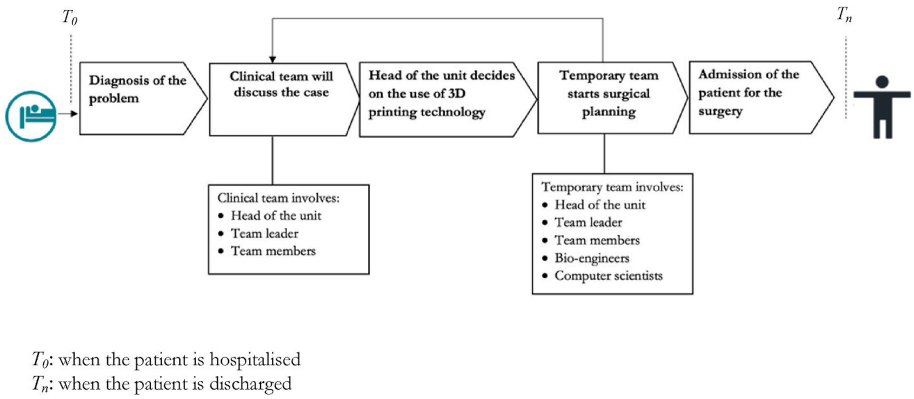

Fig. 2. The process refers to team formation and care giving process in Rizzoli Orthopaedic Institute.

printing as an underlying technology for surgical planning such as: Who makes the decision on the use of 3D printing technology? The second part included questions on organising team meetings, interactions during team meetings, follow-up/informal interactions and the types of the interactions (offline/online) such as: How often do you organise team meetings? The third part included questions on problem solving process, challenges through problem solving, and if there is any opportunity for knowledge sharing. For instance: What is your first reaction when you confront a problem? Although it is not clear how many team meetings are organised to decide about the cases, rather the follow-up meetings depend on the results concluded during the first meeting. Therefore, we scheduled our group interviews right before the team meetings to have the opportunity to observe team meetings after group interviews.

After each group interview, the teams discussed the clinical cases at hand and the treatment plans. We were thus able to capture the actual patterns of communications occurring within the teams. Our aim to perform observations right after group interviews was two-fold; first, we were able to access the same teams that had been interviewed, and second, we were able to observe and find support for the identified concepts during the interviews. A set of specialists, three levels of hierarchy (HU, TL and TM), together with bioengineers (engineers from the laboratory of movement analysis) and one of the authors, were present during group interviews and the author aimed to capture all the interactions among team participants and to recognise if the interactions implied a meaningful contribution to the study.

As data collection and analysis were parallel procedures, we started coding the data after the first group interview, and preliminary themes emerged from the data.

3.4. Data analysis

We adopted an inductive study approach following the Gioia methodology (Gioia et al., 2013). According to this approach data collection, coding and analysis are highly intertwined. Therefore, we were able to move back and forth around the subject giving us a good understanding of the concepts and their relationships. However, the data collection and analysis parts were integrated, thereby providing the opportunity to handle better the message delivered by data (Corbin and Strauss, 2014; Gioia et al., 2013). As we continuously moved back and forth between our field notes and interview transcripts, new ideas came up from the data and we were able to validate them through observations. For instance, since we started to code the first interviews, we recognised that more informal interactions occurred corresponded to more follow-up meetings scheduled for complex and severe cases. Therefore, in subsequent interviews, we asked our informants to comment on the severity of the cases they discussed, and we kept track of follow up/informal interactions.

In the early stage of analysis, we integrated qualitative data from group and individual interviews (interview transcripts) and our field notes from observations. After multiple readings of the data, the data imported in NVivo (NVivo 12) and data coding was started. In open coding phase, we identified themes and concepts in our data and grouped them into categories. We were interested in identifying opportunities and behaviours associated with knowledge sharing within the teams. In particular, we were looking for behaviours such as seeking feedback, sharing information, asking for help, talking about errors and experimenting (Edmondson, 1999) which bring the knowledge to the surface and make participants to reflect. Therefore, we performed line-by-line analysis of our data to generate categories, keeping the following questions in mind: What does this relationship suggest? Does this relationship result in knowledge sharing at the team level? How is it related to 3D printing technology? Why did it occur?

Once the text opened and concepts were labelled, we realised that certain concepts could be categorised under one unique and higher concept (axial coding). Categorisation of the concepts was gradually started based on the reasons which cause the behaviours/opportunities and labelled according to the logic behind each (first-order codes). Then we selected the core categories relating major categories to them (selective coding). Grouping concepts into categories is beneficial because it enables us to reduce the number of concepts. Fig. 3, summarises these steps in the columns labeled "first order codes" and "second order codes".

Having been identified two levels of the codes, we looked for the relationships among first- and second-level codes to answer the following questions: Where is the source of these relationships? How do they emerge? In other words, we were looking at the stream of interactions among team participants to explore the origin of the relationships, meaning, the starting point of the interactions as well as the end point and when the topic of interactions changed. The results of this categorisation revealed the source and opportunity for knowledge sharing in the data. Fig. 3, summarises these steps in the column labeled "setting where the knowledge is situated".

As mentioned at the beginning of this section, in a preliminary stage of coding, we realised that the interactions varied from one team to another team as the problems with the patients changed. Based on the complexity of the clinical cases, some teams concluded to move further steps, some of them organised follow-up team meetings and informal meetings. Therefore, we asked team leaders to comment on the severity of the cases they have treated with the support of 3D printing technology. Precisely, we asked TLs to code each case and rate the severity of the case by asking: How do you rate the severity of this case from 1 = the least severe to 10 = the most severe. The aim was to investigate how follow-up interactions correlated with the severity of problems.

4. Findings

By including contextual hierarchies in our group interviews during the surgical planning phase, we investigated temporary relationships that result in knowledge sharing; then we investigated the source and

Table 1
Source of the data and use of the data in analysis.

Data source	Type of data	Participants	Data use in the analysis
Group interviews followed by observations on team meetings (6 focused groups)	Voice record of the conversations, field notes from meeting attendance, number of participants and their role, their position in the meeting, and their movements. Visual documentation, materials and artifacts used during the meetings. Field notes on the type of relationships, visual materials supporting the relationships considering the roles in the teams.	Group 1: 6 participants (Team leaders, team members, bio engineers) Group 2: 4 participants (Head of the unit, team leaders and bio engineer) Group 3: 3 participants (Team leader, bioengineers) Group 4: 3 participants (Head of the unit, team leader and bio engineer) Group 5: 4 participants (Head of the unit, team leaders and bio engineer) Group 6: 5 participants (Head of the unit, Director of the unit, team leaders)	*Group interviews:* • To identify and understand the behaviours and relationships • To validate and confirm the concepts identified during previous observations and semi-structural interviews. *Observations:* • To identify the main actors and roles in the team. • To understand the pattern of real practices during surgical planning, facing the problem, material choice, and meeting deadlines. • To become familiar with the subject of the conversations and flow of knowledge in each single stage. • To become familiar with the process of exchanging ideas and knowledge.
Individual Interviews (17 preliminary and semi-structural)	*Preliminary interviews (5)*: Voice record of all the interviews, field notes from meeting attendance, record of social interactions, and use of artifacts, pictures and virtual bodies in their offices. *Semi-structured interviews (12):* Voice record of all the interviews, field notes from meeting attendance, record of social interactions. *Informal interviews:* Authors' notes related to the interactions among main actors in offices, hallways, and coffee bar of the hospital	• CEO of the hospital, Director of the Trauma clinic I, Site manager of the Oral and Maxillofacial Surgery of the external unit, and mechanical engineers. • Director of the Movement Analysis Laboratory. • Biomedical Engineers (2 people) • Research consultant • Associate Professor in Physical Medicine. • Orthopaedic Surgeon (7 people) • Head of the Oral and Maxillofacial Surgery department • One of the authors had a workstation in the hospital for one year during the field study. Therefore, she had opportunity to spend time with the managers, designers, engineers, and support staff.	• To become familiar with the context and provide a basis of work procedures in orthopaedic surgery. • To investigate the history, nature of teams, type of printers, number of printers available in the setting, number of staff members and general work processes. • To improve our understanding of the starting point of the clinical problems, team dynamics and team-related decisions • To identify the main learning behaviours before and after utilization of 3D printing technology

potential of the relationships for creating knowledge sharing opportunities. All the experts on the team complement each other by sharing directions for an innovative solution. The results of our study suggest that the links established by two individuals (dyads) within the teams are particularly relevant to the creation of knowledge sharing opportunities. The dyadic relationships that temporarily link two participants at the team level show the capacity to surface the knowledge stored in participants' minds. As information travels through dyadic relationships, all the participants within the team are able to capture and learn the knowledge from the dyads. Although the relationships are temporary and the uniqueness of the organisational culture in the healthcare context does not allow top-level surgeons to speak up and share their questions and doubts (Edmondson et al., 2003), there is an underlying process of dyadic relationships that facilitates knowledge sharing. Hence, the teams do not follow question and answer interactions; rather, they share their knowledge through complementation and reflection. The dyads embedded in the temporary teams carried out the most important part of the surgical planning phase. Two types of dyads were revealed in our observations, each composed of two types of ties: Head of the Unit (HU)-Bioengineer dyads, including Head of the Unit (HU)-Bioengineer ties and Bioengineer-Head of the Unit (HU) ties; and Head of the Unit (HU)–Team Leader (TL) dyads, including Head of the Unit (HU)-Team Leader (TL) ties and Team Leader (TL)-Head of the Unit (HU) ties. The reason to differentiate the ties based on the role of who is initiator of the tie is due to the type of the data being shared on each tie as well as the way the main actors approach their tasks. We realised that the potential of the dyads to enable knowledge sharing activities depends on the hierarchical order of the participants who start the ties. In addition, since the aim is to plan innovative and customised surgery, all the interactions were under the theme of 3D printing technology and its functionality.

Moreover, we observed the importance of the hierarchical structure of the teams to create knowledge sharing environment. Data from group interviews and observations confirmed that when the use of 3D printing technology intervenes in team interactions, the hierarchical structure of the teams plays a more active role in facilitating dyads formation. Newcomers (in our case including engineers and 3D printing technology experts) bring different perspectives and ideas to the team that can challenge the existing standard routines of the teams. Thus, the hierarchical structure of the teams supports team participants in understanding when to value, pay attention and contribute to the source of knowledge. We observed that the HUs helped to form dyads among team participants by keeping the functionality of 3D printing as the background scenario. TLs served the surgeons with information related to the patient's status (if they were asked) and attempted to regain their position as active members. Interestingly, the HU kept its leading role at the top level during the team interactions, and all the dyads moved on a unique path to serve the HU as the main actor. The key points in the dyadic relationships pattern were the fact that even if the HU was not a part of the dyads, the two parts of the dyads looked for feedback from the HU.

In other words, HUs play a central role in starting a meaningful pattern of knowledge sharing by giving direction and an overview of the desired outcome of the clinical cases. Building on this, we focused on the

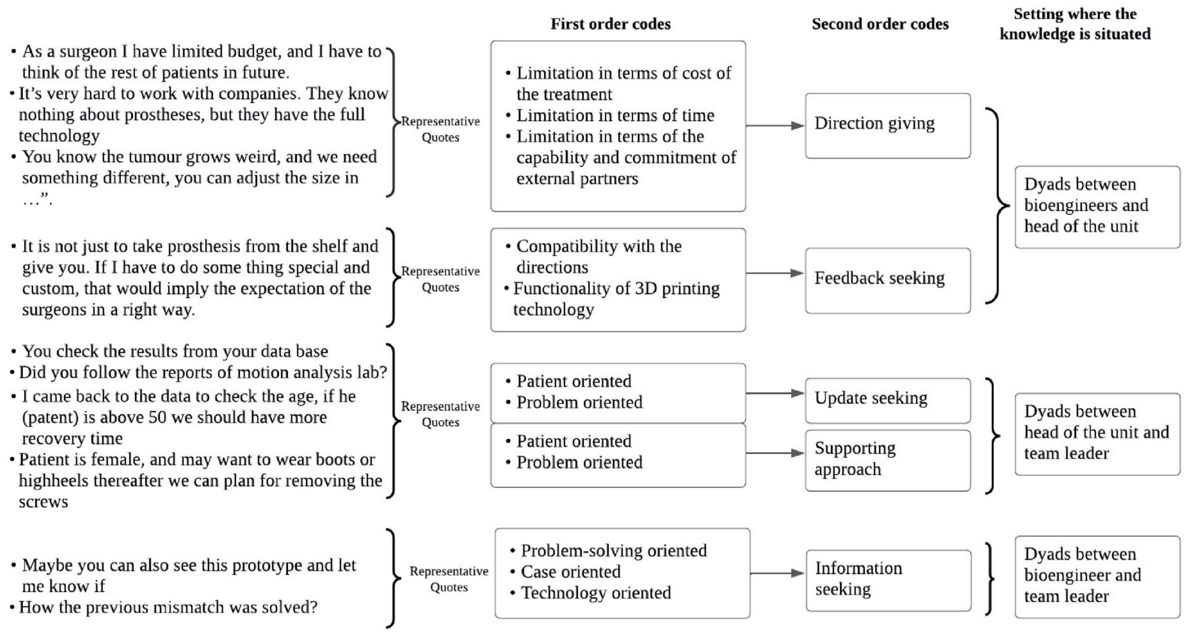

Fig. 3. Qualitative coding scheme.

interactions between HUs, TLs and bioengineers to detail the relationships and interactions.

4.1. Head of the unit (HU) - team leader (TL) dyads

This dyad includes HU-TL and TL-HU ties formed during team interactions. Focusing on dyads between HU and TL, the tie can be started by the HU (HU-TL) or TL (TL-HU) with different aims. Through these relationships TLs have a chance to update the HUs about the requested information by presenting medical data and lab results. However, the HUs represented an update-seeking approach while TLs maintained a supporting approach in providing information to HUs. In turn, HUs paid considerable attention to each item of data presented by the TLs, meaning that they processed all the data to make the decision.

In addition, the structure of the teams seemed flat with no evidence of hierarchy or organisational status difference during patient-oriented dyadic relationships. Continuous and relevant participation from the surgeons concentrated on a specific topic emerged from the beginning and steadily moved forward. Interestingly, no directions were provided by the participants, rather sharing and reflection approach was followed by the participants (mainly TLs), and all the surgeons had a chance to approach the topic of discussion providing the HU with information.

4.2. Head of the unit (HU)-Bioengineer ties

The HU initiated the tie by representing the case concerning the information emerging from the HU-TL dyad, followed by the criteria he/she expected from the 3D printing technology. The expectations were presented in terms of the initial idea or plan of the surgery through a direction-giving approach. We realised that the plan presented was almost manageable from the bioengineers' viewpoint, meaning that the HU had enough knowledge and a clear understanding of the technology originating from his/her prior experience.

Surgeon 1: 3D printing is clear and straightforward; I already know what I can do with the technology for any particular case.

However, direction-giving is not only a representation of the initial ideal treatment for the patient but also the creation of the idea building on the limitations with which the HU was confronted. The HU faces three types of constraints which form the direction-giving approach indicated by the HU. The first constraint is the cost related to the 3D printing technology.

Surgeon 2: It is complex and needs very tight efforts from the engineers. And the steps from the 3D printing are not yet well standardised, it makes the cost and time complications in producing phase.
Surgeon 3: As a surgeon, I have a limited budget, and I have to think of the rest of the patients in future.

The second limitation comes from the time consideration. Most of the cases are required to be promptly and quickly treated to prevent the situation from getting worse. The situation is more problematic in very severe cases of tumours and bone loss. If surgeons do not react quickly enough, they risk the life of the patient as well as the efforts the team has made.

Surgeon 4: In terms of deformity, we use this technology to plan and study. The patient can still survive with the deformity, so time is not the main problem here, but the sooner the better.

You know the tumour is growing so fast. Sometimes, this could be a big problem because while we are planning and discussing the construction of the device or implant, the tumour grows on the other hand, and the solution which is efficient today is not good for tomorrow.Sometimes the patient receives chemotherapy before the surgery; therefore, we have time to plan. But if you have increasing growth of the tumour, you are obliged to perform very fast.

The third limitation originates from the capability of the external partners. We found that the HU-Bioengineer ties are not limited to their internal collaborations but also to external units and how to deal with the companies to obtain a perfect outcome. Although the bioengineers were more specialised in using the 3D printing technology, the surgeons played more active roles in communicating with the manufacturing companies, which again highlights the importance of hierarchy.

Surgeon 5: They know nothing about prostheses but have the full technology … the only things they do are sell and produce and the certification and administration.

There is a discussion between us and companies. Companies say this is *the standard prosthesis from the shelf but I can do something more special for you, and you have to pay more than normal. In fact, this is very difficult to do for your budget and for everything.*

The best thing for us as surgeons is to have a joint venture with one company that is not interested in getting money from the health sector, like NIKE, FERRARI and LAMBORGINI. One that is interested in sharing the technology with others.

Having considered the limitations, the HU created the initial plan and represented the directions to fulfil it. In this phase, non-verbal interactions from the HU became more evident to clearly highlight what exactly was expected from 3D printing technology. As the HUs elucidated the main plan for the bioengineers, they started moving around, pointing to the specific parts of their bodies and making specific shapes using their fingers to better explain the process of fusion. However, these movements never occurred in the interactions among HUs and TLs. The reason for this is the fact that clinicians are trained to understand the vocabulary of surgeons in team meetings with no need for clarification, but this is not true for bioengineers. Another interpretation could be that although surgeons (HUs in our study) indicate a willingness to accept bioengineers' technological preferences, they do not expect bioengineers to have knowledge of anatomy, pathology and symptoms of the disease.

4.3. Bioengineer-Head of the unit (HU) ties

The ties initiated from the bioengineers' side indicated a feedback-seeking approach. However, the ties were not immediately formed after receiving the directions; rather, the bioengineers took pauses to think and process the information and present the solution based on the resources they had at hand that were a) compatible with all the directions, and b) manageable with the functions of 3D printing technology.

Surgeon 6: The tailor-made prosthesis forces you to think more about the case.

3D printing is all about planning. If you plan well, I believe the 3D printing is much easier, more straightforward, you are going to revise the final outcome through the position of data, after that you see the model that you use to make the final object.

4.4. Bioengineer-team leader (TL) ties

In our setting, very few Bioengineers-TL ties were formed; however, among the few observed ties, bioengineers were the ones who began the formation of the ties. The ties were different in some features. First, the tie was formed following the formation of the HU-Bioengineer ties. In addition, bioengineers started the tie by information-seeking behaviours to make sense of the situation. The tie was disentangled by the immediate formation of the Bioengineer-HU ties. Second, the team leader had the information-giving role. However, the information generated by team leaders was not technology but related rather patient related, which made the bioengineers pause and reflect about the HU.

We referred to our data on the severity of the case treated by the teams to investigate the relationship between the severity of the cases and formation of the Bioengineers-TL ties. Based on our data (Table 3 in Appendix), Bioengineer-TL ties formed in more severe cases. In other words, more severe cases call for more collaborations and interactions which are not necessarily at team meetings. However, the probability of follow up and informal interactions steadily increased in line with the increasing trend of severity. This suggests that the ties are more sensitive to the complexity of the cases considering the severity and the knowledge required to plan the surgery.

As the cases became more severe, teams established more relationships with bioengineers. The relationships did not appear within team meetings but were rather informal interactions between team leaders and bioengineers after team meetings. This concept was also supported by the data from group interviews.

Surgeon 7: I just have a phone call and say: ok we have a complicated case and I want to discuss about this patient, please come and let's have a 1 hour or 2 hours to look at this. In fact, for me, formal meetings are important, it is important but I cannot say it helps the most.

Surgeon 8: I would say informal conversations, phone calls and exchanging emails help me to resolve the problem more than formal conversations. I would say the very friendly conversations make us to exchange the information.

In our setting, the fear of failure is higher in more severe cases; thus, the HU allows the formation of more ties beyond team meetings. When the HU confronts severe cases, he/she leaves the floor to the others, and the bioengineers have greater courage to speak up and bring team leaders on board. The impact of prior collaborations was also slightly observed. Based on the field observations and the data from interviews, the ties between bioengineers and team leaders were stronger if they had worked on cases using 3D printing since the ties appeared continuously and seemed to be continuous for the follow-up practices. Fig. 4 outlines dyadic ties and knowledge sharing approaches emerging within the observed teams.

5. Discussion

The results of our study demonstrate the following. First, in temporary teams with fluid membership dyadic relationships represent the building blocks of collective knowledge sharing. The reason is that as dyads are established for a specific purpose, participants feel safe to share their knowledge to achieve a short-term purpose. In this line, hierarchy assists team members in defining and outlining the way the whole team make progress towards a solution. This becomes more evident when the team is engaged in complex tasks demanding innovative work and procedures. Based on our field study, as knowledge flow happens through dyads, dyadic relationships can reduce the negative impact of temporary relationships on the overall process of knowledge sharing within teams. Team members who engage progressively in dyadic knowledge sharing relationships tend to acquire and better integrate other colleagues' knowledge and expertise. The importance of the dyadic relationships lies in the fact that information is shared in a "step-by-step" fashion creating synergy in the knowledge sharing activities at the team level. Our findings also suggest that hierarchy facilitates the formation, integration and analysis of the information by putting team participants in dyadic relationships. The top level of the hierarchy (in our case, the HU) plays a leading role in facilitating dyadic relationships and ties within temporary teams. Overall such findings align with the extensive team literature indicating that the hierarchical structure of teams can be beneficial to team success.

5.1. Theoretical implications

Our first implication is related to the literature on team knowledge sharing by examining the challenge of temporary relationships caused by the participants' fluidity and their role on knowledge sharing. The results suggest that dyads are important in knowledge sharing activities. The team literature has approached dyads from several viewpoints, such as leader-follower, member-member and co-worker-co-worker relationships, and much of what has been learned is relevant not only to person perception, attraction, similarity, personality, values, liking and respect but is also relevant for learning dynamics in organisations. Recently, the potential of dyads and their impact on joint task performance have been highlighted by several scholars (Casciaro et al., 2021; Liden et al., 2016). Our study suggests the contribution of the dyads in the context of temporary teams. There are several reasons to believe that dyads play an important role in knowledge sharing. First, each

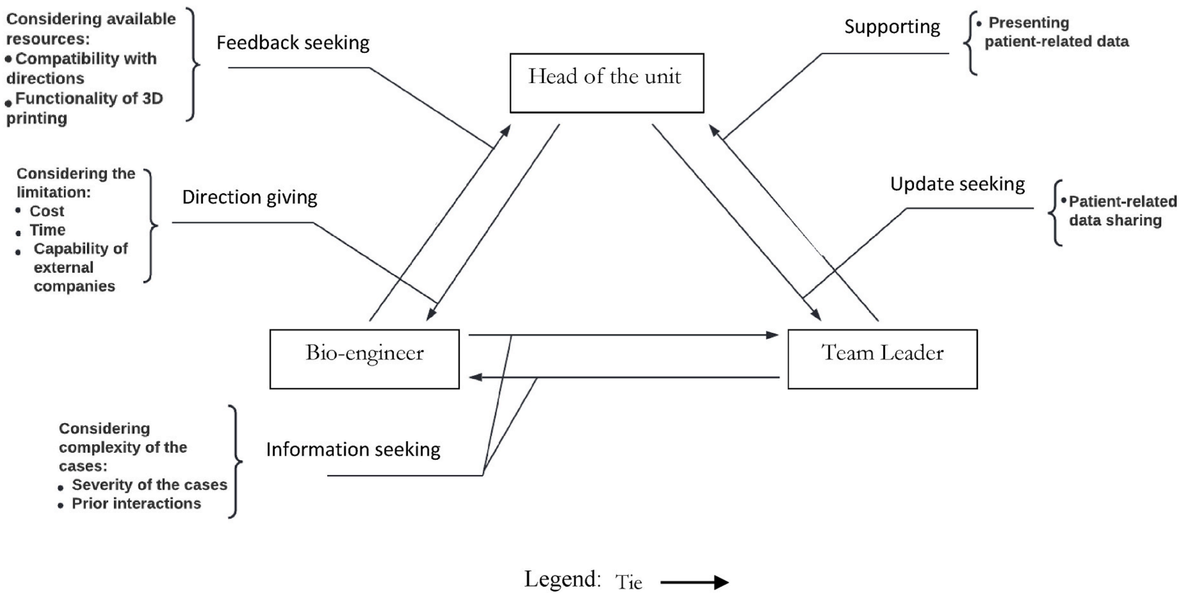

Fig. 4. Knowledge flow through dyadic relationships and ties.

participant directly contributes to the sharing process and information flow. Secondly, the boundaries around the dyads are strict and closed, making the knowledge sharing process focused and relevant. Moreover, participants will feel less uncertainty and fear of judgment through dyadic relationships (McGrath, 2015; Moreland, 2010; Rouse, 2020). Dyads are formed and dissolved based on a particular purpose, and there is less need for strong trust, commitment and socialisation which are the main challenges to the knowledge sharing in temporary relationships. Therefore, the unique role of dyadic relationships in compensating the absence of long-term and stable relationships highlights the importance of theorising their impact on knowledge sharing process.

Moreover, dyads are formed for the purpose of knowledge sharing. But it is also important to understand to what extent the dyads trigger knowledge sharing. The quality and frequency of the dyads are relevant to the complexity of tasks the team deals with. The more task complexity, the more informal is the nature of dyadic relationships established, which in these cases tend to be developed also beyond the formally scheduled meetings. Since these types of dyads are established for a specific aim and follow a clear process; they open a new source of knowledge to the innovative work of their teams. Informal dyads can continue for a longer period of time, beyond team meetings, and explore divergent solutions to manage complexity. Therefore, we advance the findings of our study by arguing that the interplay between formal meeting dyads and informal dyads is the key to resolving the complexity of tasks. The combination of within-team dyads and informal dyads creates the opportunity for knowledge sharing and innovative solutions to the problem. Moreover, attention to the type of dyads and their relation to the complexity of tasks adds value to the literature on intimate co-creation (Rouse, 2020) by focusing on different types of dyadic relationships in the context of temporary teams.

By addressing these issues, this study also contributes to the literature on hierarchy which attempted to clarify the impact of hierarchy on knowledge and information sharing in teams (Gray et al., 2022; Matusik et al., 2021; Widmann and Mulder, 2018). Although literature on hierarchy agrees that hierarchy can be less beneficial for team functioning in teams with flatter structures (Anderson and Brown, 2010; Bunderson et al., 2016), what we still do not know is the link between hierarchy and participants' knowledge sharing activities. We argue that knowledge sharing does not happen voluntarily; hierarchy is a relevant mechanism leading team members to share their prior experience and knowledge. This study adds theoretical insights to the debate on the beneficial impacts of hierarchy on knowledge sharing practices initiated by team participants. Knowledge sharing requires collaboration, trust and familiarity among team participants (Levin et al., 2002). In temporary teams, however, the fluid participation of team members reduces their opportunity to rely on common experiences, which in turn reduces learning opportunities and innovation. Hierarchy helps team participants to find people who are knowledgeable in a particular area, guiding them to share knowledge with others.

Eventually, considering fast-changing environment, ranging from technology, economy, and socio-political context, disaster and pandemics; healthcare systems face with constant challenges. There is a need for healthcare organisations to have a proper strategy, not only to benefit public, rather to offer high quality care in the changing environment by boosting their internal practices. It seems the concept of antifragile strategy (Cobianchi et al., 2020) in developing knowledge management strategies can provide advantages for healthcare organisations. Given that dyadic relationships are the key components of knowledge sharing process, healthcare organisations will be able to secure their individual and collective knowledge by supporting the formation of relevant dyads.

5.2. Practical implications

This study has implications for the healthcare context in which temporary teams are central in everyday practices. Considering the dyadic dynamics in healthcare teams, highly professional teams who aim to personalise caregiving practices provide an excellent space for knowledge sharing while engaging with innovative-emerging technologies.

As the study by Zhao et al. (2021) suggests, the application of 3D printing technology in practice needs to be "stage specific". Conducting this research within a specific context of orthopaedic surgery, opens a black box of 3D printing applications for healthcare policymakers. By focusing on the directions followed by the surgical teams and the formation of relationships to exploit 3D printing technology, new insights, ideas and initiatives will arise to support caregiving practices. Moreover, as the use of technology becomes more complex, effective relationships to work through the technology are needed. In some cases, caregiving practices may require high-level informal dyads among different participants. Based on this finding, healthcare managers will be able to facilitate the formation of dyads by integrating more resources and supporting programs in addition to formal team meetings.

Given the importance of hierarchy for team dynamics, healthcare managers might want to exploit more the positive impact of hierarchy. This can motivate managers to complement traditional tools by paying more attention to hierarchy within the surgical teams. Moreover, the findings of our study are important and can be extended to all organisations in which teams are formed to provide personalised products and services through the use of avantgarde technologies (e.g., surgery teams specialised in robotic surgery, car manufacturer sales teams supported by virtual reality, biopharma research teams using artificial intelligence).

6. Limitations and future directions

Our choice to study healthcare teams as a complex and diverse context presented some limitations. Data collection in healthcare organisations is a challenging process that requires extended periods of time to track real practices in the organisations. Although we made a lot of efforts to enrich our database, we failed to include more ethnographic data in our study. One reason for this limitation could be the extremely dynamic and complex nature of hospitals. Although group interviews helped to meet more respondents, there are strict regulations involved in gaining access to the sites; once this is achieved, the most important barrier is the difficulty of arranging meetings with surgeons who have a busy working life. Secondly, we have yet to expand the number of organisations under study. It will have more implications if the study includes multiple organisations under the same or different policies; hence, more variables at the organisation level can be observed. Thirdly, our data collection process started simultaneously with the pandemic related to COVID-19 while Italy experienced a strict lockdown. Therefore, organising group interviews, and following the interactions and work practices in the hospital setting were among the big challenges for us. Although, we attempted to improve the quality of the study by expanding the timeline of the project; pandemic was present at the background of every action during data collection. Furthermore, our findings are based on a qualitative study. We recommend the adoption of mixed-method approaches in future studies on temporary teams' knowledge sharing behaviours and the adoption of emergent technologies. We also suggest more studies on temporary teams' knowledge sharing process in which the underlying technology promotes a flat team structure to investigate if the same concepts emerge. Finally, our findings are related to a single case study. We encourage future research to explore whether similar results will be observed in other settings in which teamwork is supported by other emerging technologies.

7. Conclusion

Team members have the opportunity to share their knowledge and experience in the context of social groups where memberships are clearly defined and social relationships are stable. In temporary teams these conditions are not satisfied as memberships are fluid and relationships appear quite dynamic and unstable. Yet participants in temporary teams must synergically socialise and share knowledge to successfully fulfil complex tasks (Massaro et al., 2020). The adoption and use of novel technologies adds more complexity for team members, therefore increasing the overall fluidity and uncertainty observed in temporary teams. As a result, participants can not build trust and have a common shared understanding of team tasks; and knowledge sharing becomes a vulnerable process due to the nature of relationships. In this paper, we studied temporary relationships in the context of orthopaedic teams that rely on 3D printing technology to provide customised treatments, wherein relationships play an inevitable role in creating a sharing environment that is pivotal for innovative work. Results of our qualitative study document that dyadic relationships are important to facilitate knowledge sharing within the teams, and that informal dyads established beyond team meetings are the key to resolving the most complex and uncertain tasks. Furthermore, the role of hierarchy in leading the dyads and facilitating knowledge sharing over the resolution of complex tasks is an important factor that should be considered in organisations while monitoring how teams progress towards their objectives.

Data availability

The data that has been used is confidential.

Appendix

Table 1
Frequency table of anatomical area of the cases treated with the support of 3D printing

Anatomical Area	Frequency	Percent
Knee	27	25.23
Pelvis and hip	31	28.97
Ankle	10	9.35
Foot	7	6.54
Elbow	3	2.80
Tibia	4	3.74
Spine	24	22.43
Thorax	1	0.93
Total	107	100.00

Table 2
Frequency table of pathological area of the cases treated with the support of 3D printing

Pathological area	Frequency	Percent
Arthritis	26	24.30
Tumour/bone loss	50	46.73
Big trauma/infection	4	3.74
Osteonecrosis	8	7.48
Talocalcaneal coalition	3	2.80

(*continued on next page*)

Table 2 (*continued*)

Pathological area	Frequency	Percent
Calcaneonavicular coalition	4	3.74
Deformity/instability	5	4.67
Infection after loosening prosthesis	3	2.80
Infection/infection after loosening prosthesis	3	2.80
prosthesis loosening	1	0.93
Total	107	100.00

Table 3
Number of cases treated in team with collaboration of bioengineers and mean severity of the cases (from 2011 to 2021)

Team (clinic)	Mean severity	Std. Dev	Number of the reported cases
Team 1	8.4	0.14	33
Team 2	7	0	7
Team 3	8.9	0.18	37
Team 4	7.2	0.73	5
Team 5	8.5	0.15	22

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