Clinical Reasoning in Dentistry

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ABSTRACT

Background: Clinical reasoning is the core competency of healthcare. It involves cognition and interaction with the environment to understand clinical situations, make diagnostic and therapeutic decisions, and address clinical problems. Defining competency in clinical reasoning is a difficult objective for dental educators because of our limited understanding of this phenomenon which compromises the validity of any curricular model and assessment method that have been used to date.

Objectives: To describe the process and strategies of clinical reasoning used by dental clinicians across different levels of expertise to develop a conceptual framework for curricular design and assessment of competency.

Methods: Using “think-aloud” method, I interviewed 18 dental students about biopsychosocial issues influencing oral health identified in 6 vignettes; and 8 orthodontic residents plus 11 orthodontists about problems of craniofacial growth and malocclusion presented in 2 vignettes. The interview transcripts were analyzed to explore the process and strategies of clinical reasoning used by the participants.

Results: The reasoning process in both groups included: 1) a ritualistic approach to collect information for a treatment plan; 2) forward and backward reasoning to make and test hypotheses from clinical information; 3) pattern recognition and an integrated script of knowledge and experience triggered by related attributes of the script leading to a clinical diagnosis and plan; and 4) decision trees to evaluate treatment options and maximize the probability and utility of outcomes.

Seven reasoning strategies (scientific, conditional, collaborative, narrative, ethical, pragmatic and “part-whole”) were used by both groups. However, experienced clinicians were more confident in their appraisal of uncertain situations and dilemmas as they integrated several reasoning strategies in the process; used refined scripts of knowledge and experience in familiar situations; and were able to reflect on the impact on their reasoning of the larger social, cultural and political context.

Conclusions: Clinical reasoning in dentistry is a contextual and interactive phenomenon that requires integration of specific reasoning strategies to address the biopsychosocial factors influencing oral health. Expertise in clinical reasoning develops through continuous framing and solving problems to refine networks of knowledge and experience and develop adaptive strategies to address the contextual determinants of oral health.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

Cl	Class
EDC	Eastman Dental Center
H-D	Hypothetico-deductive
ICC	Integrated Care Clinic
MEAW	Multiple-loop Edgewide Arch Wire
NIH	National Institute of Health
PBL	Problem-based Learning
RPD	Removable Partial Denture
TAD	Temporary Anchorage Device
TMJ	Temporomandibular Joint
UBC	University of British Columbia
WHO	World Health Organization

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CHAPTER ONE: INTRODUCTION

1.1. Clinical reasoning and dental education

Clinical reasoning is central to healthcare. It involves a process of cognition and interaction with the environment to understand clinical situations, to make diagnostic and therapeutic decisions, and to frame and solve clinical problems. The acquisition of knowledge and skills needed to reason competently in clinical situations appears to be a continuous and dynamic process extending well beyond pre-doctoral education. However, a critical challenge for educators of healthcare professionals is to establish the essential competencies required for the immediate demands of clinical reasoning upon graduation. This is a difficult objective for dental educators to address because of three closely connected reasons: 1) a growing awareness of the scope of problems that involve dentists, compounded by the inadequacy of information and resources required to address the problems; 2) limited understanding of the process of clinical reasoning and strategies that should be used directly or reflectively to identify and solve the problems; and 3) conflicting views about the relative importance of the objectives and priorities of dental education.

This chapter will present a historical review about the evolution of clinical reasoning in dentistry and dental education. My objective is to highlight the growing awareness in dentistry of the wide range of problems that providing oral healthcare brings to the fore. This awareness has brought about a need for redefining the objectives of dental education (Field, 1995). Furthermore, it calls for evaluating and adopting alternative research approaches to explore what

reasoning processes are involved and what strategies are required for addressing problems in dentistry.

1.2. Clinical reasoning and healthcare professions

Clinical reasoning is an interactive phenomenon that happens within a multilayered context. The context of clinical reasoning includes the clinician, the patient, and the clinical problem, all interacting within a larger social, cultural and global environment. Higgs and Jones (2008) have depicted those interactions as overlapping “problem spaces” that individually or collectively influence how health related decisions are made. For example, the problem space of the clinician consists of the personal and professional knowledge, experiences and values that develop an individual perspective through which the clinician sees, interprets, and frames clinical problems.

The “clinical problem” denotes a wide range of health-related issues that bring about a need or demand for care. The nature of the clinical problem and the type of care that it requires determine which healthcare profession should address the problem. Historically, a growing awareness of the extent and diversity of health-related problems has spawned the existing healthcare professions (Adams, 1999). This evolution has brought about different approaches to care and consequently different concepts of health and disease. For example, medicine in large part promoted the biomedical model of health assuming that diseases happen as a result of biological malfunctions of the body with little influence from the mind. However, Parsons’s (1951) theory of the “sick role” challenged the

medical model by introducing the social aspects of health and disease in relation to the patient's role in the society. Parsons's theory launched a move to explore the psychosocial aspects of medicine from which emerged the biopsychosocial model of health care promoted by Engel (1977). The change of perspective from the biomedical to the psychosocial models of health redefined the concept of health from a simple perception of physical disease to the current view that health occurs when there is a general feeling of physical, psychological and social wellbeing (World Health Organization, 2001). This view of health manifests itself clearly in the practice of occupational therapy and physiotherapy where the care primarily involves chronic conditions and related psychosocial problems.

This conceptual diversity of health and approach to care possibly explains why different healthcare professions study clinical reasoning differently. For example, medicine has primarily focused on the reasoning strategies used to diagnose diseases (Monajemi, Rikers & Schmidt, 2007, Norman, 2005a). This seems to be related to an underlying assumption that an appropriate treatment plan will follow a correct diagnosis of diseases (Elstein & Schwartz, 2008). Alternatively, occupational therapy and physiotherapy have adopted interpretive approaches* to explore in detail, the various reasoning strategies used for interpreting the

* Interpretive approaches to research involve interpretation of any form of "human expressions" including written, verbal or physical (Smith, 1992). These expressions reflect knowledge, experience, reason, interest, intention and motivation of individuals and are embedded in the interactions of the individuals with a broader historical and social context. This inquiry provides a justified interpretation of social reality that is meaningful to the members of that society, derived from the expressions of the members of that society and open to interpretation by others.

psychosocial aspects of chronic conditions and the treatment strategies that address those issues (Fleming, 1991).

Dental education and practice are based largely on a biomedical model of healthcare from its historical relationship with medicine and surgery, and its emphasis on managing diseases of the mouth (Adams, 1999, Gies, 1926, Khatami, MacEntee & Loftus, 2008). Dentistry adopted the analytical approaches of medicine based on decision theory and information processing theory to guide the process of diagnosing oral diseases, and to establish clinical practice-guidelines (Matthews, Gafni & Birch, 1999). However, the change of perspective from the biomedical to the psychosocial models of health brings forth the diversity and complexity of problems that arise when oral health is compromised (MacEntee, 2006). This awareness has led to explorations of the psychosocial basis of diagnosis and treatment planning through inductive or interpretive perspectives rather than through the deductive or hypothesis-based studies that continue to dominate medical research in healthcare and clinical practice (Bryant, MacEntee & Browne, 1995, MacEntee, Hole & Stolar, 1997, Sheiham & Croog, 1981).

The dominance of the biomedical perspective in dentistry is evident in the historical evolution of the dental curriculum. Traditionally, curricular models of dentistry emphasized teaching of biomedical sciences and psychomotor skills and struggled to create a balance between the two themes (Hendricson & Cohen, 2001). Recent awareness of the significance of psychosocial aspects of oral health and the issues with poor access to oral healthcare poses a challenge

for dental education (Cohen, 1981, Depaola & Slavkin, 2004). However, the challenge has yet to impact the structure and outcomes of the dental curriculum in most dental faculties (Bailit, Formicola, Herbert, Stavisky *et al.*, 2005, Brondani, Clark, Rossoff & Aleksejuniene, 2008, Kassebaum, Hendricson, Taft & Haden, 2004).

1.3. Evolution of dentistry as a healthcare profession

Dentistry claimed professional status within the healthcare system in the 18th century in Europe, and about a hundred years later in North America (Gies, 1926, Lufkin, Archer & Casto, 1948). Professional associations developed and monitored the ethical codes of conduct for the practising dentist along with standards of education for dental students (Gies, 1926, King, 1998, Welie, 2004a). At the outset, the associations had members from varied backgrounds, including physicians, surgeons, apothecaries and even barbers, who practised dentistry so that the diversity of membership created a challenge to regulation of the profession. Moreover, this process occurred in an era of "medical dominance" where the profession of Medicine as a political force dictated the accreditation standards of education, research, and service in healthcare (Adams, 1999, Schon, 1983).

The authority of the medical profession stems predominantly from the concept of "technical rationality", which asserts that a professional problem-solver applies scientific evidence, *i.e.* evidence-based care, to solve the problems encountered in clinical practice (Schon, 1983). Medicine claimed ownership of the biomedical

arena, and advocated strongly the superiority of science for solving the problems of disease. With this claim, came an assumption of authority to prescribe the objectives of medical education based largely on scientific evidence. The concept of technical rationality surfaced most notably in the practice of surgery during the 18th century when surgeons sought a “noble” social status similar to the status of physicians by developing theoretical knowledge of “how and why” to operate on the body (King, 1998). Dentistry, emerging as a specialized branch of surgery, strived to develop a similar body of scientific knowledge to comply with the standards established for physicians and surgeons. Consequently, the scientific perspective prescribed the objectives of dental education, and dental politicians and educators, like their medical colleagues, sought affiliations with universities as a credible base of education and research (Gies, 1926). Slowly but increasingly, dental research attracted funding from philanthropic and proprietary organizations to explore the principal manifestations of poor oral health, and to seek effective management strategies for oral disorders.

Scientific research in dentistry moved along two routes to develop and rationalize techniques for oral rehabilitation, and to describe the pathogenesis and ultimately the causes of oral diseases. Searching for scientific evidence on the cause of diseases in both dentistry and medicine continue, and remain the primary objective of most health research (National Institute of Health). However, science could provide only some answers to the cause and management of chronic disease (MacEntee, 2007). For example, eliminating or altering many of the apparent “causes” of periodontitis has yet to cure or prevent the disease, and the

evidence needed to eliminate the disease remains elusive (Baelum & Lopez, 2004).

Alternative approaches to health research have emerged to explore the impact of diseases and disease-related behaviours in society, and have moved some of the focus of healthcare away from the science of pathogenesis and onto the role of personal and social factors influencing the initiation and maintenance of disease (Bury, 2001, Engle, 1977). One example of this research in dentistry is the interpretive investigation of the perception of older adults about the impact of the oral health on their perceived quality of life (MacEntee *et al.*, 1997). Apparently, the range of problems involving healthcare extends now beyond physical diseases and towards the social and psychological context associated more closely with personal and environmental variables (WHO, 2001). In turn, the search for clinical evidence associated with these psychosocial influences requires a more inductive form of inquiry than the deductive approach of science (Khatami *et al.*, 2008).

The social concept of a healthcare profession has been redefined also in recent years to highlight the role of health professionals in society (Welie, 2004a). Of course, past and current beliefs about dentistry as a health profession endorse the idea that dentists must be knowledgeable and competent (Welie, 2004b), but now there is a growing expectation that they should “continually revisit their own ‘profession’ and reinterpret the terms of the resulting social contract with the public” (Welie, 2004a). This reinterpretation implies a responsibility to adopt an equitable approach to professional service, yet, there is neither understanding

nor consensus about the professional responsibilities and competencies underlying this service (Dharamsi, 2003). Consequently, dental educators are confused and challenged about setting priorities to cultivate the knowledge and skills required of new graduates to fulfill their responsibilities to society (Bertolami, 2001, Whipp, Ferguson, Wells & Lacopino, 2000). Indeed, this confusion is rampant with healthcare in general, and medical education faces a similar challenge of uncertainty (Harden, 2000).

1.4. Problems and approach to care in dentistry

Historically, the approach to care in dentistry has revolved around three large themes: treating disease; treating the person; and treating all in need of care. They each reflect an evolving awareness of the range of clinical problems and the accompanying evidence that influences how dentists apply reason to address the problems.

1.4.1. Treating disease

Dentistry has always been concerned about caries and periodontal disease, pain and tooth-loss (Gies, 1926, Lufkin *et al.*, 1948). A surgical perspective on the management of dental disorders produced a wide array of biomaterials along with numerous techniques and instruments to remove and restore oral structures. Alternatively, adoption of the medical model of care produced a shift from surgery (*e.g.,* extractions and restorations) to medications (*e.g.,* fluoride) and behavioural therapy (*e.g.,* diet counselling) (Krasse, 1985). Undoubtedly, advances in oral biology are influencing dental care, and current predictions suggest that by 2030

innovations in oral biology, such as gene therapy, DNA vaccinations and tissue engineering might change current clinical practises altogether (Baum, 1991, Baum 2004).

1.4.2. Treating the person

Dentistry during the 1960's was influenced by a concern for public health with emphasis on preventive care, which began to explore the social and behavioural aspects of oral diseases and their psychosocial impact (Cohen, 1981). So, by the end of the 20th century, dentistry was well positioned to recognize changing demographics of the population along with a need to focus on the patient rather than the disease and, more recently, on provision of a more equitable distribution of oral health services (Field, 1995, MacEntee, 2010, Welie, 2004a).

1.4.3. Treating all in need of care

It appears that an equitable approach to care will broaden the social context of care from dental clinics to hospitals, schools, community-based clinics and long-term care facilities, and with all the necessary interdisciplinary collaboration that this requires (Bailit *et al.*, 2005). For example, the complexities of dentist-patient relationships in the context of long-term care facilities poses new challenges that as yet have not been addressed satisfactorily (MacEntee, Thorne & Kazanjian, 1999, MacEntee, 2010).

1.5. Evolving evidence on dental caries

Past and current concepts about dental caries are interesting examples of how dentistry sought and produced evidence to address this disease initially as a

pathological state, and then as part of a range of problems closely associated with the person and society.

Early anatomical and histological observations of teeth with carious lesions led to a belief that caries develops as a result of developmental defects within enamel and dentin. However, later, the chemical action of food and acid in saliva under the influence of an array of micro-organisms were implicated in the process of tooth-decay, all of which focused attention on the need for personal hygiene, professional instrumentation (dental scaling *etc.*) and pharmacotherapy mostly in the form of fluoride (Gustafsson, Quensel, Lanke, Lundqvist *et al.*, 1954, Hoffmann-Axthelm, 1981, Lufkin *et al.*, 1948). And so, gradually, the base of knowledge about caries and its management grew from the static of a disease to the dynamic associations between bacteria, diet, tooth-structure and community action (Krasse, 1985).

Diagnosis of caries seems to follow a process of pattern recognition whereby dentists try to detect and confirm the presence of caries through visual or tactile aids (Bader & Shugars, 1997, Maupome & Sheiham, 2000). However, recent concepts of caries suggest that caries happens as a result of a pathological process that involves many biopsychosocial factors that could contribute to its initiation and development (Baelum, Heidmann & Nyvad, 2006). This change of concept implies a comprehensive diagnostic process that extends beyond visual and tactile evidence to recognizing the pattern of factors that result in initiation and progression of the pathological process of tooth decay.

Traditionally, tooth-loss and restoration of the decayed tooth structure posed a myriad of problems relating to the choice and manipulation of materials, design of artificial structures, and techniques for preparing and restoring teeth, all dependent on a blend of mechanical and biological remedies (Lufkin *et al.*, 1948). The recent interest in evidence-based dentistry aims to provide a reasoned direction to optimize the "success" of treatment. For example, this process of decision-making compares the longevity of different restorative materials and the probability and utility of different restorative techniques (Matthews *et al.*, 1999). However, clinical reasoning for managing caries and tooth-loss extends beyond the choice of restorative materials and techniques and requires an understanding of "normal" form and function, along with all possible impacts on the quality of life of patients when the "normal" form and function is compromised.

Further "evidence" is emerging for managing caries and tooth loss through a biomedical perspective that identifies and evaluates risk factors for caries and prescribes strategies to prevent the disease. The search for the causes of dental diseases now follows "causal web models" to explore and explain the complicated interrelationship of the many factors that influence oral diseases. The "down-stream" causes such as molecular and genetic factors seem to have a direct effect on the occurrence of diseases. As the networks expand to the "up-stream" layers, encompassing the psychosocial issues, the impact of the factors on the occurrence of disease becomes more intangible; hence the reasoning required to identify and manage those factors becomes more complicated (Baelum & Lopez, 2004). For example, caries and tooth loss are more prevalent

in populations with lower socioeconomic status and poor access to dental care, and in communities where water fluoridation is absent, and where the sugar consumption is high. This broader communal perspective on caries expands the context of “clinic” to include the social and political context of healthcare. However, the complexity of reasoning in this broader context has yet to be explored adequately.

1.6. Problems, evidence, and clinical reasoning in dentistry

Dentistry as it evolved from the general sphere of surgery adopted the scientific concept of technical rationality as a guide to clinical reasoning (Schon, 1983). However, the complexities of the problems and the shortcomings of the evidence inevitably gave rise to much clinical uncertainty, even as the widening scope of professional responsibilities inspired active exploration to enhance clinical skills and treatment outcomes. As the needs and demands of the public in relation to oral health changed, the range of problems that require the expertise of dentists expanded to encompass an array of biological, psychological and social phenomena. However, our limited understanding of the problems and the contextual factors that influence them complicate the competency of our reasoning. The evolving evidence around the identification and solution of problems in dentistry demands revision of curricular objectives in dental education.

1.7. Evolution of dental education

The history of dental education in North America and Europe passed through three major evolutionary stages over the last century and a half. The traditional apprenticeship model dominated dental education almost everywhere till the mid-nineteenth century when North America established an "odontological" model[†] to provide a structured dental program leading to professional licensure and accreditation separate from medicine (Gies, 1926, Gullett, 1971, Louka, 1997). European countries in contrast, developed multiple models of dental education, based largely on medically-oriented odontological and stomotological concepts (WHO, 1969).

Attempts to adopt and adapt the medical and surgical models of care created a duality of objectives in dental education (Hendricson & Cohen, 2001). The surgical model emphasizes psychomotor skills for restoring oral structures whereas the medical model uses science to explain diseases and the principles of biological, pharmacological, and preventive treatments. In the 1960's, dentistry became more aware of the psychosocial determinants of health. Consequently, educators began to incorporate behavioural studies into the dental curriculum (Formicola, 1991). Nonetheless, many dental educators continue to question the effectiveness of their educational programs for preparing competent and

[†] Odontology and Ostomotology are competitive terms that refer generally to the focus in dentistry and dental education on the dental or medical aspects of oral health respectively. Stomotology means "diagnosis and treatment of diseases of the mouth" (Cohen, 2002) and endorses a medical approach to manage diseases of the mouth. Alternatively, odontology emphasizes the technical and psychomotor aspects of restoring decayed or missing tooth structures.

responsible dentists (DePaola & Slavkin, 2004, Field, 1995, Hendricson & Cohen, 2001, Welie, 2004a).

1.8. Approaches to dental education

Historically, the approach to educating dentists has revolved around four large themes: teaching sciences and techniques; promoting problem-solving skills; developing competencies; and community-service learning. They each reflect an evolving awareness of a range of competencies required for oral healthcare.

1.8.1. Teaching sciences and techniques

The first dental program at the Baltimore School of Dental Surgery consisted of institutional instruction with lectures and demonstrations of biomedical sciences and clinical practice over four months (Gies, 1926). The Gies report in 1926 encouraged adoption of the Baltimore model, which developed slowly into a sophisticated compendium of medical, technical and behavioural courses and specifically dental courses to develop psychomotor clinical skills. Originally, the dental curriculum followed a horizontal design to accommodate the biomedical sciences and laboratory courses in the first two years and followed by two years of clinical instruction. This model fails to connect basic sciences to clinical experiences efficiently because of limited opportunity for students to synthesize and integrate knowledge and apply it in relevant clinical situations. The “diagonal curricular design” and “step-wise curricular design” were suggested as alternative models to integrate basic science and laboratory courses with early clinical exposure (Formicola, 1991).

Increasingly, the expansion of scientific evidence along with advances in clinical and laboratory techniques and materials gave rise to a “surreal duality” as the curriculum was manipulated to provide students with adequate knowledge and psychomotor skills to practice dentistry (Hendricson & Cohen, 2001). However, it has become readily apparent that the conventional four-year North American dental program has neither the time nor the resources to “teach it all”. Some educators suggested extending the length of dental education to accommodate all the necessary courses (Cohen, 2002, Nash, 1998). Nonetheless, “curricular decompression” became both a high priority and a simple solution to the demands of limited time and scarce resources (Kassebaum, *et al.*, 2004). Currently, recommendations about curricular reform offer a change of process and overall focus by adopting problem-based and competency-based models to more readily integrate both horizontally and vertically the knowledge and clinical experiences needed to demonstrate professional competence (Field, 1995, Hendricson & Cohen, 2001, Snyman & Kroon, 2005).

1.8.2. Promoting problem-solving skills

During the 1970s, there was a shift of emphasis in medical education from teaching the ever expanding source of biomedical knowledge to developing problem-solving skills (Barrows, 1994, Elstein, Shulman & Sprafka, 1978). This happened in line with the introduction of problem-based learning (PBL)[‡] by

[‡] A course based on PBL presents problems about a patient in a sequential format as students identify information they need to solve the problem. The problem should be chosen from a range of routine to infrequent, yet significant, problems that clinicians may encounter in practice.

McMaster University in 1969 (Haslett, 2001). At about the same time, the hypothetico-deductive (H-D) model of clinical reasoning offered a theoretical basis for problem-solving in medicine (Barrows & Tamblyn, 1980). Advocates of PBL adopted this model to guide students through the process of hypothesis generation and testing (Barrows, 1998). Charlin, Mann and Hansen (1998) suggest that the selection of clinical problems and the purpose underlying them should correlate with the instructional objectives of the curriculum. Recently, there is an increasing emphasis on the quality of the clinical problems posed in PBL tutorials and there is a call now for further studies to characterize "high-quality" problems (Eva, 2005, Norman & Schmidt, 2000, Norman, 2005a).

In 1990s, dental education adopted PBL as an alternative model of education to overcome the growing detachment of basic from clinical sciences, and to improve the problem-solving skills of students (Field, 1995). Despite the increasing interest and support from many dental educators (Field, 1995, Fincham & Schuler, 2001, Susarla, Bergman, Howell & Karimbux, 2004, Whipp *et al.*, 2000), only 5% of dental schools in the US and Canada adopted PBL as their primary method of learning (Kassebaum *et al.*, 2004). Hendricson and Cohen (2001) believe that this lack of enthusiasm is due to the traditional surgical-restorative dominance in dental education in contrast to the diagnostic disease-oriented focus of PBL. They suggest also that PBL has been inserted more as an add-on to an already overcrowded dental curriculum rather than an over-riding educational approach, and that there are widespread concerns about PBL as "faculty intensive" without evidence of "effort-effectiveness". Moreover, there

remains much skepticism about the need for change from lectures to the PBL format of small-group seminars (Dharmasi, Clark, Boyd, Pratt & Craig, 2000).

1.8.3. Developing competencies and other curricular challenges

Traditionally, curricular design in dental education has identified prerequisites for entry to the program, and specific learning objectives of each sub-discipline of dentistry, along with outcome measures for graduation. The major assumption underlying this design is that students on graduation can or will integrate the fragmented knowledge and skills acquired throughout the program. Alternatively, a "top-down" approach might be more effective in achieving the expected outcomes of the program. This approach analyzes the responsibilities and tasks of the practising healthcare professional and defines the competencies relative to the knowledge, skills, and values required to practise. The program, in turn, provides an environment for the students to become competent and uses assessment techniques to evaluate competency (Hendricson & Kleffner, 1998, Leung, 2002). The top-down approach calls for a "readiness-based" model of assessment, whereby students continue training until they are competent. Therefore, each student progresses in the program differently according to ability and regardless of time (Hendricson & Cohen, 2001).

Over the years, dental educators have defined competencies and suggested assessment techniques to ensure validity of evaluations (Chambers, 1993, Chambers & Gerrow, 1994, Chambers, 2001, Plasschaert, Holbrook, Delap & Martinez *et al.*, 2005). However, little has been done to explore the effectiveness of the current curricula in addressing the suggested competencies. DePaola and

Slavkin (2004) argue that health professions have yet to develop a common language or core of professional competencies for all disciplines and that the current dental curricula do not have appropriate evaluation components to assess the core competencies. Recently, Plasschaert *et al.* (2005) reviewed the various competency statements in Europe, USA, Canada, and South America to provide a general framework for dentistry. Documents of competencies from the various countries differed in format, level of detail, and expected competency. Recent statements show a greater emphasis on decision-making, critical thinking, professionalism, information management and comprehensive patient care, which have been described as “meta-competencies”; however, they all require a complicated combination of knowledge, skills and values (Yip & Smales, 2000).

A major challenge in designing a competency-based curriculum is to link the discipline-based learning objectives to the competencies of the profession (Leung, 2002, Plasschaert *et al.*, 2005). Beltran and Beltran (2004) offered a taxonomy of competencies in dental education, developed primarily for student assessment. It defines seven levels of competencies with differing complexities. The “professional profile”, which is the highest level, encompasses meta-competencies including all the intellectual, affective and psychomotor domains of dentistry. However, connections between the hierarchical levels of competencies are unclear. The higher levels include competencies that require integration of several domains but we do not know when or how to integrate the competencies. Chambers (2001) believes that “dentistry is learned as a global set of skills,

understanding, and values that manifests itself in various discipline specific fashions when the circumstances call for that type of performance." He admits that there is no evidence to suggest that dentistry is learned and practised as a general set of skills or as a collective discipline with an integrated set of specific skills.

1.8.4. Community-service learning

The report by the Institute of Medicine in 1995 (Field, 1995) brought to the fore the issue of poor access to dental care for particularly vulnerable populations. It was followed by numerous reports and projects promoting community-based dental clinics for students to care for disadvantaged people (Andersen, Davidson, Atchison & Hewlett *et al.*, 2005, Bailit *et al.*, 2005, Brondani *et al.*, 2008, Davis, Stewart, Guelmann & Wee *et al.*, 2007, Depaola & Slavkin, 2004, Formicola, Myers, Hasler & Peterson *et al.*, 2008). This change of context from the university-based dental clinics to the community seems to help reduce the overwhelming cost of dental education (Bailit, Beazoglou, Formicola & Tedesco, 2008). However, the challenge of providing patient-centred care together with developing and assessing competencies of students poses yet another duality in curricular operations and challenges without ready solutions.

1.9. The need for a conceptual framework for clinical reasoning in dentistry

Competency in clinical reasoning is essential for healthcare practice. However, there are no clear definitions or guidelines on appropriate levels of related competencies for new dental graduates, nor is it obvious how dental curricula

teach or assess clinical reasoning. Apparently, clinical reasoning requires integrated networks of knowledge to identify and solve problems during clinical encounters with patients. Interacting with patients within the healthcare environment demands competent communications, critical thinking, professionalism, information management, ethics and awareness of the social, cultural and political context of practice. However, we do not know when and how those skills develop and integrate to facilitate clinical reasoning. There is no model or description of clinical reasoning to explain this complicated cognitive and interactive process that guides dental clinicians in identifying, framing and solving the wide range of problems related to oral health. Unfortunately, this limited understanding of clinical reasoning compromises the validity of current curricular models and assessment methods.

The objective of this thesis is to provide a conceptual framework for clinical reasoning in dentistry across different levels of expertise and problems. We conducted two studies: one at an undergraduate dental program- University of British Columbia (UBC) - that involved dental students at two stages of the program (beginning and end of 4th year); and the other at a post-graduate orthodontic program - University of Rochester, Eastman Dental Centre (EDC), that involved residents at two different stages of the program (first and second year) and faculty and recent graduates (*i.e.,* orthodontists) with different levels of expertise.

The UBC study aimed to answer:

1) How do dental students address biopsychosocial issues influencing oral health related problems?

2) What are the similarities and differences in clinical reasoning of dental students in the beginning and end of the 4th Year when they address the problems?

The EDC study aimed to answer:

1) How do orthodontic residents and clinicians address biopsychosocial issues related to craniofacial growth and malocclusion?

2) What are the similarities and differences in clinical reasoning of orthodontic residents and clinicians when they address the problems?

We assumed that different types of problems (*i.e.,* whether influenced by biological or psychosocial factors) demand different reasoning strategies. We also assumed that prior experience with similar problems has an impact on how problems are approached. Therefore, we expected to see similarities and differences in the process of clinical reasoning and strategies used by all participants in response to the type of problems and to the level of expertise attained by the participant. The findings should provide a foundation for defining and describing clinical reasoning in dentistry, and provide a conceptual framework for evaluating competency in clinical reasoning and devising educational interventions to improve the reasoning of future dental clinicians.

CHAPTER TWO: EXPLORING CLINICAL REASONING

2.1. Defining clinical reasoning

Definitions of clinical reasoning by different healthcare professions reflect the diversity within different disciplines in conceptualizing this phenomenon. Studies of clinical reasoning in Medicine have focused mainly on the process of diagnosis and in most part fall short of describing the reasoning involved in treatment planning (Elstein & Schwartz, 2008, Monajemi *et al.*, 2007, Norman 2005a). Physiotherapy and Occupational Therapy, in contrast, have explored the process of treatment-planning and the complicated interaction of issues that arise when clinicians negotiate and implement a plan (Fleming & Mattingly, 1994, Higgs & Jones, 2008). Earlier definitions of clinical reasoning described it as a cognitive process of making and testing hypotheses to evaluate and manage medical problems (*i.e.,* diseases) (Barrows & Tamblyn, 1980, Elstein *et al.*, 1978). Later, Kassirer and Kopelman (1991) described clinical reasoning as a collection of strategies used by physicians to synthesize clinical data into diagnostic hypotheses, evaluate the risks and benefits of treatment options, and prepare a treatment plan, whereas Fleming and Mattingly (1994) in occupational therapy described it as an interpretive activity of perceiving clinical problems as phenomena. They explained it as “thinking in the midst of practice”, which is a tacit process whereby clinicians make “judgment in action”. Higgs and Jones (2008) acknowledged the complexities of defining clinical reasoning considering the diversity of clinical practice. They portrayed it as a contextual and interactive phenomenon happening within a multilayered context of the patient, the clinician

and the problems, surrounded by the larger social, cultural and global environment.

2.2. Evolution of clinical reasoning research

Historically, studies of clinical reasoning adopted theories and methods of behavioural and cognitive psychology (Arocha & Patel, 2008, Norman, 2005a). Beginning in the 1950's, investigators of clinical reasoning used psychometric instruments to observe and assess the overt behaviours or performances of clinicians (Rimoldi, 1961). However, observing behaviour seemed insufficient to explain the complicated cognitive process of reasoning in the face of clinical problems. Therefore, the 1970's saw a shift of focus from clinical performance to the cognitive process underlying the performance (Patel, Kaufman & Arocha, 2002). This coincided with the beginning of promoting problem-solving skills in medical education, and an emphasis on the "primacy of process over content" (Elstein *et al.*, 1978). This shift in pedagogy moved the focus of medical curricula from teaching content-knowledge to improving the problem-solving skills of students (Barrows & Tamblyn, 1980). This movement prompted studies of problem-solving in medicine to explore the process of diagnosing diseases by expert clinicians and to improving the problem solving skills of physicians by modeling this process. In 1978, Elstein *et al.* introduced the H-D model of solving medical problems through acquisition of cues, generation of hypotheses, interpretation of the cues, and evaluation of the hypotheses. Later, more elaborate versions of the H-D model were introduced by Barrows and Tamblyn

(1980), who presented four stages in a cyclical model, and by Gale and Marsden (1982), who expanded it to a 14-stage process of diagnostic reasoning.

Nonetheless, the abstractness of the H-D models fails to explain differences between novice and expert clinicians. Comparisons of the process of problem-solving showed that experts and novices generate the same number of hypotheses in a diagnostic process; however, experts are more efficient and offer more relevant hypotheses earlier in the process (Barrows, Norman, Neufeld & Feightner, 1982).

Pattern recognition offered an explanation for the fast and efficient problem-solving skills of experts, particularly in highly visual material (Bleakley, Farrow, Gould & Marshall, 2003, Engel, 2008, Norman, 2005a). Also, it appeared that the difference in problem-solving of expert and novice clinicians is “content specific” (Elstein & Schwartz, 2008) and related to the organization of biomedical knowledge in memory - an idea inspired by problem-solving in chess (Norman, 2005b). These alternative concepts prompted research in the field of medical problem-solving to study the knowledge structure and application of knowledge in problem-solving across levels of expertise (Bordage, 2007, Bordage & Zacks, 1984, Charlin, Tardif & Boshuizen, 2000, Groen & Patel, 1988).

On the other hand, Elstein and Schwartz (2002) promoted another line of research which aimed to explore the heuristics and biases that influence diagnostic decisions of physicians. They believed that diagnostic decision-making is prone to certain fallacies regardless of expertise; therefore, identifying the heuristics and biases in this process helps develop educational and decision

support systems to improve diagnostic decisions (Elstein, 2000). A growing interest in evidence-based medicine and medical informatics supported this line of research with an objective to assist “rational” and “evidence-based” decisions in practice (Patel *et al.*, 2002).

Furthermore, starting in the 1980’s, there was a growing interest especially among nurses, occupational therapists and physiotherapists in using interpretive approaches to explore clinical reasoning (Loftus & Smith, 2008). For example, interpretive inquiry was used to explore the nature of “expertise” (Benner , 1984) and the role of intuition in reasoning of nurses (Pyles & Stern, 2007, Rew, Agor, Emery & Harper, 2000), the integration of various reasoning strategies in therapeutic decisions of occupational therapists (Fleming, 1991, Fleming & Mattingly, 1994), and the differences in the foundations, scope and type of knowledge used by physiotherapists (Higgs & Andersen, 2001, Higgs, Richardson & Dahlgern, 2004).

Here I will review some of the main findings from clinical reasoning research in medicine, nursing, occupational therapy and physiotherapy under three major categories of clinical problem-solving, clinical decision-making and interpretive inquiry of clinical reasoning. Following this review, I discuss how dentistry has fallen behind in clinical reasoning research. These reviews provide a theoretical framework which I use later to justify my choice of method for exploring clinical reasoning and interpreting the findings and implications of my research.

2.2.1. Clinical problem-solving

The process

At the outset, the primary objective of research in medical problem-solving was to model the process of diagnostic reasoning by experts. The underlying assumption was that clinical reasoning is a generic and transferable skill. Therefore, if novices learn to follow the process of reasoning by experts, they can be as successful and efficient in diagnosing diseases. Since the H-D models failed to differentiate between the diagnostic process of experts and novices, Groen and Patel (1988) sought an alternative explanation for those differences. They asked clinicians with different levels of expertise to explain the pathophysiology underlying a clinical problem, and found that experts apply "forward or data-driven" reasoning to arrive at a diagnostic hypothesis, while novices apply "backward or hypothesis-driven" reasoning to find data that confirm or reject a list of hypotheses about the problem. However, it is unclear how the initial hypotheses pop into the mind of the novices in the first place and whether or not experts are influenced by a dominant hypothesis while they are collecting and interpreting clinical information. It appeared that experts only use forward reasoning to diagnose the common problems within their domain of expertise. However, when confronted with more complex and ambiguous problems, they revert to backward reasoning (Mamede, Schmidt, Rikers & Penaforte *et al.*, 2007, Norman, 2005a). Clinical reasoning seems to be highly associated with the organization of knowledge and experiences in memory. Therefore, exploring the

differences in organization of knowledge in minds of experts and novices became the prime objective of research in medical problem-solving.

The structure of knowledge and representation of problems

The concepts of categories and schemas (Bordage & Zacks, 1984, Mandin, Jones, Woloschuk & Harasym, 1997), prototypes (Bordage, 2007), exemplars (Norman, 2000), and scripts (Charlin *et al.*, 2000) were adopted from cognitive psychology to explain how biomedical knowledge is organized and retrieved as clinicians identify and interpret medical problems and arrive at a diagnosis. For example, the prototype theory suggests that the biomedical knowledge is organized around representative examples or prototypes in memory. The prototypes contain the most essential features of a disease (Bordage & Zacks, 1984). Therefore, any new information about a disease is evaluated and classified under the relevant category. The idea of prototypes was further developed by Bordage (2007) who introduced “structural semantics” as a mental scaffolding structure for organizing biomedical knowledge. According to this theory, diseases are categorized under “dichotomous abstract qualifiers” based on the most common features of the most typical presentation of each disease (*e.g.,* chronic versus acute or local versus systemic). Diagnostic process involves a feature-by-feature comparison of the problem at hand with the pre-existing prototypes in order to find a matching diagnostic label.

Norman (2000) proposed the exemplar theory to explain the fast and efficient diagnostic process of experienced clinicians. This theory suggests that instead of a feature-by-feature comparison of clinical problems with prototypes, a “holistic

match to a prior example" facilitates a faster and more efficient diagnostic process through a "non-analytical" approach (*i.e.,* pattern recognition) (Norman & Brooks, 1997, Norman, Young & Brooks, 2007).

Furthermore, Boshuizen and Schmidt (1992) proposed a theory of medical expertise, suggesting three stages of development for organizing and integrating biomedical knowledge for a diagnosis. Initially, the novice builds a "propositional network" to explain the pathophysiological mechanisms underlying a disease, and then gives the network a diagnostic label following further exposure to patients. During the intermediate stage when exposed to additional clinical experience, the biomedical knowledge becomes "encapsulated" within illness scripts, and repeated clinical encounters refine the scripts as the clinician moves from novice to expert. According to Charlin *et al.* (2000), the "illness scripts" consist of: 1) enabling conditions, which are the perceptions that clinicians hold about the contextual features of specific diseases; 2) faults, which are the pathophysiological mechanisms underlying diseases; and 3) consequences of faults, which are the clinical signs and symptoms of diseases. During encounters with patients, clinicians recognize the relevant cues and relate them to the script of a familiar illness. A script is "triggered" and processed through a continuous evaluation of "attributes", and each script has several attributes with different probability values. The attribute with the highest probability of occurrence is the default value. Clinicians search for information to typify the signs and symptoms relating to default values, and if the information does not fit one script, another script is triggered and processed until a match is found. Apparently, script

processing does not involve a tedious feature-by-feature matching of its attributes with all presented signs and symptoms. Often, finding the default attribute for a specific disease brings the diagnostic process to closure, assuming that the remaining attributes of the scripts are also present (Charlin, Boshuizen, Custers & Feltovich, 2007). In the absence of a script to match the presented signs and symptoms, clinicians rely on their "encapsulated" biomedical knowledge to arrive at a diagnostic hypothesis.

Dual processing of diagnostic information

Clearly, there is a connection between the structure of biomedical knowledge and the process whereby diagnostic hypotheses are confirmed or rejected. These connections are acknowledged in recent conceptions of medical problem-solving as a "dual processing" activity (Elstein & Schwartz, 2008, Eva, 2005, Norman, 2009). The concept of dual processing was adopted again from cognitive psychology. It involves two "systems" for processing information. System 1 resembles pattern recognition and forward reasoning in that it is fast, efficient, unconscious and derived by recognizing similarities of the situation at hand with previous experiences. On the contrary, system 2 is highly analytical and resembles the H-D reasoning or the feature-by-feature comparison of the present situation with pre-existing prototypes.

Eva (2005) suggests a "bi-directional" flow for the process of clinical reasoning that applies to all levels of expertise. His model suggests that the initial encounter with a clinical situation creates a "mental representation" of the problem that leads to making and testing hypotheses. This mental representation influences

how clinical information is collected and interpreted. Also, interpretation of the collected information changes the mental presentation of the problem and generates alternative hypotheses. The bi-directional flow demands a combination of analytical and non-analytical reasoning. Apparently, this combined approach helped improve accuracy in diagnostic reasoning of novices (Eva, Hatala, Leblanc & Brooks, 2007). It is also suggested as a strategy to reduce errors in diagnosis of experts by avoiding "premature closure" of a non-analytical diagnostic process (Eva & Cunnington, 2006, Norman & Brooks, 1997). The dual processing model explains how illness scripts are triggered and processed through a non-analytical approach when clinicians encounter a typical presentation of a disease and how they adopt an analytical approach when they encounter a non-typical presentation of a disease for which they cannot find a matching script (Charlin *et al.*, 2007). The dual processing strategy is also used by pathologists as they evaluate visual information in diagnostic slides. The diagnostic process is initiated by a "global impression" to recognize the pattern of the condition, followed by a "focal search" to relate the specific features of the parts to the whole. This additional processing through focal search helps confirm the accuracy of the initial diagnosis through global impression and pattern recognition (Bleakley *et al.*, 2003, Engel, 2008).

2.2.2. Clinical decision-making

The main objective of this line of research is to promote "rational" diagnostic and therapeutic decisions free from biases and supported by scientific evidence (Elstein & Schwartz, 2008, Norman 2005a). Studies of decision-making are

based primarily on the theory of probability and the economic model of game theory (Arocha & Patel, 2008, Matthews *et al.*, 1999). Decision analysis considers diagnosis and treatment planning as a sequential process whereby clinicians revise their decisions as they construct and proceed along the trunk and branches of decision trees. Typically, decisions are weighted by mathematical rules to: 1) identify expected outcomes; 2) estimate the probability of each outcome; 3) evaluate risks and benefits; and 4) assign a utility value for every possible outcome. Eventually, each branch offers a probability and utility value that together offer a value for the utility or usefulness of each decision. [§] This approach carries the authority of scientific and mathematical rationality for optimizing and justifying clinical decisions, and it has been recommended as a means of evaluating clinical competency within a perceived range of normal or optimal decisions, as established by mathematical probability (Elstein & Schwartz, 2008). However, a rational treatment decision based on the rules of decision analysis occasionally conflicts with a clinician's ethical principles or with a patient's preferences for treatment (Patel *et al.*, 2002). Moreover, the analyses based on mathematical rules of decision analysis require comprehensive knowledge of all the available alternatives and their consequences, and these are not readily, if at all, accessible. It seems that diagnostic reasoning is a fairly flexible process and is not limited to application of mathematical formula to estimate the probability of a disease based on numerical data from

[§] For examples, please see Matthews *et al.*, 1999 and Patel *et al.*, 2002.

epidemiological studies (Eva, 2005, Norman & Brooks, 1997). Chambers, Mirchel and Lundergan (2010) showed that even when instructed to do so, experienced dentists and dental students failed to follow Bayesian rules** to estimate the diagnostic probability of periodontal disease. The approach to estimate diagnostic probabilities appeared to be "intuitive" rather than mathematical. Likewise, Bradley (1993) noted that designing decision trees requires a certain degree of artistry and expertise. It is not a mechanical or automatic process. In other words, some interpretive creativity is required when constructing decision trees. Perhaps decision theory implicitly relies upon such interpretive creativity, even though the conceptual basis and vocabulary of decision theory are devoid of artistry. Consequently, there is little current support for further development of decision support systems based on mathematical rules of decision analysis.

The list of identified heuristics and biases in medical diagnosis has grown substantially over the years to the point where a taxonomy has been developed to typify the cognitive errors in diagnosis based on faults in knowledge, data gathering, information processing and verification of information (Graber, Franklin

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** Bay's theorem claims to offer an objective measure of the probability of a hypothesis. Bayesian inference is considered as a scientific method of collecting evidence to confirm or refute a hypothesis. The degree of belief in a hypothesis ranges from 0 (lowest) to 1 (highest) and is calculated by the following formula:

$$P(H\backslash D) = \frac{P(D\backslash H)\ P(H)}{P(D\backslash H)\ P(H) + P(D\backslash \sim H)}$$

P(H\D) is the probability of hypothesis H, given datum D
P(D\H) is the posterior probability of the hypothesis H after D is known
P(H) is the prior probability of the hypothesis H
P(D\~H) is the chance that D infers hypothesis H when ~H is true
P(~H) is the prior probability of the hypothesis ~H
(Patel *et al*., 2002)

& Gordon, 2005). These findings emphasize the need for educational interventions and support systems to decrease the errors in diagnosis (Elstein & Schwartz, 2002 & 2008). However, the dual processing model of medical problem-solving supports the use of heuristics as adaptive reasoning strategies that help clinicians to cope with the limitations of human memory and information processing (Norman, 2009). For example, the cognitive overload of information may lead to "availability bias" whereby the clinician selects a diagnosis that is easily retrieved from memory. Apparently, clinicians are poor predictors of the probabilities of occurrence of diseases as they often overemphasize rare conditions or the ones with risky and negative consequences (Kahneman & Tversky, 1982). Eva and Norman (2005) argue that using such heuristics help more than hurt the diagnostic process. Therefore, their use should be encouraged with the caveat that clinicians should be aware of the biases and potentials for errors and be encouraged to reflect on the success or failure of their reasoning to reduce the frequency of errors in their diagnosis.

2.2.2.1. Decision support systems

Emergence of cognitive psychology and computer science led to medical informatics and applications of artificial intelligence with an aim to simulate the representations of knowledge and decision analysis in clinical situations (Norman & Brooks, 1997, Patel *et al.*, 2002). Those systems are either based on Bayesian and regression models of reasoning or follow the causal and conditional protocols of reasoning of experts (*i.e.,* expert systems). The major issue with such systems is that they are primarily based on "factual knowledge" (*e.g.,*

cause-effect relationships or numerical probability or utility values). Recent developments with medical informatics aim to develop “neural networks”(Norman & Brooks, 1997) and incorporate theories of fuzzy sets (Zadeh, 1965), approximate reasoning (Zadeh, 2000), chaos theory (Sweeney & Griffiths, 2002), and computational theory of perceptions (Zadeh, 2000), all offering a conceptual basis for language, symbols, and semantics to design decision support systems that operate in situations of uncertainty. The current trend advocates “symbolic computation” and application of heuristics, knowledge structure and experiences to replace computation with numbers (Sadegh-Zadeh, 2001). However, computerized decision-support systems are seen by some as overly reductionist, mechanistic, non-contextual, and value-free (Dreyfus, 1992). Computerized systems cannot take account of the rich, complex and multilayered meanings that patients can bring to any encounter with a clinician. However, clinical decision support systems may have a useful role in education (Kawahata & MacEntee, 2002). They can provide students with opportunities to practice the process of making decisions in simulated cases in a safe environment where patients will not be harmed.

2.2.3. Interpretive inquiry of clinical reasoning

The interpretive approach offers a broader understanding of clinical reasoning within the context of healthcare practice. Fleming and Mattingly (1994) applied ethnography and action research to explore how occupational therapists think in clinical practice. They explained the social context in which occupational therapists use several reasoning strategies, such as procedural reasoning when

identifying problems, setting goals, and planning treatment; and interactive reasoning when exploring how patients experience disability. Later, several other reasoning strategies were identified by occupational therapists and physiotherapists such as narrative reasoning to explain experiences of disease from different perspectives and interpretations (Chapparo & Ranka, 2008), and conditional reasoning to imagine the impact of the therapeutic intervention on patient's experience of disability and try to foresee future problems (Fleming, 1991). This imagination and prediction helps them to adopt a preventive approach suitable for each patient. In addition, Chapparo and Ranka (2008) introduced ethical and pragmatic reasoning as strategies that are used to deal with conflicting ethical, moral, political, and economical dilemmas. Also, Higgs and Jones (2008) included collaborative reasoning when clinician and patients tackle a problem collaboratively.

Furthermore, interpretive inquiry offers explanations for the differences of expert and novice reasoning of nurses. Benner (1984) applied the model of skill acquisition of Dreyfus and Dreyfus (1980) to reveal that nurses develop their reasoning skills across several levels including: 1) novices who perform mostly from textbook knowledge with no prior exposure to clinical practice; 2) advanced beginners who identify aspects of the clinical situation based on limited experience or directions from a mentor; 3) competents with extensive practical experience who are able to differentiate between the marginal and relevant aspects of a clinical situation, adopt different reasoning strategies, and establish an "hierarchical perspective" to execute and analyze a treatment plan; 4)

proficients who can perceive situations “as a whole”, know what to expect, and can modify a plan in response to changing situations; and finally 5) experts who perceive and act “intuitively” without thinking consciously about the action plan. Benner acknowledged the challenges of describing how experts perform because they “operate from a deep understanding of the total situation”, and generally, they know more than they can say (Schon, 1983). Pyles & Stern (2007) and Rew *et al.* (2000) too found that nurses use intuition as they change from “analytical” reasoning to “knowing in action” as levels of expertise increase.

The interpretive studies of clinical reasoning have offered new insights to the cognitive (Christensen, Jones & Higgs, 2008) and interactive (Trede & Higgs, 2008) activities involved in addressing clinical problems. For example, Christensen *et al.* (2008) describe the cognitive dimensions of clinical reasoning as the ability to think critically and take account of the complexities inherent in the context of practice. They consider the ability to reflect on reasoning (*i.e.,* meta-cognition) a major determinant of competency in clinical reasoning. Trede and Higgs (2008) discuss the significance of interaction with patients and collaborative reasoning in providing patient-centered care. Furthermore, Loftus (2006) portrayed clinical reasoning as a phenomenon of language. This concept of clinical reasoning highlights the interactive and contextual nature of clinical reasoning and explains how language is used as the media to interpret clinical problems and justify the actions taken to address them. The new concept of clinical reasoning from an interpretive perspective has broadened our understanding of this phenomenon from a solely cognitive process happening in

the mind of clinician into the larger social, cultural and political environment and provided detailed descriptions of the reasoning strategies that help to identify and solve the biopsychosocial determinants of health (Evans, Barer & Marmor, 1994).

2.3. Expertise, pedagogy and clinical reasoning

One of the main objectives of research on clinical reasoning was to map the information processing of experts and untangle the structure of their biomedical knowledge. This information seemed necessary to serve as a guideline for designing educational programs to help novices develop similar knowledge structures or learn to follow the same path when processing clinical information.

Problem-based learning (PBL) (Barrows & Tamblyn, 1980) has been the most influential curricular model for improving reasoning skills in healthcare. In most of its current forms, it is based largely on H-D models of clinical reasoning, although more elaborate models of clinical reasoning have emerged to suggest that H-D reasoning is not the most efficient and certainly not the only way that clinicians reason (Eva 2005, Mandin *et al.*, 1997, Norman, 2005b). Some argue that the authenticity of clinical reasoning in PBL tutorials fades because problems are typically adjusted in relation to their structure and complexity to fit the learning objectives of the course (Prince & Boshuizen, 2004). The sequence and presentation of problems on paper-based PBL cases usually promote reasoning from hypothesis to clinical information (*i.e.,* backward reasoning) which seems inconsistent with the direction of reasoning by experts and the clinical experience of students. Medical students trained in a PBL curriculum raised concerns about

their pre-clinical training because they believed that PBL led them to build their knowledge “the other way around” (*i.e.,* from hypotheses to clinical information) (Prince, van de Wiel, Scherpbier, van der Vleuten & Boshuizen, 2000). The students also reflected on their limited opportunity for “integrated thinking” before entering the clinic. The inability to integrate clinical information appears to be the major cause of diagnostic error; however, the traditional PBL process does not include a specific integrative exercise as part of the H-D reasoning (Groves, O’Rourke & Alexander, 2003). These concerns have raised questions about the effectiveness of PBL in “bridging the gap between theory and practice”. In fact, several studies have confirmed that medical and dental students use combined strategies of reasoning as the situation demands (Crespo, Torres & Recio, 2004, Ramsden, Whelan & Cooper, 1989), which is consistent with the recent recommendation in medical education, advocating the dual processing model of diagnostic reasoning (Eva, 2005, Norman, 2009).

At the outset, clinical reasoning was perceived as a generic and transferable skill, irrespective of the content; therefore, it could be taught and developed through specific pedagogical methods (Norman, 2005b, Ramsden *et al.*, 1989). However, recent studies confirmed that medical problem-solving is not a generic and transferable skill; that is, success in solving one problem cannot predict success in solving another (Eva, Neville & Norman, 1998, Eva, 2003). These findings endorse the need for repeated exposure to different manifestations of diseases and engagement in repeated exercises of problem-solving (*i.e.,* “deliberate practice”) (Ericsson, 2004). These practices help novices to develop the required

network of knowledge and experiences for non-analytical reasoning (Eva, 2005, Norman, 2005a). Recent reports about expertise in medicine highlight the significance of clinical experience as a repertoire of examples and “encapsulated” management strategies (Monajemi *et al.*, 2007) which help recognize patterns of problems and addressing them accordingly. For example, clinical experience helps develop and refine illness scripts in relation to expanding the contextual aspects relating to enabling conditions (Schmidt & Rikers, 2007). The impact of contextual factors on diagnostic and treatment decisions has recently attracted some attention in medicine as the concept of expertise extends beyond “routine expertise” (*i.e.,* ability to repeatedly diagnose diseases accurately and efficiently) to “adaptive expertise” (*i.e.,* the ability to employ flexible and innovative approaches specific to each situation when faced with complex problems) (Mylopoulos & Regehr, 2007). The difference lies in the ability to be flexible and innovative to cope with complex situations rather than only being accurate and time efficient in reasoning. Mylopoulos and Woods (2009) argue that this change of concept extends the domain of expertise beyond the cognitive abilities of an individual clinician to the larger context within which they encounter medical problems. Therefore, this shift of focus calls for interpretive approaches to study the contextual nature of expertise in medicine.

This new perspective of medical expertise cautions against adopting deliberate practice of clinical reasoning as an educational activity designed to develop a routine for information processing, assuming that fast and accurate diagnosis is the ultimate outcome measure of success. Instead, the practice should include

reflection on the contextual aspects of clinical problems and adopting flexible and innovative reasoning strategies to address the problems specific to their contextual demands (Ericsson, 2007, Schmidt & Rikers, 2007). Interpretive study of clinical reasoning in other health professions such as physiotherapy (Higgs & Jones, 2008) and nursing (Benner, 1984) has confirmed the contextual nature of clinical reasoning and the significance of flexibility and intuitive reasoning of the experts.

2.4. Exploring clinical reasoning in dentistry

Psychometric measurement of how dentists diagnose clinical problems and decide on the appropriate treatment showed how inconsistently dentists approached diagnosis and treatment (Kay, Nuttall & Knill-Jones, 1992, Reit & Kvist, 1998). Many diagnostic tests are both insensitive and non-specific, which probably explains why dentists use specific tests inconsistently, and why there have been increasing emphasis on improving decision-support systems and practice guidelines. Since the 1970's, there has been growing interest in how dentists could or should solve problems and numerous conceptual explanations, such as decision analysis, preference-based measurements, rating scales, standard gamble techniques, time trade-offs, and quality adjusted life (tooth) years, game theory, and Bayesian-based utility measures were applied; all of which are known collectively as medical decision theory (Fyffe & Nuttall, 1995, Matthews *et al.*, 1999). However, dentists do not seem to apply Bayesian rules in their diagnostic process (Chambers *et al.*, 2010).

Expert systems appeared in dentistry in the 1980's with a range of computer-based decision support systems for diagnosis and treatment planning in several dental specialties, such as orthodontics (Sims-Williams, Brown, Matthewman & Stephens, 1987), prosthodontics (Kawahata & MacEntee, 2002) and oral medicine (Hubar, Manson-Hing & Heaven, 1990). Initially, the systems were simplistic in scope and application, but recently there is talk of applying more sophisticated systems based on the theory of fuzzy logic (Akcam & Takada, 2002). As mentioned before, there is now an awareness of the significance of language, symbols, and semantics within the context of clinical situations where uncertainty is a dominant feature (Sadegh-Zadeh, 2001, Zadeh, 2000). However, I am not aware of a practical application of these new ideas to analyze the clinical reasoning of dentists.

The 1990's brought the beginning of explorations into the process by which dentists made clinical decisions, largely influenced by the theory of information processing. Maupome and Sheiham (2000) used Gale and Marsden's (1982) Model of H-D reasoning to explore the diagnostic process of dental students when they addressed dental caries. Their findings suggested that dental students use a combination of H-D reasoning and pattern recognition to diagnose caries. Bader and Shugars (1997) argued that caries is a visible disease that triggers the clinician to action based on a script describing the color and size of the lesion, and a hypothesis about whether or not the disease is present or absent.

Most studies that have compared the clinical reasoning of dentists with various degrees of expertise focused on the outcome of the diagnostic and treatment

decisions rather than on the process of reasoning used by the dentists (Balto & Al-Madi, 2004, Knutsson, Lysell & Rohlin, 2001). Apparently, the outcome and process of reasoning by dentists are not very consistent. Comparing the reasoning process of dentists with differing levels of expertise showed that experts used “forward reasoning” to identify relevant information, search for key information and organize the findings to form a diagnostic hypothesis (Crespo *et al.*, 2004). Students and less experienced dentists generated an initial hypothesis and then moved backward to confirm or reject it. However, in all levels of expertise, some clinicians moved back and forth between their original and revised hypotheses to come up with a final diagnosis. It seems that, expert clinicians rely heavily on their clinical experiences to explain the pathophysiological mechanisms underlying the disease, whereas students and inexperienced dentists rely more on textbooks and other information acquired from didactic courses. The major difference between the expert and the novice was the emphasis placed by experts on the impact of psychosocial issues, such as behaviours and beliefs of patients. Expert dentists seem to rely more on previous experience to construct an individualized treatment plan to address patients’ special problems and needs, rather than work through a H-D process to an ideal treatment plan (Ettinger, Beck & Martin, 1990).

Summary

In all, research in clinical reasoning in dentistry has largely paralleled the equivalent research in medicine, understandably in view of the close historical

relationship between the two professions. Medical decision theory has dominated much of the discourse, and influenced such projects as computerized decision support systems. Other research traditions have included approaches that have been strongly influenced by cognitive psychology, such as the H-D method and pattern recognition. Closely related to this is the research into expert and novice differences, such as the literature about forward and backward reasoning.

Research on clinical reasoning has diverged more recently to address specific objectives and questions of different disciplines. Even within each discipline, differences in conceptual understanding of clinical reasoning and approach to research have diversified the course of this inquiry. Recently, medical educators attempted to synthesize the findings of research in medical problem-solving and offered recommendations for education (Bordage, 2007, Charlin *et al.*, 2007, Eva, 2005, Norman, 2005a&b). This integration converged the findings of research towards a new conceptual model (Eva, 2005, Norman, 2005a, Norman, 2009). However, despite the repeated calls for integrating findings and objectives of clinical reasoning research (Loftus & Smith, 2008, Norman, 2005a, Patel *et al.*, 2002), the “methodological pluralism” continues (Arocha & Patel, 2008). This pluralism has been helpful in unraveling the complexity of clinical reasoning as a cognitive, interactive and contextual phenomenon. Yet, it is not clear if a universal and generic model for clinical reasoning can serve all healthcare disciplines. As mentioned in the previous chapter, differences in types of problems and approach to care in each discipline and the respective diversity in clinical practice pose a challenge for integrating the objectives and findings of this

research across disciplines. Higgs and Loftus (2008) call for “clinical reasoning research and practice to be grounded in an understanding of reasoning as occurring within practice models and clinical reasoning models”.

The following chapter will present how I adopted an interpretive approach to explore clinical reasoning across different problems and levels of expertise in dentistry. I will present the findings of my research in line with the existing knowledge about clinical reasoning in other healthcare disciplines. I describe how the specific type of problems in dentistry and the context within which they interact with the clinician call for adopting specific process and reasoning strategies by dentists.

CHAPTER THREE: METHOD

3.1. An interpretive approach to explore clinical reasoning

Interpretive inquiry is a general term that refers to interpretation of any form of human written, verbal or physical expression (Smith, 1992). The expressions have a broad historical and social context reflecting the knowledge, experience, reason, interest, intention and motivation of people (Angen, 2000, Marton & Booth, 1997). This form of inquiry provides an interpretation of social reality that is meaningful to the members of the society, derived from the expressions of its members, and open to interpretation by others (Smith, 1992). I adopted an interpretive approach for this research based on four essential premises as follow: 1) clinical reasoning is a contextual and interactive phenomenon that is expressed through language; 2) it is an interpretive process in and of itself that requires further interpretation when spoken; 3) the product of the interpretation (*e.g.,* description, theory, model) can be justified by its rigor, meaningfulness and practicality; and 4) the interpretations are open to further exploration by others.

In this chapter, I will first explain through personal reflections how my research questions evolved as I tried several methods to explore clinical reasoning. I will discuss how the findings from those exploratory studies helped me refine my research questions and objectives and the respective methods that I used to address the questions. I will follow this with a detailed description of my research questions, objectives, method and design.

3.2. Personal reflections: the challenge of selecting proper research questions and methods

The UBC Experience

At the outset, this research was a case study (Stake, 1995) with a fairly broad objective to explore and describe clinical reasoning as it is expressed and addressed within a dental curriculum. Traditionally, case studies involving programs, communities, organizations, *etc*. begin with a number of tentative or prospective research questions (Angen, 2000, Stake, 2005). As the research progresses, new questions and issues can emerge to change or specify the focus of the study, and the change occasionally demands a change of method (Stake, 1995, Yin, 2008). Alternatively, a case study can explore a phenomenon of interest within the context of the case, but the case is not the focus of the study; rather, it provides a context for exploring and understanding the phenomenon of interest (Stake, 2006). The criteria for selecting the cases are determined by the objectives of the study, with priority given to a case that maximizes opportunities to learn about the phenomenon.

Initially, a case study seemed appropriate to my interests because it offered flexibility to try and "test" alternative methods that could address my tentative objective. The first step was to select a case and a tentative research question. So I selected the UBC undergraduate dental curriculum to study how clinical reasoning is taught to and learned by dental students. I chose UBC primarily because of my active involvement in the faculty since 2002 as a research and teaching assistant. I have been a clinical instructor and PBL tutor in all four years

of the curriculum. This involvement ensured an already established rapport with most faculty and students to facilitate the process of recruiting participants for interviews. It also allowed me from a position of familiarity to access the information I received from participants.

At about the same time, I conducted a critical review of clinical reasoning in dentistry and dental education, which confirmed that the dental program at UBC is a suitable case because it is among a few dental schools that adopted problem-based and competency-based models of education (Clark, Harrison, MacNeil & Walton *et al.*, 1998, Walton, Harrison, Whitney & Best *et al.*, 2006). Theoretically, these models facilitate development of the competencies required for clinical reasoning, while the clinical portion of the program follows a comprehensive-care model that emphasizes “patient-centered” education. The model encourages students to address all the treatment needs of their patients if at all possible, and replaced the more traditional curriculum in which students rotated through discipline-based departments (*e.g.,* surgery, prosthodontics, *etc*.) and performed specific clinical procedures for an array of patients (Formicola, 1991). This traditional model assumes that students will integrate the discipline-based knowledge and skills into the multidisciplinary context of clinical practice when they graduate.

As my study progressed, the research questions and objectives became more specific. Firstly, I reviewed the curriculum in relation to the content and objective of all the courses (Appendix. 1). It appeared that clinical reasoning is addressed in almost every course and clinical activity throughout the curriculum. For

example, students acquire the required knowledge for clinical reasoning in the didactic discipline-specific modules that include lectures and PBL tutorials. So, in theory, this knowledge is available during their clinical practice in the Integrated Care Clinic (ICC)[††] as they diagnose problems and devise treatment plans for patients. Students start treating patients with simple problems in the middle of the 3rd year and progress to more complicated problems during their 4th year (Integrated Clinical Care Manual, 2007). They learn about clinical reasoning also in 10 diagnosis and treatment planning seminars during the second term of 3rd and 4th year. Students together from both classes attend small group seminars guided by a facilitator to discuss several clinical cases that have been managed by 4th year students.

The analysis of the curriculum helped me select a more specific context to study clinical reasoning. During the diagnosis and treatment planning seminars students discuss a wide range of clinical problems through presentations of treatment plans and outcomes of treatments. Therefore, I designed and conducted an exploratory study, using an interpretive approach, to understand how dental students and their mentors talk about clinical problems and reflect on their experiences of the process of diagnosis and treatment planning related to those problems. Over a course of 3 years, I observed more than 20 seminars and recorded detailed field-notes (Morse & Field, 1995, Patton, 2002) of my

[††] An integrated care clinic follows the comprehensive care model where the interdisciplinary procedures required for care of each patient are provided, as much as possible, by the same student. This ensures continuity of care and an opportunity for students to integrate their discipline-based competencies.

observations about how clinical reasoning was expressed in dialogues between students and faculty. In addition to those observations, I interviewed 9 students and 5 facilitators of the seminars about the presentations and discussions. During informal open-ended interviews with the faculty, I asked them to reflect on their experiences of the seminars that I observed. They also commented about how, in their views, those seminars help improve students' skills of diagnosis and treatment planning. In addition, I asked the students, in informal open-ended interviews, to talk about their reasons for selecting a specific treatment plan to present in the seminars, their experiences of diagnosis and treatment planning, and the challenges they faced in the process. I also conducted follow-up interviews with the same students after their seminar presentations and asked them to reflect on the experience and what they learned from the discussions.

The observations and interviews offered information about how students and faculty discuss and justify diagnosis and treatment decisions. However, the presentations were given after the students completed all of the procedures required for diagnosis and treatment planning in the clinic. Typically, at UBC, students: collect information about a patient's medical, dental and social history; record patients' concerns about oral health and their needs and demands for treatment; collect clinical information; diagnose problems; and develop a treatment plan. Students consult with several instructors to confirm the accuracy of their diagnoses and the treatment plans; however, it was unclear how the interactions with the faculty influence the process of arriving at a final decision about the diagnosis and treatment. Also, preparing a thirty-minute presentation

about the patient requires additional thinking, organizing and processing of information. The information I gathered provided little, if any, explanation as to how dental students approach clinical problems when they first encounter them; what reasoning process they go through as they encountered new or similar problems; and what strategies they use to identify and address the problems. I decided to select an alternative method to explore these questions as they evolved during my inquiry. Therefore, my new objective was to explore the process of clinical reasoning as it happens during a student's first encounter with clinical problems.

Ideally, I could have observed students interacting with patients and instructors in the clinic. However, the process of diagnosis and treatment planning in UBC dental clinics takes several appointments on different days with different instructors. Hence I would have had to follow the patients and students whenever they were involved in any interaction related to a treatment plan. It is an intrusive and distracting method, especially if I asked question during the process, and it would have required informed consent from patients, students, and instructors.

Consequently, I decided to select another context to explore clinical reasoning as it happens. I chose the treatment planning seminars again, this time approaching the students who were listening to presentations by their peers. For example, in some sessions I asked the students to write whatever they were thinking about while they were listening to each presentation. The notes I collected from students provided very limited information about their process of reasoning. It seemed that writing the notes during the seminars was too distracting, and

students made notes only when they made occasional eye contact with me during a seminar. Moreover, the content of the notes were disjointed. I also asked each student to write a journal about the seminars and reflect on what was discussed in each session and what was learned from the discussions. However, yet again, the reflective journal did not clearly describe the reasoning or learning process, possibly because the students did not understand the intention of the reflective activity and approached the task as if I asked for a “course evaluation” of the seminars.

I searched for alternative approaches to prompt clinical reasoning in a simulated setting that was not intrusive to patient care and student learning. The “think-aloud” method (van Someren, Barnard & Sandberg, 1994) seemed most appropriate for students during individual interviews with me as they think aloud about patients and their problems. The following section will describe in detail how I modified the traditional think-aloud method and used several situational vignettes (Hughes & Huby, 2002, Peabody, Luck, Glassman & Dresselhaus *et al.*, 2000) to simulate specific contextual issues to prompt certain aspects of clinical reasoning.

At about the same time, my critical review of clinical reasoning and how it evolved in dentistry and dental education helped me to recognize the need for a conceptual framework based on empirical evidence to describe the process of clinical reasoning and the strategies used by dental clinicians. Without this framework my inquiry could not address my initial research questions about teaching, learning, and assessing clinical reasoning in dental education. This

framework, I believed, was a foundation needed for defining competency in clinical reasoning in dentistry. It could also direct future research to explore how clinical reasoning of dental students improves with different curricular models or educational interventions, and how they might be assessed. Therefore, my research questions evolved further to address the following questions in particular: “How do dental students address biopsychosocial issues influencing oral health related problems?” and “What are the similarities and differences in clinical reasoning of dental students in the beginning and end of the 4th Year?”

I would look for similarities and differences in how students reason across both stages of the program. This, I assumed, would help me to explore how prior experiences with similar problems influences the process of clinical reasoning and the strategies used by students. It would also help me to include students with different experiences and competencies. I used the UBC dental curriculum not as a “case”, but as a context where I could approach dental students at different levels of competency.

The Eastman Experience

After completing the UBC study, I left Vancouver for two years to attend an orthodontic residency program at the University of Rochester, Eastman Dental Center. I saw the opportunity to continue this research but in a different context with the questions: ”How do orthodontic residents and clinicians address biopsychosocial issues related to craniofacial growth and malocclusion?” and ”What are the similarities and differences in clinical reasoning of orthodontic residents and clinicians?”

This additional venue helped me re-apply the think-aloud method with clinical vignettes to explore clinical reasoning amongst a different group of dental clinicians. The new participants compared to dental students generally had a wider range of expertise and experience with clinical problems.

In the following sections I explain how I used the think-aloud method and situational vignettes as a medium to prompt clinical reasoning. This will be followed by a description of my research design, data collection and analysis.

3.3. Think-aloud method

The think-aloud method of problem-solving (van Someren *et al.*, 1994) has been used extensively in psychology (Li, 2004, Young, 2005) and in healthcare to design expert systems and to analyze the knowledge and cognitive processes of experts (Boshuizen & Schmidt, 1992, Elstein *et al.*, 1978, Funkesson, Anbacken & Ek, 2007). During individual interviews, participants are asked to express their thoughts as they address a problem. The process of problem-solving usually precedes uninterrupted unless there is a prolonged silence in which case prompts are used to remind the participants to continue speaking about their thoughts. The thoughts as spoken are then transcribed and segmented, which can occur in many forms depending on the purpose of the study. For example, a "bottom-up" or inductive approach can identify for computerized expert systems the detailed knowledge structures of experts. Alternatively, a "top-down" or deductive approach can compare verbalized thoughts of the participants to a pre-existing model of problem-solving.

3.4. Vignettes to prompt clinical reasoning

Vignettes include any form of text, image, or other audiovisual aid used to prompt a response about specific situations or questions (Young, 2005). They became popular for use in social science and healthcare research because they provide a relatively inexpensive media to stimulate and direct discussions about the issue of interest. Medicine, in particular, has used “clinical” vignettes extensively as a research, educational and assessment tool to prompt the process of problem solving and decision-making by medical students and physicians (Barrows & Tamblyn, 1980, Peabody *et al.*, 2000). A clinical vignette usually includes an excerpt from a clinical scenario or sequences of clinical events supplemented by diagnostic aids, such as results from laboratory tests and radiographs (Boshuizen & Schmidt, 1992).

3.5. Personal reflections: my interpretive approach to data collection and analysis

I used the think-aloud method to record the reasoning of dental students and orthodontists during individual interviews. I used diagnostic aids (*e.g.,* photos, radiographs, *etc.*) of real patients and created situational vignettes to simulate real scenarios of clinical encounters with biopsychosocial issues. I will later explain how I selected the problems that I used in each study and how I created situational vignettes. All interviews were open-ended and there was no time limit for addressing the problems in each vignette. I provided at the beginning of each interview a brief introduction about the purpose of the study and the interview

including instruction on thinking-aloud. I did not control how participants collected clinical information about the patients. Instead, I advised them to ask questions or request any diagnostic aids that they needed at any time as we proceeded through the vignette. I used probing questions during the interviews and asked the participants to elaborate on their reasoning when I thought it was necessary. My questions occasionally interrupted the natural course of reasoning, but they were necessary to explore how each individual interpreted different situations and how they diverged or converged their reasoning towards different or similar outcome (*e.g.,* diagnostic or treatment decisions). My questions could also have directed the process of reasoning by bringing to the fore aspects of problems to elaborate on their reasoning. However, I tried to minimize my influence on the interview process by asking only open-ended questions such as “Why would you do that?” or “What would be the next thing that you would do?” I used those questions only when there was a long pause or when the participants suggested a specific approach without elaboration.

I discuss the process of data collection and analysis of each study separately and in detail in the following section. The entire process of designing my research, collecting, analyzing and interpreting information from the literature and from interview transcripts was influenced and directed by my background as a dentist, an orthodontist, an instructor and a researcher. My personal and professional knowledge, experiences and beliefs offered me a personal frame of reference which helped me to be attentive to specific issues that surfaced during the interviews. Being familiar with the jargon of dentistry and orthodontics helped me

follow the discussions and understand the opinions of participants. My knowledge of reasoning strategies and processes applied in other healthcare disciplines and the experience of my exploratory studies helped me recognize when and how similar strategies were used in dentistry and orthodontics. I analyzed the data as it emerged during the interviews. Each interview made me more familiar with the application of reasoning strategies and processes in dentistry. I also identified unique strategies that helped the participants approach the biopsychosocial issues influencing oral health related problems.

My analysis involved both deductive and inductive approaches to the information collected (Patton, 2002). The deductive (top-down approach) helped me identify excerpts from each interview that represented a specific process or strategy which was previously introduced in the literature[‡‡]. I then analyzed the transcripts again line by line to identify processes or strategies specific to dentistry for which I could not find an existing definition or description from the literature. I also used Patton's (2002) approach for "logical analysis of qualitative data", whereby I searched for "patterns" in each interview and across the interviews in each study in relation to the process of reasoning. I will describe this approach later in more detail.

The EDC study was a parallel to UBC study in relation to design, data collection and analysis. I adopted the same approach and used similar methods to my interpretive inquiry of clinical reasoning in orthodontics. I was more familiar with

[‡‡] Chapter 2 provides a review of these processes and strategies.

and cognizant of reasoning strategies and processes as they surfaced during my interviews with orthodontic residents and experienced orthodontists. However, I tried to remain sensitive to the specific approaches for addressing orthodontic problems and the similarities and differences across the levels of expertise.

I was also sensitive to the dynamics between myself and the participants in both studies. All participants knew me personally or professionally prior to the interviews. At UBC, as a graduate student, I was an instructor for the dental students and I was a classmate of the orthodontic residents at the EDC and a student of the professors.

The informed consent reassured the participants about the purpose of the study and that their position would not be jeopardized as a result of participating in my study. In addition, I tried to use only open-ended questions to prompt reasoning without approving or disapproving of the participants' comments about a problem or a treatment approach. This helped me reassure the participating dental students and residents that they were not being judged by me or my advisors about their reasoning abilities, and that I was only interested in hearing their thoughts and exploring the process of their reasoning. It also helped me to feel comfortable about asking the faculty members at both institutions to elaborate on their opinions and approaches to problems. My frame of reference certainly influenced my opinion regarding problems and different approaches to address them. However, I did not reveal my personal and professional views about the problems during the interviews.

Here, I explain the design of both studies in detail and elaborate on the process of data collection and analysis.

3.6. Research design

I conducted two studies with similar objectives and methods in two different contexts. One involved students at the beginning and end of the final (4th) year of their undergraduate dental program and the other involved residents, recent graduates and faculty of the post-graduate orthodontic program. I will discuss the objectives and design of each study separately.

3.7. The UBC study

In this study, I:

1) selected two clinical cases that were previously presented by students in the diagnosis and treatment planning seminars in the Faculty of Dentistry at UBC;

2) built six vignettes to represent a realistic simulation of clinical encounter with problems (Appendix. 2);

3) asked faculty members to validate the vignettes as a method to prompt the clinical reasoning of dental students, and relate the vignettes to the their expectations of students at the beginning and end of the final year of the dental program;

3) described the students' performance in clinical reasoning at the beginning and end of the 4th Year, and compared their performances to the process of clinical reasoning and strategies used by them at the beginning and end of the same year;

3.7.1. Constructing vignettes

I selected two patient-cases with a range of common, important, and contentious problems from the seminars that I observed during my exploratory studies. They represented a range from simple to complicated problems, each with biological and psychosocial components. I constructed also six vignettes to present similar problems for discussion in the seminars as they are likely to be encountered by students in the clinic (Appendix. 2).

3.7.2. Validating the vignettes

I selected purposefully nine faculty members, one from each specialty of dentistry and two general dentists from the list of full-time instructors in the Faculty of Dentistry's clinic (Coyne, 1977, Patton, 2002). First, I selected senior members who were involved in designing and delivering courses or teaching modules. I assumed that they were more familiar with the structure and content of the curriculum in relation to the content of courses. I sent out a letter of invitation (Appendix. 3) explaining the purpose and process of my study and asked them to participate in a one-hour open-ended interview. However, I got no response from some of the faculty. Therefore, I invited others from the same specialty to participate until I interviewed one faculty from each specialty.

I developed an interview guide (Appendix. 4) relating to the construct and content of the vignettes as a tool to prompt clinical reasoning among students. The guide was based on the existing models of clinical reasoning (Chapter. 2) I asked specific questions from the faculty about how the vignettes could help to distinguish the different domains of clinical reasoning used by students.

With their formal signed consent (Appendix. 5), I taped the faculty's interviews. The vignettes were presented to the faculty in the same order as planned for the students, and each faculty member was asked to comment on them. I specifically asked if the problems were likely to reveal a student's knowledge, communication skills, ethics, awareness of psychosocial factors, treatment options, prognosis, and context of practice.

The transcribed interviews with faculty were analyzed using a combination of top-down and bottom-up approaches. First, I read all the transcripts to check for accuracy of the content and also to get a sense of what was discussed by each participant. Using a top-down approach, I looked specifically for segments of the interviews where the faculty commented on the validity of the vignettes in relation to the purpose of the study. For example, in relation to the content validity of the vignettes, I looked for evidence confirming that: 1) the vignettes were realistic; 2) the sequence of presenting information was reasonable and similar to presentations in the clinic; and 3) the problems represented common and realistic situations.

To ensure that the construct of each vignette was reasonable, I looked for confirmation that: 1) they would prompt students to reveal their skills in all domains of clinical reasoning; and 2) they would distinguish between the skills expected of students at the beginning and at the end of the 4th year. In addition, I looked for comments about the content and how it was presented that might influence the collection and analysis of information from students. Subsequently,

after the first two interviews with faculty, I changed a vignette to provide a more realistic ethical dilemma (*i.e.,* Vignette. 2)

3.7.3. Selecting students

I delivered the letters of initial contact (Appendix. 6) to each senior 4th-Year dental student, and at the end of a lecture I explained the study to the junior or incoming 4th-Year class of students, distributed the letters of invitation to everyone, and asked them to participate. I excluded all foreign-trained dentists among the students because their previous professional training and experience is varied and they might have been in a different level of expertise in clinical reasoning compared to the local dental students. From the remaining 40 students in each class of 3rd and 4th year, at least 25 students offered to participate in the study.

I purposefully selected students for a similar distribution of participants with below-average, average, and above-average academic standings. Finally, 10 students at the end of their 4th year of the program and 8 in the beginning of the 4th year participated in the study.

3.7.4. Ethical considerations

I did not have information about the academic standing of students, therefore, when the students offered to participate, the manager of academic affairs arranged the groups according to academic standing, and if necessary suggested additional students for me to contact so that the distribution of rank

was even. Also, to ensure confidentiality of all the participants, I assigned pseudonyms to everyone in all the transcripts and reports.

I clearly explained the purpose and process of the study to everyone and offered everyone an opportunity to participate. I also respected the autonomy, anonymity and confidentiality of participants so that their status within and without the Faculty is never in jeopardy.

3.7.5. Data collection

Semi-structured, tape-recorded individual interviews of about one hour were conducted in a quiet room at the Faculty of Dentistry. At the beginning of the interview, after obtaining consent (Appendix. 7), I explained the think-aloud method (Appendix. 8), and presented each vignette with a request that the participants explain their thoughts as they considered the scenario, diagnosed problems and developed a treatment plan. They could ask for additional information at any time during the interview. When necessary, I prompted the students to elaborate on their explanations or asked for clarification. All comments about the problems, clinical observations, diagnoses and treatment were accepted without evaluation. The interviews were transcribed verbatim.

3.7.6. Data analysis

Firstly, I read each transcript carefully for accuracy and a general understanding of each interview. I used a combination of bottom-up (inductive) and top-down (deductive) approaches to my analysis. Using a top-down approach, I first divided the data for each interview into smaller segments that each represented a

specific stage in the process of identifying, interpreting and solving problems and coded each segment accordingly. For each segment, I used a term that best captured the meaning of the segment as the label for the code. For example, the following was coded as “exploring the chief complaint”:

> I’d probably start by asking a little bit about why she feels she needs a new denture. It says a little bit in the chief complaint here, that it’s not stable and it’s broken. I’d ask her how long it’s been like that.

This segment was followed by the process of “clinical examination”:

> I’d probably do a new patient exam: checking head and neck, check TMJ, check inside the mouth for oral pathology, as well as outside . . . check the bite of the dentures she currently has.

Later, these two segments and respective codes were put under a broader category of “identifying problem” which denoted the first step in the reasoning process.

Based on descriptions by Higgs and Jones (2008), I also used the top-down approach to code the interviews in relation to the reasoning strategies that students used. For example, “conditional reasoning” is a strategy that possibly helps clinicians to evaluate a problem specific to an individual patient. It helps to explore the sources of problems, anticipates problems in the future, and evaluates possible outcome of interventions. The following excerpts of an interview were coded as conditional reasoning:

> I’d feel more inclined to keep the teeth in at forty . . . as a person ages I’d be more inclined taking teeth out than when they’re younger, because they’re not going to be around as long to have the denture. . . . The bone’s going to have less chance to resorb. In the long term, they’re not going to be around for those problems.

> You can give her a poorer or better prognosis depending on what they want. . . . If she doesn't want to take care of [her teeth], if she just wants a new denture, you warn her that: 'you know, you've still got these underlying problems. While we could make the denture for you, but in the long- or even in the short-run potential problems could occur. . . . She's already got an infection there, it could get worse, the caries could progress, she could lose a few other teeth. Her denture might be relying on those teeth and they're not going to hold anymore.

I then adopted a bottom-up approach to search for a strategy unrelated to any of the existing strategies identified in the literature.

The initial process of coding and categorizing focused on summarizing each interview in relation to the process of reasoning and strategy used by students. To compare and identify patterns as described by Patton (2002), I summarized in tables the steps in reasoning used by each group of students (Appendix. 9). The most dominant colour in each column and the entire table represented the most common strategy used by specific students and their group respectively.

3.8. The EDC study

In this study, I:

1) selected two patients who had previously attended the orthodontic department at the University of Rochester, Eastman Dental Center and built two clinical vignettes supplemented by diagnostic aids to represent a realistic simulation of clinical encounters;

2) described the performance of a) 1st and 2nd Year orthodontic residents; b) orthodontists who graduated within the preceding 10 years; and c) orthodontists who graduated more than 10 years previously;

3) compared the findings at the EDC with those from the dental students at UBC to help develop a conceptual framework for clinical reasoning in dentistry across levels of expertise and problems.

3.8.1. Constructing vignettes

For this study, again, I selected clinical cases from the data-base of the orthodontic clinic at EDC that represented a range of common, important and contentious problems relating to craniofacial growth and malocclusion. I specifically chose problems representing severe crowding and discrepancy in growth of the upper and lower jaws that usually necessitated tooth extraction or expansion of dental arches. Similarly, I selected orthodontic problems that could be addressed by moving teeth or by a combination of tooth movement and jaw surgery. I removed identifiers from the diagnostic records and presented the chief complaint of each patient along with their extra- and intra-oral photos to initiate the interviews (Appendix. 10).

3.8.2. Selecting participants

The residents were in the 1st or 2nd years of the two-year post-graduate program in orthodontics. Recent graduates with less than 10 years experience were either teaching in the orthodontic clinic or were available for the interview at a convenient location for them and myself.[§§] The orthodontic faculty members each had a minimum of 10 years of clinical experience in orthodontics. I sent a letter of

[§§] I interviewed two recent graduates of the program on one of my personal trips to the city where they both practised. They both selected a quiet room at their workplace as a convenient location for the interview.

invitation to everyone (Appendix. 11). Eight residents (4 from the 1st and 4 from the 2nd year of the program) along with 11 orthodontists (3 recent graduates and 8 experienced clinicians) participated in the study.

3.8.3. Ethical considerations

To ensure confidentiality of the participants, all the names and identifiers were removed from interview transcripts and they were assigned a pseudonym interviewee to protect their identity. All of the information will remain confidential and in no way jeopardize the status of either residents or faculty in the program.

3.8.4. Data collection

Similar to the UBC study, each participant received instructions about the think-aloud method prior to the interview (Appendix. 8). They were asked to consider the chief complaint and diagnostic records of the two patients, and to think out loud as they identified and diagnosed problems and constructed treatment plans. This process was conducted without interruption unless a long period of silence necessitated a prompt to resume the description of thoughts. Interviews lasted from 30 to 90 minutes, and all were tape-recorded and transcribed verbatim.

3.8.5. Data analysis

Again, I used a combination of top-down and bottom-up approaches to analyse the reasoning protocols described in this part of the study. I read all the interview transcripts, summarized and coded them relating to the process of reasoning. I used a top-down approach to look for reasoning strategies, followed by a bottom-up approach to look for new strategy or processes specific to orthodontics or

related to reasoning at different levels of expertise. I compared the process and strategies of reasoning among the levels of expertise, looked for “patterns” in the process of each group, and compared the findings to the UBC findings.

CHAPTER FOUR: FINDINGS

This chapter presents the findings from both the UBC and EDC studies that serve as the empirical evidence in support of a conceptual framework for clinical reasoning in dentistry.

My findings from the UBC study are presented in the following order:

Firstly, I present the views of faculty members of UBC validating the vignettes as media to explore how dental students reason clinically. I also present their expectations of students in the beginning and end of 4th year. I describe the process of clinical reasoning and related strategies that I recorded among the dental students in each group. Finally, I discuss the similarities and differences between the groups, and compare the findings with the expectations of faculty members.

My findings from the EDC study relate to the reasoning process and strategies used by all of the orthodontic participants, followed by a description of the similarities and differences in reasoning between the three orthodontic groups.

4.1. The UBC study

4.1.1. Validating vignettes for prompting clinical reasoning of dental students

Faculty members who assessed the six vignettes at UBC confirmed that they were realistic and the presentation of information was similar to the usual diagnostic and planning protocols used in the Faculty's clinic. They believed also that the vignettes would prompt students to demonstrate their skills in related competencies required for clinical reasoning and identify the similarities and

differences in the way students reason in different stages of their education. They also offered suggestions for minor changes to one vignette, which I made before interviewing the students.

4.1.1.1. Validity of the vignettes

Vignettes 1 & 4 each present the chief complaint of a patient (Appendix. 2), and I quoted exactly from the patients' charts and used copies of the diagnostic records, so the faculty accepted this and commented only on the reality of vignettes number 2, 3, 5 and 6.

Vignette 2 presents an ethical dilemma of patient autonomy versus beneficence. This vignette presents a scenario in which the patient could not afford the cost of the restorative treatment suggested by the student. Instead, the patient asks the student to extract all her teeth, including "healthy teeth", and to fabricate complete dentures. All faculty members confirmed that this scenario is encountered by most clinicians regularly.

Vignette 3 presents another ethical dilemma around a conflict of interest when students are required to complete specific treatments (management of a disease and construction of dental crowns) for a patient before they graduate, but the patient cannot pay for the treatment in full. However, they are told they can not proceed to make the crowns until the patient paid for a "caries management program". I assumed that this scenario presents another ethical dilemma involving the patients' refusal to pay and the students' requirements for graduation. Most faculty participants agreed that "the students will be divided [between] those who . . . try to . . . finish [their] requirements and those who say

[requirements] play no role" [FH***] and so some might opt unethically to make the crowns without managing the disease.

Vignette 5 contains a conflict of opinion between two instructors - one a general dentist and the other a specialist - who disagree on the treatment appropriate for a patient. One instructor (a general dentist) suggests monitoring the lesion seen in the patient's mouth while the other (a specialist) suggests a biopsy. I assumed that the scenario intends to prompt students to think critically about the validity of their own knowledge when confronted by disagreements between authority figures, and also how they justify their own decisions, which according to one faculty member relates to a "compromised position of trust" for students in opinion of faculty. [FC]

Vignette 6 presents a patient who is offended by an instructor's criticism of his smoking habit. The instructor attempts to scare the patient by telling him that if he doesn't stop smoking, he will die from cancer. Some faculty members believed that the scenario was "realistic" [FI] whereas others found it "a bit of an overkill" and "too harsh" [FD]. However, I decided to leave it unchanged.

4.1.1.2. Presentation of information

All faculty members believed that the sequence of presenting information to the students was reasonable. One faculty member compared the sequencing of information in the vignettes to "problem-based learning" cases in that "you get a

*** The letter "F" in the pseudonym refers to "faculty". "JS" represents a student in the beginning of the 4th year (*i.e.,* junior student) and "SS" the end of 4th year (*i.e.,* senior student). I then assigned letters "A", "B", "C", etc. to participants based on the order in which I interviewed them (*e.g.,* FA is the first faculty member whom I interviewed.)

bit of information, then you explore. You ask questions and you develop reasoning skills and ask for information as you go on." [FF]

4.1.1.3. Multidisciplinary problem solving

The faculty confirmed that each vignette incorporated a wide range of knowledge associated with many clinical disciplines of dentistry.

4.1.1.4. Addressing domains of competency

The faculty acknowledged that the 6 vignettes addressed all of the competencies expected of a graduating dental student, such as knowledge, communication, ethics, awareness of the prognosis of conditions and treatment options, awareness of the psychosocial aspects of a patient's condition, and a broad awareness of clinical practice.

4.1.1.5. Faculty expectations from students

Faculty assumed that senior students would be more aware of the "big picture" beyond individual problems of teeth, whereas less experienced students would concentrate on teeth without awareness of the larger context of dental care:

> [Junior students] would just hone in on teeth instead of looking at the big picture. . . . [Senior students] . . . start to look at the big picture. [FD]

They also anticipated that more experienced students could integrate information more readily than their juniors and evaluate all aspects of the situation, and finally put everything together:

> It's important to look at all six of the domains [of competency] . . . and realize that they aren't in a vacuum. You've gotta develop your knowledge base and to develop and strengthen and consolidate that knowledge base, [you should] try to apply it to clinical situations. You develop patient-centered communication skills, you've also got to be able to educate your

> patients and communicate your knowledge base with them. . . . If what we are trying for is a patient-centered clinical method that takes a biopsychosocial approach, it's all got to be done together; which makes it really difficult for the students and it is intimidating at the beginning. We've all been there; it's a matter of eventually just kinda making a break through. Takes some time before you have an epiphany and it works. [FE]

Faculty believed that the limited knowledge of junior students would challenge their abilities to communicate with patients. One faculty member explained there is a "step-wise progression from acquiring . . . to applying . . . to communicating knowledge" [FE]. Clinical experience, I was told, seems crucial to developing competency for such integration:

> [Senior] students are probably better equipped to manage a case like this simply based upon the time and experience. . . . You can't communicate what you don't know [or] what you've never seen. . . . By the end of 4th year, they are gonna know more about clinical dentistry and options and comprehensive care . . . because . . . they've been exposed to more. [FC]

The limitation of "scientific" knowledge to support clinical reasoning of students was acknowledged because dentistry seemed to be "light years away from evidence-based practice" [FA]. However, others believed that this evidence is "emerging" [FF] and that they expect students to present the evidence base for their clinical reasoning [FD]. Some commented on the challenge of encouraging students to apply evidence-based dentistry:

> No matter how many PBL cases we do . . . they don't have time to read literature. . . . They take our words for granted . . . and they don't read. [FH]

More experienced students were expected to have a higher awareness of the healthcare environment as they started to know "the ropes" [FF] and "how to work around the system" [FB] of the clinic. It was assumed by some that this awareness would empower students for their relationship with the faculty and patients.

Ethical development of students was an uncertain and controversial topic for most of the faculty. Some were unsure that ethics could be taught or improved through teaching since "ethics are part of basic values, beliefs and attitudes that are not going to change very easily" [FA] Some did not believe that teaching ethics would make a difference [FA], whereas others felt that it could only be "fine tuned" [FF]. There were even faculty members who believed that the environment of dental school would:

> [a]ctually have a negative effect on students . . . the money, the competition, the institution. . . . The students see it. That's worrisome. [FA]

> We are playing games with the students. We are not intending to, but we do. . . . I've been a victim of [having to] demonstrate that what I teach them is wrong. I've been in that situation many times. [FI]

In all, faculty believed that clinical experience helps students develop their knowledge and skills in most domains of dentistry. They also made suggestions regarding the process of the study and possible issues that could arise during the interviews with students. I incorporated their few suggestions for enhancing the reality of the scenarios in the vignettes.

After analyzing the interviews with faculty, I conducted the interviews with students, and I present my findings in the following section about the similarities and differences in the reasoning of students. Later, I will return to the assumptions made by the faculty members about these differences to discuss the validity of those assumptions.

The following presents the process and strategies of clinical reasoning by dental students.

4.1.2. The process of clinical reasoning

The process of reasoning used by students involves four stages: 1) collecting and evaluating information; 2) identifying and interpreting problems; 3) evaluating options; and 4) arriving at a diagnosis and treatment plan. However, students followed the process in different order and did not necessarily go through all of them for every problem. In all, the process of diagnosis and treatment planning followed one or more of the following: 1) ritual; 2) forward or backward reasoning or a combination of both; 3) pattern recognition and use of scripts; and 3) decision analysis.

4.1.2.1. Ritual

All students adopted a routine and systematic approach to collecting clinical information, which includes: 1) obtaining medical, dental and social histories; 2) exploring the chief complaint of the patient; 3) collecting information from clinical examinations; and 4) collecting information from diagnostic-aids, such as radiographs, odontograms, and diagnostic casts. Subsequently, they planned a sequence to the treatment usually starting with management of disease followed by rehabilitation and maintenance of health. For example, a junior student explained how:

> [a]t UBC, we like to get the medical history . . . and then the dental history and then. . . . You'd have to read the odontogram. . . . Once you collect all your data . . . then you make up a treatment plan. [JSB]

> You break it up into phase one, two and three of treatment. . . . phase one is disease control. . . . second phase, you think about making a new [denture]. [JSC]

Ritual seems to guide students through the "routine" process of collecting information and helps them "stay on track" [JSB]. However, some students followed all the steps of the ritual without a clear understanding of its implications. For example, some used classifications of periodontal diseases because, as one student stated, "we always classify [the conditions]. . . . Honestly, I don't know [why], treatment is always the same. . . . It's just more work for us to draw up an [individual] treatment plan" [JSG]. Many students felt that it was time-consuming and delays treatment. One student explained:

> In an emergency case . . . [when] I don't have a whole day to . . . go through the routine of assessing the patient . . . [I] address things like pain, bleeding, swelling, infection. . . . You've got to get the patient out of pain and you can deal with the rest [of the ritual] later. [SSG]

4.1.2.2. Backward and forward reasoning

Students used both backward or deductive and forward or inductive reasoning to diagnose clinical problems. When they observed a white lesion in the mouth, for example, some started with differential diagnoses and hypotheses, and then worked backwards to accept or reject each hypothesis:

> [The lesion can be] a hyperkeratosis caused by trauma. . . . [or] lichen planus [which] sometimes has diffuse pattern of light patches. . . . You might be thinking about any kind of viral [causes]; however, this doesn't look too much like that. . . . [It could be caused by] a known drug reaction. [So I try to] find out if they're taking any drugs and see if there's anything that's causing trauma. . . . Candida is sometimes white. . . . [I try to] see if it rubs off, and then leaves erythema behind. . . . [or] leukoplakia . . . when you don't know what it is; [when you] rule everything [else] out. . . . [I am] concerned about malignancy, like a squamous cell carcinoma. [JSC]

Alternatively, some students started the process by collecting information that later led them by forward reasoning to a diagnostic hypothesis. However, this

process was often followed by reasoning backward to rule out alternative hypotheses:

> First thing would be to ask the patient about medicine, drugs, smoking, alcohol use. . . . I'd check the other side [of the mouth] to see if it is bilateral . . . bilateral [lesions] usually [have] a better prognosis as far as the white lesion goes. . . . If you could rub it off . . . it is a candida infection. . . . I'd look for anything in the mouth that could be irritating those areas. . . . There is always a concern that it could be a displasia or cancer. . . . [if] it has a cobble stone appearance, you consider things like Crohn's disease or inflammatory bowel disease. SSD

A combination of forward and backward reasoning seemed to compensate for limited experience, and they used both approaches when dealing with signs and symptoms that are common to several problems, such as:

> [If t]he pain comes and goes . . . [does it] get worse? What sort of things [precipitate it -] biting or cold and hot food? Where is the pain coming from? . . . Is it an endodontic type of pain or gingival inflammation or just generalized pain? I'm trying to narrow it down to get a differential [diagnosis]. SSB

4.1.2.3. Pattern recognition and scripts

Visual and historical cues helped students to recognize the pattern of specific diseases, like caries, periodontal diseases and other mucosal abnormalities. Recognizing the pattern helped them bypass the process of making and testing hypotheses. This was followed often by requests for additional clinical information to expand the differential diagnosis.

Caries Script

Caries is the most common disease of teeth, and most students diagnosed it from the colour and appearance of the lesions on teeth. Some students sought further information about the tactile feel of the lesion to confirm the diagnosis.

Evaluating the etiology and risk for caries and tooth loss required a more elaborate exploration, which moved the diagnostic process to the psychosocial status of a patient:

> I can see a shadow of decay. . . . the extent of how her teeth are decayed. . . . [I need to explore] why she has these carious teeth or why does she even have a plate . . . [She is] young for a plate. [SSE]

> These are pretty big lesions. . . . This is where you'd want to focus on caries management, and try and find some etiologic factors. I don't know what [the patient's] socioeconomic status is, or if he has a poor diet, or something from his medical history [such as] xerostomia. [JSD]

The "scripts" for diagnosing caries consisted of an integrated network of information about the physiological status of saliva and estimates of bacterial counts in the mouth along with details on diet, hygiene, and socioeconomic status of a patient that contribute to the initiation and progression of caries. When triggered and confirmed, the script guided students to a therapeutic decision.

Periodontal diseases

Scripts for periodontal diseases were triggered mainly by visual cues about the normal versus abnormal appearance of the gingiva around teeth, where, according to one student: "We're looking for that nice pink healthy colour [of the gingiva], not red and inflamed. [SSJ] Measurements of gingival recession, periodontal pockets, and other numerical data supplemented the visual cues in the scripts to help classify the severity of the disease. The classification was used then to determine the course of treatment:

> If there's severe attachment loss, you can see it . . . also the pocket [depth]. . . . You can classify what type of patient it is. . . . [You] see the severity of their condition and [decide] how you would go about treating them. [JSA]

Mucosal lesions

Visual cues helped to diagnose mucosal lesions. Malignant lesions, for example, were triggered by a script that stated:

> [t]he bigger it is . . . the more erythematous, non-homogenous it looks . . . the more likely it's cancer. . . . There are certain things that I have on the list [of differential diagnosis] depending on the colour and stuff like that. [SSB]

Other "stuff" in the script included information about the location of the lesion. The location of the lesion influenced the prognosis of the condition. For example, one student explained, "there's a higher risk in the retromolar area for cancer [than buccal mucosa]" [SSH]. Also, cues from the patient's psychosocial background influenced prognosis and treatment. However, in general, all students struggled with diagnosing mucosal lesions, even when applying forward and backward reasoning or a combination of both strategies. Apparently, none of the students had developed a reliable diagnostic script for oral lesions:

> [The lesion] is not blowing up in my face. . . . if it was ugly, looked like something very suspicious . . . then you might want to biopsy it. . . . I've never seen that kind of presentation before. [SSJ]

4.1.2.4. Decision analysis

Making a decision to treat a problem usually involved a process of: 1) interpreting the problem; 2) developing options; and 3) evaluating the pros and cons of each option. One student decided to restore a patient's dentition by considering the facts that:

> She doesn't have any posterior occlusal support and room for her denture. . . . I'd like to see whether she's happy with [the vertical dimension of occlusion]. . . . [I would] determine if these teeth are restorable or not and whether we're going to be using them as over-denture abutments or whether we're just going to be doing a complete upper denture. . . . [I

> would] determine whether we can place any artificial teeth there or not, and if we do, can we open up more space by doing an enameloplasty or orthodontics. But that's pretty hard. . . . You have to present her with options of bridges, implants. . . . A bridge anywhere on her would be a long span [bridge that would] compromise the natural dentition. . . . This is a case that is complicated. It might look easy now but it could haunt you later during the building of a denture. So, this is something that I would prefer to refer to somebody who is more experienced. [SSG]

Nobody suggested a Bayesian approach or numbers to quantify the probability or utility value of the options. Instead, decision analysis seems to be an interpretive activity whereby students integrated their scientific knowledge and experience to assess the problem and options for intervention, and to ensure a reasonable and practical outcome, as reflected in this student's explanation:

> The literature was mentioned in the lectures [regarding the longevity of a restoration]; I kind of just . . . ballpark it from there. . . . It looks like about ten years from those numbers [that the restoration would last]. . . . That's what the literature gave. But every case is going to be different. . . . I haven't been around a long time, so I can't really tell that: 'well, that's going to fail'. So, I'm basically going on what other people have said [and] using [their opinion and experiences] as my gold standard. . . . So you are kind of: 'okay, if the ideal case [lasts for a specific number of years] . . . and this is not ideal . . . then just chopping away the years [of expected longevity of the restoration]'. . . . [you should consider] that there is a large range [of treatment success] . . . depending on . . . the situation [of each patient]. [SSJ]

4.1.3. Reasoning strategies

The following presents the main reasoning strategies that students used to interpret and address the problems in the vignettes. Strategies include scientific, conditional, collaborative, narrative, ethical, pragmatic and "part-whole" reasoning.

4.1.3.1. Scientific reasoning

H-D reasoning and decision analysis with Bayesian formulas emulate a "scientific" method for analyzing and solving problems. However, I found that students favoured pattern recognition and scripts, when available, and they used an interpretive approach rather than mathematical formulas to analyze their decisions. They based their knowledge on theory and experience derived from text books and manuals of didactic and clinical courses supplemented by opinions of instructors and other students. They were aware of the limitation and uncertainty of "scientific evidence" to support their decisions because:

> [The literature] gives me an indication of what sort of treatment has been done on teeth like this. . . . [but it's important to consider] has it been successful or is it just a five year recall or has it been a ten year recall [of patients in the study to evaluate success of treatment]. . . . Another thing [to consider] is: every patient is different. [Their] oral hygiene is different. Their habits are different. Everything is different. . . . You have to look into more parameters: how was the study done, what type of patient [they looked at] . . . What was their guideline for success. [SSG]

4.1.3.2. Conditional reasoning

The most dominant feature of students' reasoning was their uncertainty about the prognosis of problems and interventions and the conditionality of their diagnostic and therapeutic decisions on a complicated interaction of several biopsychosocial factors. Conditional reasoning involved a historical analysis of the biological, psychological, and socioeconomical factors that contribute to the initiation and progression of problems. This analysis helped the students to: 1) explore the source of problems; 2) envision the problems that could arise in the future; and 3)

evaluate the possible outcomes of their selected intervention. One student's explanation of his reasoning reflects this type of analysis:

> You can't skip [caries management program] altogether because there's existing disease process going too far. It's going to compromise the treatment. If you crown that tooth before getting rid of the caries, the caries might spread around. . . . There's just too many problems down the road . . . making it not worth it. [SSJ]

Another student explained that achieving objectives of treatment required "cooperation and determin[ing] how motivated [the patient is to] take care of [her teeth] on her own. . . . It can't just be me trying to fix the problems" [SSB]. Quite often, as explained by another student, achieving the desired outcome depends on patients' economic status and commitment to invest financially in the treatment:

> I can understand dental treatments are expensive, but it all depends on how you prioritize; like you can spend $200 on buying a cell phone or something or you could spend $200 on fixing your teeth. . . . It's her decision to decide whether she wants to spend that amount of money. [JSF]

Some students evaluated the options for treatment by considering future problems and recommended a treatment that would be "financially a benefit" in the future:

> To save these teeth as long as possible would be financially a benefit to her . . . [because] by [age] 80, she is going to have no bone there and she is going to need implants and may need a bone graft on top of that. So there could be a whole new set of problems and financial burdens that might come on [in the future]. [SSB]

Several factors such as the students' ability to render a treatment, or limitations of time and clinical facilities, pose further barriers to desired outcomes. A senior student reflecting on the limits of his clinical competence mentioned that he felt

confident “picking up a hand-piece and drilling anything” but he didn’t feel confident making “drastic, life-changing decisions for a patient.” SSI

4.1.3.3. Collaborative reasoning

All students referred to the significance of interacting with patients and seeking their opinions about treatment decisions in an effort to: 1) reach a shared understanding of the most desirable and feasible treatment outcome; 2) share the responsibility of making decisions; and 3) educate the patient to facilitate decision making or promote a change in behaviour:

> When you treatment plan with a patient you educate them. . . . You give all various options, so that a patient can decide [and] be informed. JSE

> If the patient never thought about quitting smoking, you have to move him to another stage: pre-contemplate to contemplate. . . . Inform him that smoking will increase his chance [of] cancer. SSF

In most situations, students seemed to accept that patients make the final decision and that their role as educators is to help the patient make an informed decision. Sometimes the decision requires consultation with an instructor or specialist especially when:

> With dentition like this, that there’s just so many things that can happen and there’s so many options . . . this is definitely one that I would take to my mentor and be like: ‘Let’s hack this one out together’. SSI

4.1.3.4. Narrative reasoning

Interpreting problems often required an interactive process whereby students tried to understand from the patient’s perspective the meaning of the problems and expectations from treatment. Some reflected on the assumptions that they

bring to this interpretive process, and on a comparison of values and beliefs between themselves and their patients:

> She probably doesn't value teeth as much as a dentist would. . . . [extracting healthy teeth is] not something that I would do on myself [or] for my family members. . . . [But] it's hard for me to put myself in that situation, cause I won't be in that situation financially, so I don't know what it is like. . . . I think the patient needs [to replace her missing teeth]; but let's just say she doesn't have any money for food or other things and here I am like: 'you HAVE TO get these crowns, you HAVE TO get these crowns'. . . . I know that we dentists think differently [than patients]. SSB

Sometimes, interpreting a situation in a vignette triggered recall of encounters with similar problems and telling the story of that encounter to justify reasoning:

> One patient that I can think of right now . . . wants all his [teeth] extracted. He's an ex-cocaine addict; twenty-years [of substance abuse]. . . . He's been dry for like sixty days. . . . he's trying really hard, and he's like: 'I just want them all out.'. . . . He's something like forty-two [years old] as well. . . . I'm just cleaning him up and it's kind of left and right now [regarding treatment decisions] . . . he teeters. . . . We haven't actually written up and signed anything . . . but . . . every once in a while he says: 'Ah, I just want them all out.' SSI

4.1.3.5. Ethical reasoning

A deductive approach from ethical principles was used by some students to address the ethical dilemma in vignette 2. Others approached the problem inductively by considering the patients' needs and demands for care, her financial situation, and her right to be informed about the pros and cons of different options.

The deductive top-down approach

When one dominant ethical principle directed the reasoning of students, a deductive top-down approach was used to address the ethical dilemma. For example, in the vignette where a patient wanted all of her teeth extracted

because she could not afford to restore them, some students felt very strongly against extracting “healthy teeth”, and on the ethical principle of “do no harm”, they refused treatment and referred the patient to another dentist:

> If she really insists, she has to go to another dentist and get it done. . . . Even though a lot of people don’t value teeth that much, it’s like I want my finger chopped off. You go to a doctor and they don’t want to do it. It’s against my ethics I guess. . . . I don’t see any reason for pulling any of these teeth out. . . . It’s like chopping a person’s finger off just because the person feels like it. JSF

> It’s not the right thing to do. . . . You can pull your teeth out, but once they’re out, they’re out. It’s not like you get a bad haircut, your hair grows back in a month or two. You only get one set of teeth [and] I wouldn’t feel comfortable [extracting healthy teeth]. I wouldn’t sleep at night, I wouldn’t do it. SSF

However, the patient’s autonomy was the dominant ethical principle for other students when faced with the same dilemma:

> If that’s what she [patient] wants after she knows all her options . . . you do what the patient wants. Yeah, I think I would [extract her teeth]. JSH

These examples show how dominant ethical principles (non-maleficence and autonomy) can direct a deductive approach to this ethical dilemma and result in different solutions. The ethical stance of the students served as an anchor to justify their clinical decision. When a dominant ethical principle justified the reasoning, the decision was made relatively fast and the students seemed to be confident in their decision:

> I’m at the point in my life where I’m not going to compromise my morals and my values for another person. So, I don’t think it’s appropriate, and I’m not going to pull out her teeth. I’ll say that that is her choice and if she chooses to have them extracted, she’ll have to go to another dentist. JSC

However, competing ethical principles challenged some students who seemed unsure about their decision:

> We always say: 'oh, let's not be paternalistic: do what the patient wants. But, if you're not comfortable with something, don't do it.' . . . We'd be pulling two completely sound, healthy teeth. I really would not want to do that. Whether or not I would, that's another question. . . . I guess I don't have a feel for where my comfort is. . . . Just because a patient signs informed consent doesn't mean they should be able to do whatever they want. [JSB]

The inductive bottom-up approach

Alternatively, some students adopted an inductive approach to address the same dilemma by interacting more elaborately with the patient and evaluating the specific social, cultural and economical context within which they had to deal with the dilemma:

> I know it's expensive. . . . but the reality is that sometimes you just can't afford anything but clearance [of teeth] and a new denture. . . . It's really sad that the money would dictate what kind of treatment you would get, but that's the way the world is I guess. . . . If she really, really can't afford it [and] the alternative is walking around with no teeth . . . that's a worse alternative. So, I probably would end up doing it [extracting all her teeth]. [JSB]

Combination of inductive and deductive approaches

Some students adopted a combination of deduction and induction to resolve the ethical dilemma:

> I am more in favour of patients making their own decisions, but leaning more toward the paternalistic side. . . . [I believe that] nobody knows a person as well as they themselves do and I can't say what's best for a person and I strongly feel that she shouldn't have all her teeth extracted. . . . But I don't know for sure that that's not the best option for her. . . . If [the problem] was going to cause an infection in her bone, and all sorts of medical issues, then I would just have to tell her that she'd have to go see someone else. . . . If I could see that she understands the options and [extracting all her teeth] is what she wanted, then I would probably be able to extract all the teeth. [JSC]

Here we see the use of deduction from the principle of autonomy combined with induction from concerns about the potentially adverse consequences of

extracting teeth. The combination approach helped the students to arrive at a decision with which they felt comfortable. Another student explained how he wrestled with the same issues by using this approach:

> The patient can go to the dentist next door and the dentist can say: 'okay, fine, I'll extract your teeth and do the dentures'. So, do you just ignore the patient and say go next door or do you clue this patient [about the options for treatment and consequences of each]. . . . [It's] like [respecting patients'] autonomy, this is what they want, [but] can you do it? The dentist next door is gonna do it, so why don't you do it? I consider both sides. . . . I would give the patient all the information and recommend the patient take some time to think about it; not to make a rushed decision right there and then. . . . I get a signature saying that this is what they want . . . cover all the paper work [on informed consent]. . . . I would probably do it in the end because she's probably going to go next door and receive the same treatment and might not have such an informed consent as maybe I would have providing it; so I feel comfortable. . . . I would not refuse treatment as long as I know it's an informed decision. SSG

Using previous experiences

Some students used their previous experiences with similar problems to guide their resolution of the dilemma inductively:

> Ultimately it's her decision. . . . But I would strongly tell her to think of a different option. We'll work with her [to come up with a solution to her financial constraint]. . . . If cost is an issue, [we can] arrange a payment plan or [we can] even [make a transitional denture] for the time being. . . . I had a patient in the clinic and he wanted the same thing [extracting remaining teeth to avoid the cost of restoration] and he came back three or four months later thanking me and telling me: 'well, thanks for not letting me pull out my teeth'. SSE

4.1.3.6. Pragmatic reasoning

Clinical reasoning often involves problems that require interactions between patients, instructors and others. Some problems are inherent in the social, economical and political environment of the teaching clinic or the healthcare system generally. Dental students had to follow certain rules and requirements to

graduate which sometimes placed them in situations of conflict of their interests with patients or instructors or made them feel vulnerable in relation to interpersonal relationships and power dynamics.

Pragmatic reasoning typically involved the challenge of providing the best care possible for patients who could not afford the treatment recommended. Students referred to the "type of patients" who attend teaching clinics as predominantly of lower socioeconomic status, and who had "neglected [their] teeth for a long time . . . [had] no money to do comprehensive treatment and . . . just want a quick fix" [SSF]. Seeking financial aid posed a challenge to students who felt that they should try to help the patient by providing alternative payment plans [JSA] or providing pro bono services:

> If it was my clinic, I would do it [restorative treatment] and say: 'you know what, just pay me when you have [the money]'. Because, realistically, we have to help people. . . . I know everyone has got bills . . . but I'm not going to be hungry because I did three or four fillings pro bono. . . . You've got to help people out sometimes. [SSE]

A junior student stated:

> I think you'd probably starve to death if the patients would decline [to pay] and you sent them out of your office. I don't think that's a realistic scenario. . . . People don't have unlimited money, and aren't always willing to listen to what you have to say. You could [refer patient to someone else]; you'd be referring a lot of patients though. [JSB]

To help patients with financial problems, some students tried alternative strategies, which required "bending the rules" of the clinic:

> If the patient [is] really really tight on money . . . I still do the same thing because talking to patient about diet doesn't cost money, right? And taking fluoride from the clinic, it doesn't cost me much money! [laugh]. . . . It's just a code [for treatment worth] 5 credits . . . [it's] not a big deal. But, I'll still do it for free for the patient. I would write on the chart that [treatment] is done

> and blah blah blah, but I wouldn't enter it under a computer code. . . . there are students who are doing free stuff on patients, and instructors say OK. They understand the patient is poor. . . . It is an educational facility and we are helping poor people, so [it's OK to provide free services for poor people]. [SSA]

However, waving the fee for a selective number of patients raised yet another ethical dilemma involving the principle of justice. Students who faced this dilemma acknowledged that what they were doing was not "fair"; however, they believed that the strict rules of the clinic left them no choice:

> You can't be part of the [treatment] program unless you have your caries under control . . . I'll write ["caries management"] in the treatment plan and then I won't ever ask them for the money for it. . . . But if a patient says no problem [and] they [can] pay for it, then I do charge them for it because I need some credits too! [laugh]. . . . I don't know if that's right, I know it's not fair. See, I think that it should be free. If I didn't have to charge them or if I didn't need the credit, I wouldn't have charged any of my patients for it. . . . [Caries management] is part of my job and I should be doing that for all my patients. [SSB]

Others believed that waiving the fee for poor patients was justified:

> The fee for caries management at our school, I disagree with. . . . I can understand [why the patient doesn't want to pay]. . . . You ought to be providing that sort of information for her anyway. [JSD]

Students encountered inter-personal problems between themselves and faculty members. Conflicting opinions of instructors seemed to be a "very typical" scenario on the clinic floor since "everyone's got ego in this place" [SSI]. Students reflected on the political environment of the school and "the games that have to be played" [SSD] around the conflicts, and they feel vulnerable because of their lack of clinical and professional experience, their lack of power to voice their opinion, and the fear of making "life worse" for themselves if they became a target for unfair assessments [JSB]. Most students preferred to "just suck it up" to avoid

conflict with their instructors [JSE]. For example, an Asian student reflected on her cultural perception of the authority of instructors. She felt "underneath the instructor" and stated, "even though [the instructors] may be wrong, we should never be disrespectful to them" [SSA]. Students in general believed that "you just don't argue with anyone" in the clinic [JSB], even if an instructor seemed unreasonable or wrong. The key to pragmatic reasoning for survival by many students was to "fly below the radar" and "keep quiet on a lot of things and just let it be" [SSD]. One student explained:

> When I got into Dentistry, the first thing the lady that graduated from here said: 'never draw attention to yourself!' . . . I had an instructor tell me that too. . . . I'm not really sure [why]. . . . [maybe cause] if you're way up high . . . you have like a higher spot to fall from . . . You make a mistake and then everyone notices, so I guess maybe it's something like that. . . . It's better to do your stuff and then go home. They say that's the safest way: Don't draw attention to yourself. [JSG]

4.1.3.7. "Part-whole" reasoning

Students used several reasoning strategies whereby they shifted their focus from one aspect of a problem to another, from one specific problem to another, and to the inter-relationship of the problems within the multi-layered context of the healthcare environment. Evaluating treatment options for each tooth frequently required an overall assessment of the occlusion to evaluate how that tooth related to the rest of the dentition. A single tooth is only one part of a complex and dynamic biological system; therefore, any changes made to each part of the dentition should be evaluated in relation to the overall changes of this dynamic system to ensure that proper form and function is achieved. A senior student

referred to this issue when he was evaluating the restorative treatment plan of a patient:

> We might be able to save [a tooth] with a root canal and then a post and a core and then a crown. . . . We get study models [and] go through excursive movements [of the jaw] because the occlusion is important [to evaluate and see] if he has interference or group function [before and after the tooth is restored]. . . . [proper occlusion] would take some of the stress [of mastication] off of the crown that we need for support [of the partial denture]. . . [the restoration] would last a little bit longer I would predict [if we achieve a proper occlusion]. [SSC]

A treatment plan seemed more complicated when it involved more than one part of the system. Students were required to evaluate the restorative plan in relation to the individual teeth and overall fit between the dentition and surrounding structures. One senior student elaborated on this analysis:

> She looks overclosed . . . although she has anterior stop, she's lost that posterior support [of occlusion]. . . . If you look on the left side of the patient, the upper [first molar] and the lower [second molar] come in complete overclosure towards one another. The occlusal tables [of upper and lower teeth] are very different. . . . so, [to make] a new denture in this area, you're gonna have problems as far as clearance goes between these teeth. . . . opening the bite might be difficult as well because you'd have to open it quite a bit to get the occlusion of the lower [second molars] and you'd lose anterior contact, so it's not an easy case at all. [SSD]

Often, interpreting problems and evaluating options for treatment involved zooming out of the context of a specific problem to the larger context within which the problem occurred in order to "treat the whole patient, not just the chief complaint" [SSI]. One student emphasized the point when he stated: "[i]n dentistry you tend to focus a lot on the mouth, but you've got to remember there's a person around that mouth as well; So see what [the patient] wants" [SSE].

In the following section, I describe the contextual aspects of clinical reasoning and the interactions of the contexts.

4.1.4. The context of clinical reasoning

Clinical reasoning of students occurred in a multi-layered context including their personal frame of reference, the patient's frame of reference, the problem (influenced by biological and/or psychosocial factors), the context of the UBC dental clinic and the larger social, cultural, political and economical contexts. I present examples to show how students considered them and integrated different reasoning strategies to consider quite specific factors and in relation to the situation as a whole.

4.1.4.1. Personal frame of reference

It seemed that a combination of knowledge, values, beliefs and past experiences shaped a personal frame of reference for students; a lens through which they identified and interpreted patients' problems. One student stated:

> Why do we incorporate [caries management] a lot? Because it's been beaten into us for four years! [laugh] That's all [the faculty] talk about. . . . To me it's a common sense way to approach the problem: to solve the problem, you have to address why it happened. If you continue just to patch the holes, you never address why, and the patient continues to go down a road where the disease progresses or continues . . . and it's not fair to the patient when you have the expertise and the knowledge of why it's happening [and] to not pass that [information] on to the patient is doing a disservice to the patient. SSD

However, some clinical experiences seemed to have a negative impact on students' perception of certain treatments. This is reflected in the following comments of a student about her reluctance to provide treatment to patients who needed dentures:

> I would refer her to someone else [for dentures]. . . . [making a denture] would be opening up a can of worms that I wouldn't want to deal with. . . . In private practice, I don't anticipate making that many dentures, [because] the amount of work and effort that goes into them, and the level of patient dissatisfaction, [makes it] not worth the stress of providing a treatment that might be the best option but, it's a lot of work and maintenance. . . . Patients are very finicky when it comes to their dentures. They expect them to be what their natural dentition is, and they're not [the same]. . . . They get dentures and they need to get'em re-lined, or re-made in five years [and] they think like you've done something wrong; when in reality, their mouth is changing . . . and even though I try ad nauseam to explain things to patients [about the changes in the mouth which affect the fit of dentures], they don't want to hear it, and they only get frustrated with you, and then you're carrying that frustration. [JSD]

4.1.4.2. Patient's frame of reference

The approach to some problems differed based on whose frame of reference dominated the interpretation of the problem. If the students interpreted the problem based solely on their personal frame of reference, the problem could be perceived differently from when they tried to look at the problem from the patient's perspective. For example, one of the students felt "no ethical problems with scaring people into stopping smoking . . . [by using] smoking as a heavy crutch", because "[smoking is] a terrible habit and it's bad for [the patient]" [SSI]. In his view, if a patient has a pre-cancerous lesion in the mouth and smoking can increase the risk of cancer, then scaring the patient about that risk of cancer as a motivation for smoking cessation is "justified". However, some students looked at smoking as a habit that is difficult to break. One of the senior students discussed this issue and the need to look at the problem of smoking from the perspective of patients to provide a supportive approach to smoking cessation:

> I know it's pretty publicized what smoking does to you in terms of your health and your teeth . . . but maybe [the patient] just doesn't want to know.

> . . . You've got to see where [the patient] is on the motivation ladder to quit smoking, the key is to help him one step at a time throughout. . . . like, my dad smokes. I've been trying to get him to quit for years. His excuse is that death is for non-smokers too, so don't worry about it! . . . I'm sure every smoker wish they were non-smokers in terms of their health . . . but that's what some people enjoy. . . . I think it's the responsibility of a dentist to inform their patients and give them advice on stopping smoking and health advice . . . but it's not our place to judge or accuse patients. [SSE]

This alternative interpretation of the same problem (*i.e.* smoking habit of a patient) was due to the dominance of the personal frame of reference of the first student (SSI) over the perspective of the patient in the second example (SSE). One of the senior students who considered the patients' frame of reference emphasized his responsibility as a dentist to "create a supportive, caring, understanding environment" [JSD] instead of scaring the patient to the point that "you've alienated him . . . ostracized him, and you haven't done any good" [JSD]. Patients' misconceptions about certain problems or treatment challenge students to address patients' demands, as reflected in this student's comments about dentures:

> Dentures are not as great as people might think they are. A lot of people think that if they get all of their teeth pulled, then they won't have anything to worry about anymore, and they can just get false teeth, and you can make them look however they want, and everything's going to be all perfect. That's not really the case. [JSC]

Dealing with such misconceptions often requires additional time to educate patients about the benefits of treatment options, and to "convince" patients that the treatment is in their best interest. For example, students recognized that the preventive approach "doesn't click in all that often" for people who believe that cavities could just be drilled and filled [SSD]. Therefore, presenting caries

management as “part of the general protocol of dental treatment” rather than as an ”add on” or ”money grab” [SSD] achieved a positive response and acceptance from patients.

4.1.4.3. The nature of the problem

The specific nature of some problems influenced the way that students approached them. For example, most students considered pain, bleeding, swelling or infection to be urgent problems to address before anything else. The impact of each problem on general health and quality of life also influenced the approach to care. For example, most students chose to biopsy a white mucosal lesion because it was “better to be safe than sorry” [SSB]. Even the type of tooth with a problem seemed to determine the approach to treatment:

> Automatically, I want to keep canines . . . because they’re the strongest tooth in the mouth. . . . they’re the last tooth you want to lose. [SSI]

4.1.4.4. The healthcare environment

All students reflected on the impact of the environment of the dental clinic on their reasoning. Some commented how they will approach care differently when they graduate. They acknowledged that the context of clinical reasoning extends beyond the UBC dental clinic and that they had to consider the larger healthcare environment with all the inherent issues of access to care for poorer patients. One student projected how dental practice would be influenced by the neighbourhood where dentists worked:

> It depends on what your neighbourhood is like; if you practice on the downtown-eastside [of Vancouver], you’re not going to be doing crowns and bridges and implants. . . . But a lot of patients come here, they end up going for sub-optimal treatment because they can’t afford anything else. [JSB]

4.1.5. Integrating reasoning strategies

Zooming in and out on different problems and moving back and forth between the different contexts of clinical reasoning requires an integration of relevant strategies. The following example shows how one of the senior students moved from her personal context to that of the patient, the clinical problems and the larger context of healthcare, while she integrated scientific, conditional, collaborative, ethical and pragmatic reasoning:

> [The patient] probably doesn't value teeth as much as a dentist. . . . but I let her know that [regarding] her teeth on the top [jaw], there is no reason to take them out . . . and you should really try to keep your teeth as long as possible because it helps keep the bone that's there. . . . even though it seems like the cheaper way to go . . . I wouldn't want her to lose her teeth so young. . . . [When she gets older] she is gonna have no bone there and she is gonna need implants and by then her sinuses may have been pneumatized and she may need a bone graft on top of that. So, there could be a whole new set of problems and financial burdens that might come on if she just decides to extract the teeth now. . . . I guess after explaining to her everything that is involved and if she really really really did not wanna save the teeth and she is OK with that, then I would [extract the remaining teeth] . . . I wouldn't be happy about it. I hate doing treatment that I don't agree with [because] I don't think that that's in her best interest to do that. . . . some instructors say yes [to providing compromised treatment, but] other instructors won't allow that, even if the patient wants it. . . . Then usually what happens is [laugh] [that] the student will bring [the patient] in on another day with another instructor that they know will allow [extracting the remaining teeth]. [SSB]

In all, "part-whole" reasoning dominated here, as she moved in and out of several contexts to address the specific problem of the patient's request along with the larger contexts of biological consequences and the practicalities of working with different instructors. This was followed by conditional reasoning which helped the student deal with situations of uncertainty, such as unpredictable outcome of treatments and the patients' cooperation.

4.1.6. Similarities and differences in reasoning

Clinical reasoning of students differed at several levels within and between groups of students. The major difference appeared to be the impact of their personal frame of reference for identifying and interpreting problems. This interpretive process determined how students appraised alternative treatments and how they determined their own preference.

Previous experiences with similar problems helped students to recognize the pattern of problems, or to use scripts related to diagnosis or management of diseases. Both junior and senior students used their experiences as references to guide their choice of treatment, however, they acknowledged their limited experience with complicated problems such as "how much root you would need for you to extrude the tooth, and do the crown on there, versus just extract it" [JSA], and:

> It's not a walk through the park everyday. . . . I feel that occlusion cases are very difficult for me still . . . because I have had hardly any experience in restoring a full occlusion case. [SSI]

Limitations of knowledge and experience more frequently compromised the reasoning of the junior compared to senior students, and seemed to have a significant impact on their abilities to integrate information into a coherent plan. However, they could not think of a specific time or course that taught them how to integrate information for diagnosis and treatment planning. Clinical experience helped students recognize the similarities in each situation. One senior student explained that by "looking at your own patients and saying: 'Oh! it's a similar situation as that patient, this area's a similar situation as [another] patient,' [those

experiences] kind of [help you] put it all together" [SSJ]. On the contrary, junior students struggled with "putting everything together," as one student explained:

> It's hard to put everything together . . . I know bits and pieces here and there, but it's just integrating everything, which hopefully I'll get better at it this year. . . . There's so much [information] . . . I need to be able to integrate everything together. . . 'Cause they say treatment planning is one of the most difficult things in dentistry. Right?. . . What's the best option for this patient? At which stage would you do what? In what sequence? . . . I could just throw a bunch of stuff at you: 'Oh, we'd extract this one . . . we can rotate this one with orthodontic treatment, we can manage the caries here. . .', But integrating everything into a logical, sequential plan as well as evidence or experience for why you'd want to do that; That's what I don't have at this stage. . . I know bits and pieces from every aspect of dentistry, but it's just integrating everything . . . I'm going to have to work on that. [JSA]

Generally, all students adopted a ritualistic approach to collecting information and planning treatment, although more experienced students seemed more flexible in using their "own routine", while junior students followed the clinic's protocol more closely.

Junior students placed more emphasis on evaluating problems related to individual teeth, and later tried to integrate all of the information. Following this ritual, they moved out of the context of teeth and associated biological and pathological problems into the psychosocial context within which they occurred. More experienced students prioritized problems at the outset based on their significance, urgency and inter-relationship with other problems. They started the process by exploring patients' expectations and motivation to collaborate in defining and achieving treatment objectives. It seemed that senior students emphasized the personal context of each patient rather than the problems of specific teeth. One student stated:

> I start off by telling [my patient] that: 'Well, in order for us to take care of your teeth . . . we are gonna have to come up with a complex treatment plan' . . . I just wanna let her know that it will need some commitment. . . . I'll just say something along the lines of: 'You know, taking care of your teeth is something that requires both my help and your help'. . . . I think it will just give me a general idea of what type of patient I am dealing with . . . I don't wanna put more effort in if the patient is not willing to put more effort in. 'Cause I think it's a waste of time and if the patient isn't motivated themselves, then you are not really gonna get anywhere with them. [SSB]

It seemed also that the senior students were more aware of their personal frame of reference, their individual view or philosophy of care and how that influenced their interpretation of problems and their approach to care. This is evident in comments made by a senior student:

> Caries management is the most important [part of treatment]. If people were all on caries management they wouldn't need [dentures], they wouldn't need crowns, they wouldn't need anything else. . . . I think every patient should be on a caries management program . . . every patient, no matter where I set up [my practice] is going to get that and there's not going to be a fee. I think it's trivial to charge a patient a fee for oral hygiene instruction and caries management because that's what you do [as a dentist] . . . telling people dietary counselling, sugar intake, and oral hygiene instruction, that's bare bones; You should do that for everybody. [SSE]

Senior students reflected on their responsibilities as soon-to-be dentists. They believed that at the final stage of their education, they were "almost at the same level as instructor[s]" [SSF]. However, they were well aware of the limitations of their knowledge and experience and the responsibility to recognize when a case is "doable or not doable" [SSG] and to discuss the limits of their competence with patients. They also seemed to be more aware of the healthcare environment of the dental clinic and its resources, and they were more comfortable approaching faculty and staff for help and support.

4.1.7. Expectations of faculty and student performances

Here, I return to the faculty members' expectations from students and compare them to the evidence from interviews with students.

As most faculty speculated, the senior students were clearly better at "looking at the big picture" and the significance of the psychosocial issues that influenced their approach to problems. They had a more sophisticated network of knowledge and experience that helped them in framing and solving problems in different contexts. They seemed also to be more aware of the limits of their knowledge and experience as they reflected more frequently and clearly about their personal frame of reference and how it influenced their approach to problems. Also, as expected, the more experienced students were more successful at integrating their knowledge and experiences as they identified and prioritized the problems, integrated several reasoning strategies and devised more coherent treatment plans. They were also more aware of the contextual factors that influenced the outcomes of their interventions and they placed a higher emphasis on patient collaboration and motivation in achieving the desired outcome. The students' struggle with "scientific" evidence in their reasoning was also an expectation of the Faculty, and seemed to be related to limitations of the evidence relevant to their patient's problems.

Generally, the expectations of faculty members about students' competency in clinical reasoning were vague, probably because we do not have a clear definition of the competencies.

Following this study, I explored the clinical reasoning of orthodontic residents and experienced orthodontists, which offered a different context for reasoning and involved the biopsychosoical factors that influence problems related to craniofacial growth and malocclusion. It also helped me explore the difference in clinical reasoning across a wider range of experiences and expertise. The findings from the EDC study helped me develop the conceptual framework of clinical reasoning and examine the transferability of my findings across different problems and levels of expertise in dentistry.

4.2. The EDC study

My study of orthodontists and residents at the EDC involved problems relating to craniofacial growth and malocclusion. I presented the problems in the context of two vignettes as I explained above. Here, I follow the same format I used earlier in this chapter. Firstly, I describe the process of clinical reasoning, followed by a description of the reasoning strategies used by the participants. I then compare the reasoning of all the participants relative to their clinical expertise. Later, I will compare the findings of the UBC and EDC studies and discuss the similarities and differences in the process and strategies of reasoning across different problems and levels of expertise.

4.2.1. The process of clinical reasoning

The participants engaged in the clinical reasoning process by: 1) reviewing patients' clinical information and diagnostic aids; 2) diagnosing, listing, and prioritizing the problems; 3) offering options for treatment; and 4) elaborating on

their preferred options. This process however, was not linear. Some participants moved forward and backward as they weaved their way through the diagnosis and treatment options to a final plan. Sometimes, this process helped them identify new problems, change the priority of the problems, come up with new ideas for treatment, or modify their decision about their preferred plan. Detailed descriptions and examples of each process follow.

4.2.1.1. Ritual

Some participants adopted a ritual to the planning process that started with exploring and describing the features and relationships of the jaws, teeth and facial tissues. They used visual cues and measurements from the diagnostic aids available to classify the patients according to available normative values from population studies. They looked also for signs of disease and other deviations from the norm. One participant explained this process as follows:

> Usually I look at the profile picture first . . . then I look at the facial [pictures to] see if there [are] any gross asymmetries. . . . [I] look at the smile to see how much tooth is showing at rest and [evaluate] general smile characteristics. . . . just to get a general idea of how much crowding we have. . . . [and to] see what the [dental] classifications are. . . . [then I evaluate] the models. . . . so the next thing I usually do is take a peek at the [radiographs]. . . . look at the [jaw] joints and just [do] a quick overview of everything else. [RGC†††]

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††† I used the letter "JR" for the first year residents, "SR" for the second year residents, "RG" for the recent graduates (less than 10 years of experience), "EO" for the experienced orthodontists (over 10 years experience), and "E" for orthodontist with over 30 years of experience who were considered "expert" in orthodontics by their peers. The last letter on the right represents the order in which I interviewed participants from each group (*e.g.,* EOA is the first experienced orthodontist whom I interviewed).

This process was followed by developing a list of problems, prioritizing them, assessing treatment options and developing a treatment plan, as reflected in this participant's description:

> So, this case is . . . Cl II [jaw relationships] . . . [with] vertical [growth tendency of the mandible, and [dentition is] crowded. . . . I am gonna start formulating my treatment plan. . . . I would say: 'no, we have a lot of crowding on the lower . . . we can't procline [the lower teeth] any more, which means we need to extract [teeth]. . . . I would extract upper and lower [first premolars]. . . . the treatment plan would [require] maximum anchorage [to retract the teeth]. [RGC]

The general description was followed usually with technical details about the way in which teeth might be moved. Experienced clinicians had a more technically specific ritual for assessing information. Some interpreted the numbers and normative values diligently to confirm or reject an hypothesis about particular observations in the radiographs. However, most of them did not rely on the measurements from their radiographic analysis to interpret the relationships of the teeth, jaws and soft tissues because, as one clinician explained, "It's an art, it's not a science; numbers makes it science, art is what you see. . . . I trust my eyes more than the numbers" [RGB]. Some used only a selected series of numbers to confirm their visual evaluation of the radiographs, because, as one experienced orthodontist explained:

> I don't really ponder too much over numbers, because I [have] done enough numbers in my life time that I don't [need to]. . . . [If I need to use any numbers, I would check] mandibular plane, Landes, facial angle. . . . I wanna know where the maxilla is in the space, the mandible, both in relationships. . . . lower 1 to A-P, upper 1 to A-P [angles of incisors to different planes], upper face to total facial height proportions; that's it. [EOA]

4.2.1.2. Backward and forward reasoning

Diagnostic reasoning of the participants often involved a combination of forward and backward reasoning. This process helped them to make and test hypotheses about the relationships between the teeth, jaws and facial tissues. The process seemed longer and more confusing for the participants with less clinical experience. One of the senior residents who moved back and forth between hypotheses and data to interpret a set of the patient's jaw relationships demonstrated this confusion:

> He's got an open-bite . . . narrow alar width. You can see the sclera below his eyes . . . doesn't show a lot of malar prominence, so it might be some maxillary deficiency there. . . . maybe his nose [is] being narrow if the maxilla is back, kinda pulls everything back. . . . looks like he is pretty edematous and erythematous on top [gingiva], so it suggests to me that he is probably a mouth breather; is he? [Shiva: No] Any medical contributing things? Asthma or anything? [Shiva: No] Any habits? [Shiva: No] . . . . From the profile, again it looks like he is kind of flat in the malar, his nose is big. . . . I don't know . . . [pause] . . . [regarding patient's] profile . . . [pause] he could be retrognathic convex; but I like to look at his numbers [of cephalometric analysis] in a minute. . . . [Looking at the ceph] . . . . so, [patient has a] very decreased anterior cranial base length . . . normal posterior [cranial base length] . . . increased Frankfort to S-N [angle of the cranial base to a reference plane]. . . . So it just looks like he is a . . . I don't know. . . . [he has a] very divergent facial profile . . . . Facial plane says he is prognathic . . . he looks . . . [pause] . . . I mean looking at his [profile] . . . he looks more retrognathic to me, but he might be just orthognathic with a protruded maxilla. No, that wouldn't be protruded, I think he is more. . . . numbers say that the maxilla is protruded, but the fact that he is. . . . maybe he isn't [protruded]. Maybe everything is normal, it's just his vertical growth [that is a concern]. . . . I think maybe [he has] breathing problems [that is causing this pattern of jaw relationship].[SRC]

This diagnostic process seemed to be quite straightforward for an experienced orthodontist who could readily see discrepancies between the jaws and correlate them with facial and dental features. A forward reasoning process from the visual

cues observed in clinical photographs and radiographs led to diagnosing the related problem:

> Looking first in the anteroposterior perspective . . . he appears to be retrusive both in his upper and his lower jaw. There is not a huge difference . . . between the upper and lower jaws, but both of them are back pretty far from the forehead. . . . [the patient has] an overall more vertical skeletal pattern, [which is] more indicative of an open-bite which you do see in the teeth as well as [in] the relationship of the lower jaw to [palate]. . . . You also see the bending of the mandible that we associate with mouth breathers, so he is very indicative of [an] open-bite pattern and other features associated with mouth breathing. [EOD]

Also, a combination of forward and backward reasoning helped some participants to evaluate the cause of the problem in order to prevent recurrence. This combination of questioning was used by one orthodontist to rule out the most common causes of an open-bite:

> Gingiva looks slightly inflamed in the anterior region; maybe he is a mouth-breather? Does he complain about breathing? snoring?. . . . [The jaw joint] feels fine? . . .. Habits with his tongue or anything?. . . . Has he noticed his bite changing?. . . .He still has adenoids, but airway looks competent. . . . The palate [is] sitting in a fairly good position. [RGA]

Another recent graduate when searching for the signs and symptoms of an open-bite, noticed the patient's large tongue, dismissed his initial hypothesis and considered the size and position of the tongue to be the primary cause of the problem:

> What drew my attention right away was the anterior open-bite. . . . [it] looks like a bit of cross-bite, which kinda fit[s] when you think open-bite could be [caused by] mouth breathing, then red flags are up. . . . and I see a lot of tongue just right away, whole bunch of tongue. So to me, I am now thinking maybe the etiology is a bit of big tongue. [RGB]

4.2.1.3. Pattern recognition and scripts

The experienced orthodontists used patterns and scripts to identify the possible cause of the open-bite. It appeared that for most experienced clinicians, mouth-breathing was a "default" script for the open-bite:

> Your typical open-bite pattern presents some phenomena along with it. . . . one of which [is] airway obstruction." [EA]

Joint-disorders and tongue-thrust were considered along with mouth-breathing as causes of open-bite because, according to one experienced orthodontist:

> When you see somebody with an open-bite . . . we key on [the jaw joints] first . . . for some sort of aberration, degeneration. . . . [They] are nicely shaped, so in him I don't believe that that's the source of his open-bite problem. . . As far as the etiology, he appears to be somewhat of a mouth-breather. . . . I think that's more of the source of his open-bite. . . . He also seems to have a pretty significant tongue-thrust. [EOD]

More experienced orthodontists were able to identify and interpret discrepancies more quickly and easily, apparently with their diagnostic and treatment scripts, which helped them identify similar patterns. It also helped them decide which treatment approach would lead to a more predictable and desirable outcome. One expert used a script for diagnosis, treatment and alternative possibilities very quickly as follows:

> [Looking at photos, I see a] Cl I anterior open-bite . . . now [I want to see] the ceph [radiograph] . . . [I see] skeletal open-bite features: steep mandibular plane, obtus gonial angle . . . palatal plane is not bad . . . short posterior facial height, lips apart, no third molars present . . . . [looking at the panoramic radiograph] . . . [I see] nothing that is gonna change [or] influence the plane [that I have in mind]. . . . What's the age [of the patient]? [Shiva: 17] OK . . . I would ask if he or the parents have any facial changes they would like to see. That would influence the treatment plan. . . . there is long vertical facial height. The smile [shows] a little excessive gingival [display], but not a lot. . . . I think I would use the multiple loop [a specific treatment] approach [to close the open-bite], specially if 3rd molars are

already out. That would work fine. . . . Of course, I would have to find out [about the patient's] cooperation. . . [it] is really important. If the parent says there is not gonna be any cooperation, I would consider oral surgery [to close the bite]. . . .You could also consider the temporary anchorage device. My experience isn't all that great with it. . . . but if the cooperation [is OK] and the parents were behind everything, age is 17 . . . [which is a preferred age for the treatment considered], I would consider multiple loop [technique for treatment]. EB

4.2.1.4. Decision analysis

Everyone came up with more than one treatment decision for each patient, and analysis of the decisions helped some participants to reflect on their views about different treatments, and to justify why and how their preferred option would ensure a more predictable, desirable, or stable outcome. The example below shows how one experienced orthodontist offered different treatment options:

> Right off the bat, I am thinking [that] there would be potentially two different options . . . surgery [with extracting] lower first bicuspids and upper second bicuspids and then you would be treating with at least a mandibular advancement. Probably the maxilla would be involved as well to get better upper lip support. . . . [but] if it's gonna be an orthodontic-only type of treatment plan, then I would be probably thinking about the same extraction pattern. . . . explaining to the patient that this is a compromised type of treatment and if that's what they are looking for, we can avoid [mandibular advancement] surgery. EOB

Following these comments, he evaluated the pros and cons of those options:

> If he wants to make a significant change in his skeletal profile and his facial relationships, [then his treatment would be] a pretty straight forward surgery case. . . . I would treat him in a similar way with regular braces . . . But I would get a different result, significantly different. I don't think the skeletal relationship would change [his appearance a] dramatic amount. But I think he would wind up with a nice [bite] in relatively stable position and overall facially, he would have not had any dramatic detriment. . . . You've got so much crowding [of his teeth] that you need to take out teeth. Once you take out teeth, the tooth movements could have some negative ramifications on the overlying soft tissue. With jaw surgery you can get yourself out of that, because you go back to move the skeleton to ideal position and that re-establishes or modifies soft tissue profile and contours which is good.

> Orthodontics doesn't allow you to do that and so he's got some things that facially is going against him in an orthodontic-only approach. EOB

I illustrate in Figure 4.1. a decision tree to summarize the lengthy process of decision analysis by a senior resident who addressed the same problem. His analysis included a thorough evaluation of all potential outcomes resulting from different approaches and estimating the probability and predictability of achieving each outcome, which he evaluated further. Eventually, the resident chose orthognathic surgery as the ideal treatment, followed by orthopedic advancement of the mandible and orthodontic movement of teeth. He considered the orthodontic treatment alone as a less desirable option.

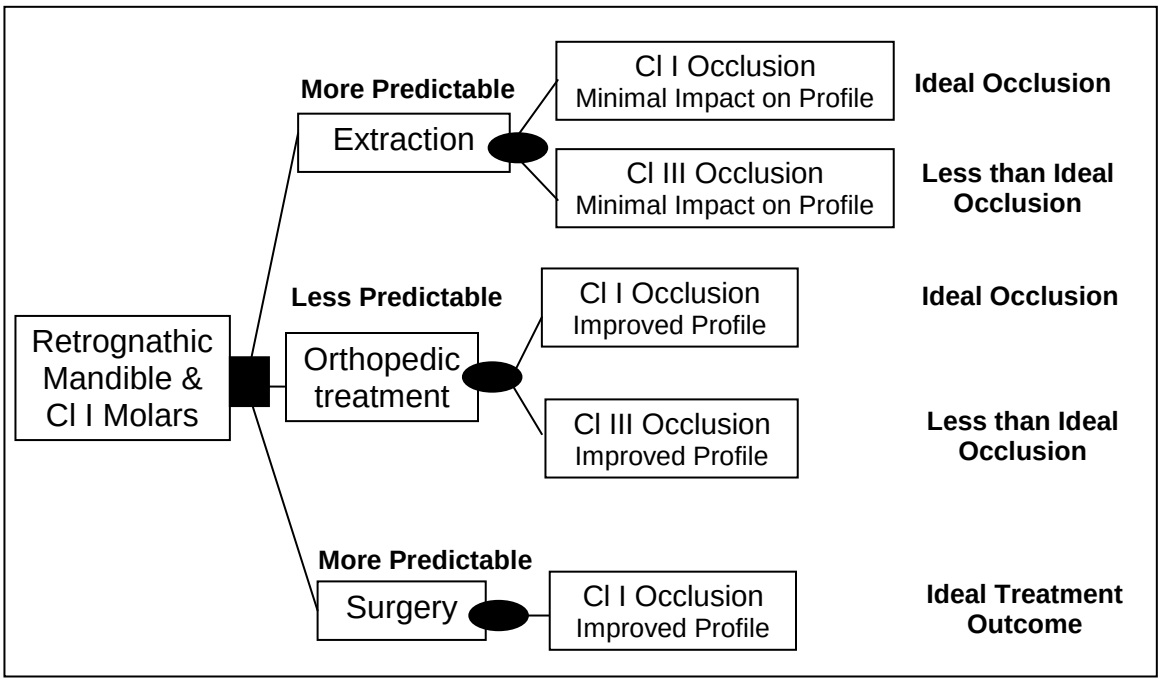

Figure 4.1. Example of a decision tree (from interview with SRD)

Decision analysis seemed to be a common approach to evaluate and choose between available treatment options. However, neither of the participants of the EDC study used numbers or Bayesian formulas to compare options. Another resident approached the same clinical problem but selected a different treatment option by considering the risks and benefits of different treatments relative to the predictability and desirability of the outcomes:

> I am thinking what would be more predictable [and] more efficient. . . . kind of like the philosophy 'keep it simple'. . . so, [comparing orthopedic advancement of the mandible] versus just extractions [and orthodontic alignment of teeth] . . . the [orthopedic treatment] is gonna make it a little more complicated. . . . You're weighing the simplicity of the two: if you do the [orthopedic treatment], it's more complex. It might improve his profile better though. So what's the trade off? . . . [pause] . . . I don't know, I am thinking in my head: is it worth it? Is it worth the extra complexity [to advance the position of the chin]. . . . I think his profile is acceptable, so I am leaning towards the simple treatment plan; that makes it more predictable. With [orthopedics] and the whole complex combination of things, the chance of something could go wrong [is high]. . . it's kind of the risk for reward thing: the reward would be if everything does go ideally, he would look better in the end. But the risk is: there is a greater chance that something won't go right and then he will actually look worse . . . [pause] . . . I think I will lean towards just the extractions, yeah. . . . Ethically, I would bring [the surgical option] up and say that is an option, but practically, it's not something that I would recommend. Because I don't think [that] his profile or skeletal discrepancy is so severe where I think that it's worth . . . I don't know, I am just not into having to cut someone open. I haven't had any patients go to surgery yet and I don't know what the rate is of [surgical complications]. But, I just prefer not to [cut]. I am a less invasive person I think. [JRA]

Often, participants explained that the outcome of suggested treatments depended on unpredictable factors such as growth and patient cooperation. When evaluating the success or failure of treatment options, the experienced orthodontists relied heavily on their previous experiences and reflected on their lack of experience or bad experiences with some treatments:

> Personally, I feel limited in what I can accomplish as far as posterior intrusion [of molars]. Plus, any posterior intrusion that I can come up with, I question the stability of. So, from that stand point, do I think that I can accomplish posterior intrusion? Probably not. . . . Hell, I used bite-block therapy? I have. Have I been successful with it? Only moderately. [EA]

4.2.2. Reasoning strategies

Most of the following strategies were presented earlier in this chapter, so I will explain how they were used specifically by the residents and orthodontists.

4.2.2.1. Scientific reasoning

Some clinicians used "scientific evidence" in support of their preference for specific treatments. They believed that adopting a new treatment required scientific evidence of long-term success. One experienced orthodontist explained:

> Recent articles . . . suggest mini bone plates would be a more appropriate type of cortical temporary anchorage devices than simple TADs for [intruding molars]. . . . We don't have really any great histological studies . . . but we do have some in dogs that suggest [that it takes] 3 months for [periodontal ligaments] of a dog to [remodel]. . . . So you gotta extrapolate [that] for human being at least 6 months holding [the molar] in that position [to retain the intrusion] . . . . and that's an awful lot to ask of [patients]. But, if as time goes on and more cases are treated like that and the results come on the literature that this is the procedure and this is how long you have to do it and this is the stability, [then] that's great. Right now, we've got that evidence in the surgical literature cause we've been doing it for so many years as to how long things take . . . and here is your hierarchy of stability [of outcomes of treatment with surgery]. So, you've got some evidence to use in your decision making. With the TADs and mini bone plates, [new treatment] they show by case reports, but there is not a lot of long-term studies, so you are basically using patients as guinea pigs. Someone has got to do it, but I am not necessarily comfortable going down that path when I know that there are other very predictable means of accomplishing the same thing. [EOB]

Some participants relied on their personal experiences in the absence of scientific evidence to support the success of new treatments. An experienced orthodontist reflected on “clinical judgment” to cope with limitations of evidence:

> The research is already there . . . [about using the] multiple loop [technique to close the bite]. There are 3 studies that show very minimal [incisor extrusion and compromising esthetics of smile]. But, there again, these are 2 years plus [follow up studies of treatment outcome]. What’s really [the] long term [results], hasn’t been shown. . . . Its’ pretty amazing now I think, I don’t have a numerical millimeter, but I just have the clinical judgment where I think it’s not worth trying [the] non-surgical [approach to close the] open-bite. . . . It’s a clinical judgment where you evaluate the patient’s desires for change, [if they demand] facial changes or none, [and evaluate patients’] compliance . . . and you could ask them: if we can get a similar results without the surgery [and instead using multiple loop technique], would you wanna try it? EB

4.2.2.2. Conditional reasoning

Uncertainty was a dominant feature in how the orthodontists and residents reason when they had to deal with unpredictable skeletal growth and patient compliance. Young patients were perceived as “moving targets” in relation to the growth of their jaws. In the absence of “crystal balls” to project growth patterns, the plan for treatment had to be flexible to accommodate unpredictable and undesirable conditions. One clinician explained:

> It may take you 12 months to alleviate all the [dental] crowding and get everything set-up and then monitor jaw growth as you go and at that point re-evaluate and say: ‘do I need [an orthopedic treatment to advance the mandible]. . . . the other option too is: as this patient gets older, and if the appearance of the profile becomes more of a concern to the patient, [then] the patient is set up for a possible surgical procedure. . . . So you are not really compromising anything. . . . I don’t like to make all those decisions up-front. . . . I always tell the parent and the patient and put it in the letter that I send to the [referring] dentist that: ‘if aberrant jaw growth continues, an orthognathic surgical plan may be recommended’. EOA

Patient cooperation seemed to be the key to achieve the objective of some treatments. The detrimental effects of poor oral hygiene called for a treatment plan that allowed maximal change in the least amount of time. Poor oral hygiene, if observed in the vignettes, was one of the red flags that participants used to identify potential issues regarding compliance of orthodontic patients:

> You've gotta question what kind of cooperation and compliance you are going to get, given [the patient's] oral hygiene. . . . Because the best predictor of future behaviour is past behaviour; and since he hasn't spent too much time on his mouth right now! EOE

Another common indication for conditional reasoning was choosing a treatment that would minimize the possibility of relapse:

> You could treat this case [with specific bracket system] . . . You could probably fit [all the teeth in without extracting any teeth] but . . . you are just setting up for [a] relapse later. So, I wouldn't treat this case [without extracting teeth]. EOA

4.2.2.3. Collaborative reasoning

Collaborative reasoning involved discussing and interpreting the chief complaint of the patient and parents; educating them about the problems, and following with a discussion of treatment options, expected outcomes and potential complications. An experienced orthodontist talked about the significance of educating patients and parents:

> You are trying to give the patient all the options that they are going to benefit from and to never be afraid to talk to them about: 'hey you know, there are couple of different ways of doing this [treatment]. These are some of the changes that I would like to potentially see. But, if we want these changes, this is the path we've gotta go down. . . . Sometimes you just gotta say this [option] really is the best way to go and here is why I can't do anything else because here is the downsides of doing this and here is what the risk is and sometimes there is some risks that you are comfortable with and sometimes not. EOB

Everyone acknowledged the need for a shared understanding of the problems with patients and parents to individualize treatment objectives based on specific needs and demands of patients and parents; for example, “depend[ing] on how [the patient] feels about his profile” [EOC]. In some cases, a compromised treatment seemed reasonable since “they may not be looking for 100%” [EB].

Also, finalizing an interdisciplinary treatment plan called for communication and coordination with other specialists:

> Right at the beginning of a case . . . I am meeting with the oral surgeon [and] saying: ‘what are you looking [at] here, this is what I am thinking about’. [EOE]

4.2.2.4. Narrative reasoning

Understanding a patient’s chief complaint required an interpretive process whereby the participants tried to explore patients’ perceptions of their problems, their needs for treatment, and their desires for change. This interpretive activity was influenced by assumptions of the orthodontists:

> I never had a 14 year old male or parent want to change [a retruded] chin. Never, not even once. . . . [one of my colleagues] feels that [the only] time that parents go for orthognathic surgery is if [their child’s jaw is] really asymmetrical. . . . I would very much doubt that the parents would ask. Not that we shouldn’t mention there are things that could be done. [EB]

Also, narratives were used by some participants to interpret a specific problem in light of previous experiences with similar situations:

> I’ve done [a specific treatment] on a girl and now she is coming back because [it has failed] even with the . . . . retainer. . . . her mother was like “hard core naturalist”; I mean seriously, all herbs and all that stuff . . . and absolutely didn’t wanna hear anything about the orthognathic surgery. . . . The girl is coming back now in her 20’s and she’s got an open-bite [again] . . . . she is [planned for] surgery. [EOE]

4.2.2.5. Ethical reasoning

I did not create a situational vignette to pose an ethical dilemma to the participants of the EDC study. However, an ethical dilemma emerged when participants believed that the patient's autonomy conflicted with the best care:

> My generation has come through when informed consent has become extremely involved. Informed consent says very clearly: 'you are not deciding for the patient, you are just giving them their options, the benefits and the risks, time-frame and costs and then let them ask questions.' So, I am never afraid of surgery as an option. Even if it is the only option. . . . because . . . I've looked at the case clearly enough that I thought: 'You know, this really is the most predictable . . . and beneficial thing in my own mind for the patient', and if they don't want that as the treatment and I don't think another option is going to be beneficial, then I may say: 'You know, there is another option here, I don't feel comfortable doing that and here is why: Cause I think that would be detrimental for X, Y and Z. But if you want that done some place else, you are welcome to explore that and get a second opinion'. EOB

Limited evidence to support the long-term success of new treatments raised another ethical dilemma in relation to "using patients as guinea pigs", when conventional approaches provided predictable means of accomplishing the same objective.

4.2.2.6. Pragmatic reasoning

The impact of the larger context of practice was evident in the reasoning of the more experienced orthodontists. One of them reflected on cultural, financial, political and interpersonal factors that can sway him away from surgery:

> Most people in this area, I find, don't opt for [surgery]. . . . I think it sounds too serious to most of them. . . . you've got to look at where we are at here too . . . it's kind of like the old: 'to every carpenter everything looks like a hammer and nail' kinda thing, you work with what you've got. . . [oral surgeons] have quit doing [orthognathic surgeries] because the insurance doesn't pay for them to walk into the operating room and I think it's sad . . . to go through that much education and then they basically end-up doing

> implants and third-molar extractions. I mean, it's just a crime! [laugh]. . . . In 17 years, I've had five surgery cases. . . . I am trying out a new [oral surgeon] right now, cause the last one didn't return my calls after at least 20 calls. Never ever returned a call, not before surgery, [so I] didn't know when it was being scheduled and not [even] after the surgery, he's never returned my call. EOE

Similarly, another reflected on how his personal relationship with local surgeons had influenced his decisions for or against surgery:

> I think a lot of your surgical decisions are impacted by the successes and failures that you've had and I think a lot of that has to do with developing a good working relationship with a specific surgeon. . . .There have been various times in my career where I was not really comfortable with that surgical relationship to the point where I felt that we had predictable dependable results every time and to me, nothing is worse than an orthognathic result that falls way short. . . . The flip side of that has to do with when you do develop a working relationship that is a very successful one and I've been there too. . . . If you have the kind of working relationship where the results are extremely predictable and you can count on them, that would influence your decision-making and tip the scale in favour of the surgical decision. EA

4.2.2.7. "Part-whole" reasoning

Clinical reasoning in orthodontics requires integrating several reasoning strategies whereby participants identified, interpreted and addressed problems. This process required assessing the inter-relationship of the problems and arriving at a plan to optimize the outcome of interventions.

Orthodontic plans usually involved analyzing the relationship of teeth within and between jaws and within the confines of the surrounding tissues. Even the size of an individual tooth could change the arrangement of dentition and influence the treatment plan:

> The upper left second premolar is a logical [tooth] to extract. . . . I hate the fact that the upper right second premolar is small . . . cause now I have to

> do a lot of retraction of my first bicuspid and then the cuspid and then get my anterior teeth aligned. [EC]

Alignment of teeth and jaws influences how the teeth fit together and the appearance of the face from the front and the profile. Emphasis on moving teeth to fit together optimally led some orthodontists to accept a less than optimal facial appearance and profile as an acceptable outcomes of treatment:

> I am not sure that we are gonna ever be able to achieve an optimal facial profile, even though he has an obviously retruded mandible. . . . The case would lend itself to a successful orthodontic result, probably a less than optimal facial improvement. [EA]

Alternatively, for some, improving facial relationships was the primary objective of treatment even though an orthodontic-only treatment would provide a satisfactory relationship of teeth. However, as one participant explained, “with jaw surgery you can get yourself out of . . . negative ramifications on the overlying soft tissue . . . [You can] move the skeleton to ideal position and that re-establishes or modifies soft tissue profile and contours”, whereas “orthodontics doesn’t allow you to do that” [EOB]. For others, the treatment plan aimed to optimize the facial relationships as much as possible, but not at the expense of disrupting an ideal relationship of teeth, as shown in this participant’s approach to the problem:

> I would extract four second bicuspids. . . . cause we only need minimum anchorage to align the teeth and [patient has] Cl I molar [relationship, which is ideal]. [The treatment objective is] really not to change the profile, it’s just to correct the crowding. . . . if the patient was saying they’re concerned about the [retruded] chin, I would later . . . consider genioplasty. [EB]

In all, achieving a proper occlusion and ideal facial profile were the main objectives of treatment for all participants. However, some favoured one

approach over the other and some tried to optimize the outcome of treatment in relation to both.

4.2.3. The context of clinical reasoning

Like the dental students at UBC, the context of clinical reasoning among orthodontic residents and clinicians at the EDC included their own personal frame of reference and that of their patients, surrounded and influenced by the larger social, cultural and political environment. Interacting with problems within each context required various reasoning strategies.

4.2.3.1. Personal frame of reference

A combination of knowledge, experiences and values shaped everyone's frame of reference to how problems were perceived and interpreted. For example, I found that the participants evaluated and interpreted "esthetics" very subjectively and inconsistently. When assessing a patient's profile, some did not perceive a retrognathic chin to be an esthetic concern whilst others were quick to recommend surgery when responding to this situation in the vignette to give the patient "a little bit more of a chin" [RGB]. The more experienced orthodontists had a personal reference to rank the severity of the imbalance in skeletal and soft tissue relationships around the jaws:

> To me, an orthognathic case has to rank in severity, as far as skeletal relationships, higher than this [vignette] case. . . . the ranking [is based on]: how discrepant is the skeletal relationship. . . . on a 1 to 10 basis, I think that [this is] maybe a 5." [EA]

Another orthodontist reflected on how he often starts the process of treatment planning by identifying the need for an orthodontic or a surgical approach:

> The first thing I am thinking is: there should be more than one treatment plan with this, perhaps a surgical treatment plan. Is there gonna be an orthodontic plan that I would be comfortable with, and I go from there. . . . If I think the face is in a range of what I consider to be a normal variation, then I pretty much have decided that this is gonna be an orthodontic-only treatment plan. If there is something about the facial esthetics . . . [that] puts the patient clearly in a position where I would really wanna move the bone itself and I really don't believe that I have got something in my armamentarium to do it. Then I start to think maybe surgery should be at least one option [EOB]

Later, he reflected on his experiences and specific training in orthognathic surgery and how that explains his specific approach to treatment:

> It's just the training that I had. . . . When I went to the [residency] program we did have a good surgical experience. When I got to private practice. . . . I did some more work in terms of going to lectures, doing extra readings. . . . I've been very cognizant in the literature about studies that compare surgery to orthodontics-only and [their] outcomes. . . .Once you [are] comfortably doing and talking to patients about [the surgical option] and they accept treatment and you get good results . . . it's a positive feedback. . . . I was asked to teach orthognathic surgery [so]. . . . I just started looking at cases and thinking about cases like that and treatment planning in my own practice and they are working out. . . . I just started believing in it as an option. [EOB]

According to yet another experienced orthodontist "experience is the best teacher" [EOD]. Some preferred a treatment option over the other based on their personal preferences:

> One could try that [close the open-bite by intruding molars, using TADs], but . . . that seems to me 6-9 months worth of working crazy mechanics versus 2 hours on the operating table just getting it done. [RGB]

4.2.3.2. Patient and parents' frames of reference

Most participants talked about how the frames of reference of patients and parents influence their interpretation of problems and treatment decisions. One recent graduate mentioned that the patients in her area did not perceive gummy smile an esthetic problem and therefore did not seek treatment for it:

> I don't think people in our practice at least are that esthetically driven that they come for orthodontics only for the purpose of like gummy smile or something. . . . Rarely am I swayed to doing a surgical treatment [to correct a gummy smile] unless that's what they are really driven [to correct]. RGA

4.2.3.3. The nature of the problem

The complexity and severity of problems influenced the reasons offered to justify a particular decision about treatment. For example, one experienced orthodontist stated, "one of your harder cases from mechanical point of view is . . . a long face. . . [with retruded mandible and] a gummy smile and an open-bite . . . [because] it's always gonna be a compromise somewhere" EOC. The problem became more challenging when participants concluded that the ideal treatment could not be rendered for various reasons:

> In [an] ideal world . . . we do [surgery], but [if patients] don't have insurance or . . . they just want to be able to bite into a piece of pizza. . . . We do [orthodontics-only]. . . .This is a case you want to send to your nearest competitor! EOC

All of the participants reflected on reasons for anticipating difficult treatments, such as problems related to asymmetrical jaws, or limitations in predicting the growth of patients.

4.2.3.4. The healthcare environment

Clinical reasoning of the orthodontists was clearly influenced by the larger local and global healthcare environment. They perceived, for example, that access to surgery was limited for some patients because of financial constraints (Please see section 4.2.2.6. "Pragmatic Reasoning").

4.2.4. Integrating reasoning strategies

Clinical reasoning among orthodontists required an integration of several strategies. The most dominant strategy was “part-whole” reasoning whereby all participants evaluated discrepancies in the relationships between the jaws, teeth and facial appearance, and devised plans to treat the discrepancies. “Part-whole” reasoning also involved evaluating the larger social, cultural, economic and political factors influencing the approach to care. Another dominant strategy was reasoning that occurred conditional on several factors that are difficult to manage, such as growth, patient cooperation and unpredictable treatment outcomes.

4.2.5. Similarities and differences in reasoning across levels of expertise

There were clear similarities and differences in reasoning of the orthodontists across different levels of expertise. In general, the more experienced orthodontists used a more refined and individualized ritual to evaluate information and discern relevant aspects of problems. They could easily identify and interpret relationships between the parts of the dentition, jaws and facial tissues. They could also recognize the pattern of discrepancies early in the diagnostic process, and they could use previously developed diagnostic and treatment scripts to quickly choose a treatment approach for similar problems they addressed previously.

The orthodontic residents had difficulty interpreting the discrepancies without prior experience of them. This was evident when they were uncertain about their diagnosis or treatment plan.

In all, clinical experience accounted for developing and refining the personal frame of reference, which in turn influenced how participants: 1) interpreted and applied knowledge; 2) identified and interpreted problems; 3) refined and individualized diagnosis and treatment planning rituals; 4) recognized patterns and used diagnostic and therapeutic scripts; and 5) justified preference for certain treatment approaches.

Here, I present some of the main findings in relation to similarities and differences in reasoning of participants across different levels of expertise.

The first-year residents

Generally, the junior residents went through a lengthy ritual of evaluating and interpreting information. Compared to the experienced orthodontists, they spent more time analyzing dental and facial relationships. Sometimes, they got confused and couldn't make sense of the relationships:

> I wanna look at the soft tissue profile . . . OK, this makes it difficult, cause he looks retrognathic. If I extract [teeth]. . . humm . . . [pause] . . . interesting . . . [pause] . . . I am thinking [his dental and facial relationships do not match] . . . so I am trying to think here . . . [pause] . . . how would you make his chin look stronger . . . . Humm . . . interesting . . . [pause] . . . I am just trying to think in my head, why does he look retrognathic. JRA

This confusion about the "part-whole" relationships came to the fore again when this participant tried to justify his treatment plan:

> Here's a kind of a dilemma: I am wondering if I pull the second premolars, I can still unravel the [dental] crowding and on top of that maybe allow me to have better anchorage . . . [pause] . . . wait, wait, no, I take that back. . . the only thing that still gets me though is the upper curve of spee [curve of dental arch] . . . I am not an expert. . . . but for some reason it just doesn't seem [right]. . . . I think that all [will] correct itself automatically. JRA

Most of the residents could come up with alternative treatment approaches. However, they felt unsure about the accuracy of their diagnosis or the success of their suggested treatment. They all reflected on limitations of their knowledge and experience. For example, one junior resident stated:

> I know there is something that is called the MEAW [to correct the open-bite]. [But,] I haven't read the literature on it to be honest, even though I was supposed to! . . . This case is tough [to treat] because I am not very experienced with open-bites . . . [pause] . . . humm . . . [pause] . . . would [the bite] be stable? . . . I don't feel very comfortable with this case. . . . Gosh! This is a [tough case]. . . . I don't know. I think with my level of experience, I would be nervous treating this case. . . . Honestly, I am not even sure if I diagnosed it correctly. . . . I am not really 100% confident of my diagnosis. JRA

The second-year residents

Some senior residents had difficulty understanding the mismatch that they observed between the teeth, jaws and facial appearance. They followed the lengthy ritual of evaluating information and eventually concluded that they could not sort it out. However, compared to the first year residents, they were more knowledgeable about alternative treatments. Clinical experience, no matter how limited, was beginning to help towards a preference for certain treatments, but tentatively. One senior resident said:

> My third [option for treatment] would be, and I doubt I would even attempt it, [to] extract [teeth]. . . . upper and lower second premolars and bring everything forward in an attempt to close the bite down anteriorly. . . . You would be bringing your molars forward out of the wedge [of occlusion], so that theoretically autorotates the mandible [up and forward and closes the bite]. But I wouldn't do it. SRB

Recent graduates

The recent orthodontic graduates could interpret the mismatch of teeth, jaws and facial appearance without confusion or inconsistency. Their rituals seemed to be more refined when compared to the residents. It seems that they abandoned some of the diagnosis and treatment protocols of the EDC and adopted the ritual and routines of the clinical practices they joined after graduation and developed their “way of doing things”. They would refer to personal experiences with certain problems or treatments, no matter how limited. One recent graduate stated:

> We do use quite a bit of TADs. . . . I did one case in my other office with molar intrusion and it wasn’t as effective as I thought it would be. . . . But we’ve had a few cases where we put in a fixed removable [tongue] crib for 4-5 months and we were able to close the bite. [RGA]

Experienced orthodontists

The experienced orthodontists had developed diagnostic and therapeutic scripts, which helped them recognize patterns of discrepancies in “part-whole” relationships very quickly. Often, they could diagnose the discrepancies in their first look at the facial and dental photographs of the patients. They could then predict what skeletal relationships to expect from the radiographs. Some did not need to look at the diagnostic casts of the patients. It seemed that the treatment plan was formulated without additional information.

The experienced orthodontists had clearly developed their “own way of doing things”. That was reflected in their comments about preference for specific treatment approaches and techniques. However, they could easily analyze the pros and cons of alternative approaches and justify their reasons for or against

them. At this point in their professional development, they were well aware of the benefits of their own management strategies.

Mostly they used conditional reasoning with strategies to avoid complications. Previous experiences helped them foresee problems prior to initiating treatment.

In summary, their reasoning was dominated primarily by their personal frame of reference, which was reflected in the narratives about personal success and failure with different problems and treatments over a long period of time:

> Most cases, if the patient is not concerned about the facial changes, I think you can get a reasonable result [with a specific treatment technique]. . . . But again, cooperation [can be an issue] and that's why sometimes in the adolescent . . . it's less predictable. In the adults, very predictable, very. . . . [I have] used this technique for] 15 years. . . . I don't know . . . maybe a hundred, you know, a lot. [EB]

4.3. Comparing clinical reasoning of UBC and EDC participants

Here I summarize the similarities and differences in the process and strategies of clinical reasoning between the participants of each study in Tables 4.1. and 4.2. Comparing the process of reasoning of participants in both studies shows that they all used a systematic approach to evaluate information. The junior students at UBC and the EDC residents followed closely the diagnostic and treatment planning protocols of their schools. However, the more experienced dental students, orthodontic residents and orthodontists had developed their own routines for this process. Although some used backward or forward reasoning to evaluate information and hypotheses, most of them adopted a combined approach. Junior dental students and orthodontic residents did not use diagnosis and therapeutic scripts for the problems in the vignettes. However, senior dental

students used scripts for diagnosing and treating common dental problems such as caries and periodontal diseases. The recent graduates and more experienced orthodontists recognized patterns and scripts from previous experiences. Decision analysis helped most of the participants to appraise different treatment options and arrive at a decision. However, this process was dominated by interpretation rather than numbers of the probability and utility of the decisions.

All seven reasoning strategies were used individually or collectively by participants in each study. The scientific reasoning they used involved a combination of analytical and non-analytical approaches to problems. The evidence included scientific knowledge when available along with their own knowledge and experience supplemented by information from their peers and mentors. The more experienced participants relied more on personal experiences with similar problems. Conditional reasoning was used often by all participants to determine the complicated interaction of the biopsychocosial determinants of oral health-related problems. This strategy also helped the more experienced participants to use their experience to deal with uncertain situations and predict outcome of interventions. Collaborative reasoning helped the participants of both studies to arrive at a shared understanding of the problems and treatment objectives with patients, parents and consultants. This interactive strategy was complemented by narrative reasoning to interpret the problems form the patient's point of view. The UBC students used deductive "top-down" or inductive "bottom-up" approaches or a combination of both when confronted by ethical dilemmas in the vignettes. Some used previous experiences to justify their approach to the

dilemmas. Ethical reasoning was used also by the orthodontic participants. Dental students used pragmatic reasoning while they discussed the impact of the socioeconomic issues on their treatment decisions. However, the senior students were more aware of the resources available to help patients with financial constraints or when they were confronted in the vignettes with conflicting opinions of their instructors, or the power imbalances of the dental clinic. The orthodontic residents did not refer to the broader context of treatment. Contextual issues were brought up more often by the recent graduates and experienced orthodontists when they reflected on how certain issues influenced their approach to problems. Using “part-whole” reasoning helped the more experienced participants to integrate the reasoning strategies and contextual information in their decisions. For example, junior students concentrated on problems of teeth and struggled with integrating the available information to arrive at a coherent and comprehensive treatment plan. In contrast, senior students placed a higher emphasis on the patients and their motivation for improving their oral health and their cooperation to achieve the objectives of care. Likewise, the more experienced orthodontists were better able to integrate reasoning strategies and contextual issues in their decisions, whereas the residents struggled with making sense of the relationships between the parts and whole of the dentition and the hard and soft tissues, but did not discuss the impact on their decision of the larger context of care.

Table 4.1. Process of clinical reasoning used by participants at the University of British Columbia and the Eastman Dental Center

Studies		University of British Columbia		Eastman Dental Center			
Levels of Expertise		Students		Residents		Orthodontists	
		Junior	Senior	Junior	Senior	Recent Graduates	Experienced
Process of Reasoning	Ritual	Systematic approach to evaluating information					
		Long Followed UBC protocols	Personal routine	Long Followed EDC protocols	Personal routine	Flexible, fast & efficient Personal routine	
	Backward & Forward Reasoning	Combination approach					
	Pattern Recognition & Scripts	Had not developed the required networks of knowledge & experience	Used diagnostic & therapeutic scripts	Had not developed the required networks of knowledge & experience		Used diagnostic & therapeutic scripts	
	Decision Analysis	Generally dominated by interpretation of probability & utility of decisions					

Table 4.2. Reasoning strategies used by participants at the University of British Columbia and the Eastman Dental Center

<table>
<tr><td colspan="2">Studies</td><td colspan="2">University of British Columbia</td><td colspan="4">Eastman Dental Center</td></tr>
<tr><td colspan="2" rowspan="2">Levels of expertise</td><td colspan="2">Students</td><td colspan="2">Residents</td><td colspan="2">Orthodontists</td></tr>
<tr><td>Junior</td><td>Senior</td><td>Junior</td><td>Senior</td><td>Recent Graduates</td><td>Experienced</td></tr>
<tr><td rowspan="12">Reasoning Strategies</td><td rowspan="3">Scientific</td><td colspan="6">Combination of analytical & non-analytical strategies</td></tr>
<tr><td colspan="6">Evidence from scientific knowledge & experiences of self, peers & mentors</td></tr>
<tr><td>Very limited clinical experience</td><td>Some clinical experience</td><td>Very limited clinical experience</td><td>Some clinical experience</td><td>Used experience as evidence when available</td><td>Often used experience as evidence</td></tr>
<tr><td rowspan="2">Conditional</td><td colspan="6">Dominant strategy used to address uncertainties about the impact of biopsychosocial factors on treatment outcomes</td></tr>
<tr><td colspan="4">Limited knowledge & experience to provide treatments and predict outcome</td><td>Experience available to predict outcome</td><td>Adaptable & flexible to address unpredictable problems and outcomes</td></tr>
<tr><td>Collaborative</td><td colspan="6">Used to arrive at a shared understanding of the problems and objectives of care</td></tr>
<tr><td>Narrative</td><td colspan="6">Used to interpret problems or justify reasoning</td></tr>
<tr><td>Ethical</td><td colspan="2">Used deductive and inductive strategies and previous experiences</td><td colspan="4">Used when conflicts involved two or more ethical principles</td></tr>
<tr><td rowspan="2">Pragmatic</td><td colspan="2">Reflected on socio-economical issues influencing decisions;</td><td colspan="2" rowspan="2">Limited reference to the impact of the contextual issues</td><td colspan="2" rowspan="2">Reflected on the impact of contextual issues</td></tr>
<tr><td>Limited awareness of resources</td><td>Higher awareness of resources</td></tr>
<tr><td rowspan="2">“Part-whole”</td><td>Focused on teeth</td><td>Focused on patients</td><td colspan="2">Struggled with interpreting relationships of teeth, jaws and appearance</td><td colspan="2">Able to interpret relationships of teeth, jaws and appearance</td></tr>
<tr><td>Limited ability to integrate strategies & contextual issues</td><td>Able to integrate strategies & contextual issues</td><td colspan="2">Limited ability to integrate strategies and contextual issues</td><td colspan="2">Able to integrate strategies and contextual issues</td></tr>
</table>

4.4. Summary

Clinical reasoning in dentistry involves a non-linear process of diagnosis and treatment planning. The process usually starts with a ritual of evaluating information from patients' history as well as visual cues and measurements obtained during clinical or radiographic examination. The diagnostic process involves both analytical and non-analytical approaches depending on the nature of the problem at hand, and on the previous experience of the clinician confronting the problem. A combination of knowledge, experiences, values and beliefs of the clinician develops a personal frame of reference that guides an interpretive activity whereby problems are identified and prioritized. This frame also directs the treatment planning process to identify and evaluate alternative approaches that can address the problem. These interpretive activities are also influenced by the interactions of the clinician with patients and others involved with the problem (e.g., parents of the patient, mentors, clinical specialists). Often, these interactions aim to arrive at a shared understanding of the meaning of the problems and their impact on the patient's quality of life, and to determine the objectives of care. Ultimately, the interplay between the clinician, the patient and others influences how the problems are identified, prioritized and addressed. The clinical reasoning of the participants demonstrated in the approaches taken to the vignettes involved an integration of several reasoning strategies (*i.e.,* scientific, conditional, collaborative, narrative, ethical, pragmatic and "part-whole" reasoning) to address the problems as they surface within the larger cultural,

social, political and financial contexts of their clinical practice. Using a “part-whole” reasoning strategy appeared to help the dentist to zoom in and out of problems from a local or specific anatomical level to the larger psychosocial context. This required moving back and forth between the problems and alternative treatment options to arrive at a treatment plan which optimized the interventions, foresaw future problems, and was flexible in relation to addressing the changes in situation if new problems should arise.

CHAPTER FIVE: DISCUSSION

In this chapter I portray and describe a conceptual framework for clinical reasoning in dentistry based on the findings from the UBC and the EDC studies. Following this introduction, I compare my findings to the literature related to clinical reasoning in dentistry and other healthcare disciplines. I then reflect on the rigor and limitations of my study, discuss the educational implications of my findings, and suggest future directions for research on clinical reasoning in dentistry and beyond.

5.1. A conceptual framework for clinical reasoning in dentistry

Figure 5.1. portrays a conceptual model of clinical reasoning in dentistry developed from the findings of this study. The multilayered context of clinical reasoning is shown as overlapping ovals to denote: the personal frame of reference of the dentist, the frame of reference of the patient, the problem(s), and the larger healthcare environment which represents the social, cultural, political and economical context. Two overlapping ovals, shown in grey, portray the process of clinical reasoning (both analytical and non-analytical) and the interaction of the seven reasoning strategies introduced in Chapter 4. The lower oval portrays the non-linear nature of diagnosis and treatment planning as a cyclical process that represents on one side, analytical reasoning (making and testing hypotheses, evaluating options and making choices via decision analysis) and the non-analytical reasoning (pattern recognition and use of diagnostic and therapeutic scripts) on the other. These processes are used either separately or

in combination. The upper oval carries “part-whole” reasoning in the centre as the core reasoning strategy that helps integrate the remaining reasoning strategies that surround the core. This core strategy helps the clinician to identify and address each problem separately or in relation to other problems and the situation as a whole. It also helps identify and integrate the contextual factors influencing clinical decisions as the novice or expert clinician zooms in and out on different problems and moves back and forth between different contexts.

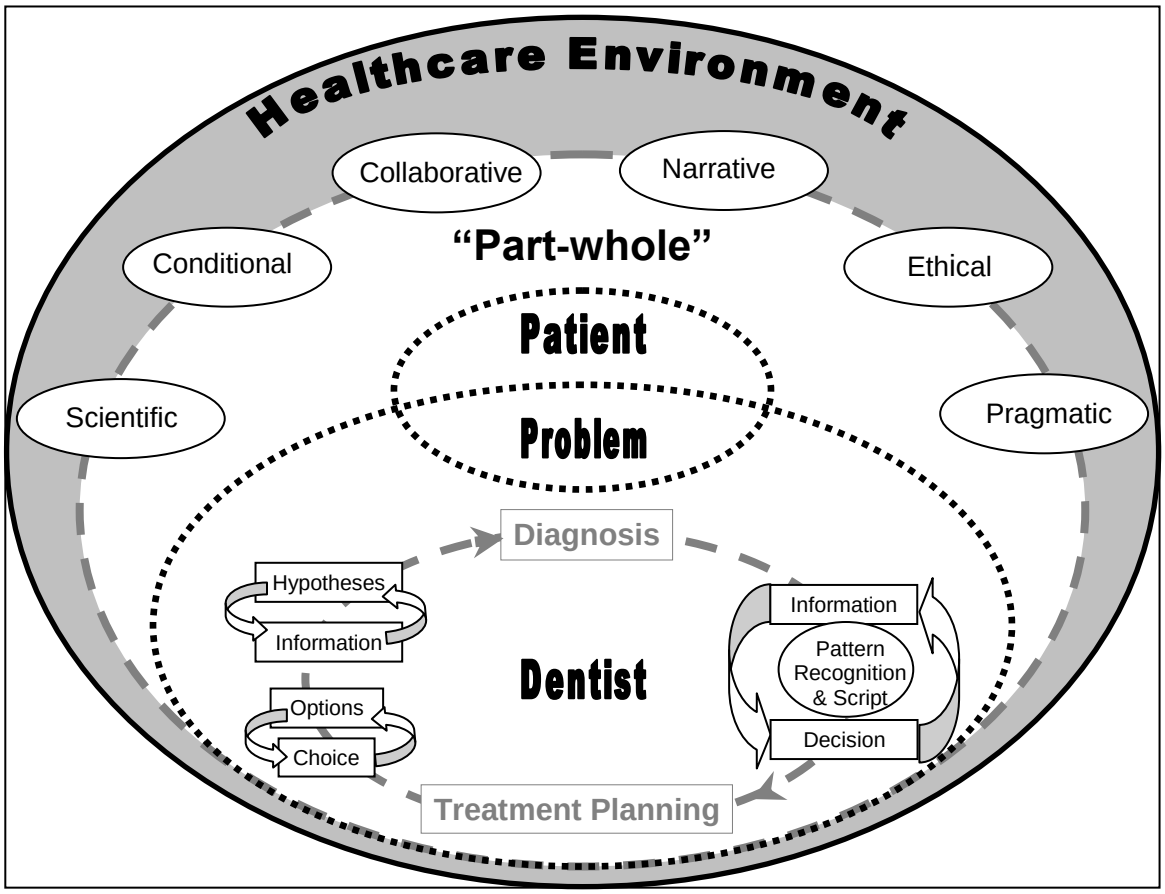

Figure 5.1. Model of clinical reasoning in dentistry

5.2. Broader context of my findings

The three phenomena of process, reasoning strategies, and development of expertise, are intertwined with no clear break between them. Therefore the boundaries will appear blurred in this discussion.

5.2.1. The process

My initial research question was based on the premise that clinical reasoning in dentistry is an integrated process of diagnosis and treatment planning. Therefore, I paid equal attention to exploring both activities. My findings show that dentists rarely follow a linear process as they unravel and address clinical problems (*i.e.,* starting with diagnosis and ending with a treatment plan). As they evaluate information, non-analytical approaches such as pattern recognition and illness scripts help those with more experience to arrive quickly at a diagnosis. I found that some of the illness scripts I witnessed included the therapy along with the diagnosis (*e.g.*, caries scripts, using the multiple loop technique to close an open bite). The original descriptions of illness scripts do not include the treatment regimen, possibly because the emphasis has been to explore the diagnostic process in medicine where they have failed to unravel the structure of knowledge and experiences related to treatment (Norman, 2005a). Clinical experiences seem to contribute to “encapsulated” management strategies used by senior medical students (Monajemi *et al.*, 2007). It has been suggested that encapsulation of knowledge happens through repeated retrieval and application of knowledge about pathophysiology of diseases through repeated application of

this knowledge in clinical encounters with diseases. This detailed knowledge is not addressed directly or explicitly while clinicians diagnose disease, but it is available for retrieval when they are asked specifically to elaborate on their reasoning (Boshuizen & Schmidt, 1992, Charlin *et al.*, 2007). However, the contribution of clinical experience to the therapeutic component of scripts is still unclear in medicine and dentistry.

The diagnostic ritual ensured a comprehensive collection and appraisal of information by participants of my study. Neufeld *et al.* (1981) found no correlation between the amount of clinical information collected and the accuracy of medical diagnosis. Apparently, offering additional information only increases the confidence of clinicians about their decisions, whether right or wrong (Oskamps, 1965). Redelmeier *et al.* (2001) have shown that clinicians who search actively for information are more confident in their decisions. I left the process of information collection entirely in the hands of the dental students and orthodontists I interviewed without offering additional information unless they specifically asked for it. This allowed them to explain the ritualistic approach they use to collecting information for a diagnosis and treatment plan and I found that the more experienced clinicians customized the rituals for themselves as they evaluated information (*e.g.,* experienced orthodontists used their selective list of measurements to analyze radiographs).

The diagnostic rituals were often followed by a linear process of listing the identified problems, prioritizing the problems and planning treatment. However, when evaluating alternative treatment options, most participants needed to re-

evaluate clinical information, re-assess the accuracy of their diagnosis and revisit their treatment plan accordingly. My review of the evolution of clinical reasoning in dentistry (Chapter. 1) highlights the impact of biopsychosocial factors on oral healthcare which demands a comprehensive approach when addressing problems typically addressed by dentists. In chapter 4, I showed how problems relating to a single tooth had to be addressed individually and at the same time with a careful evaluation of how each intervention relating to individual teeth would relate to the dentition as a whole and to the surrounding hard and soft tissues. I also showed how the problems relating to oral health were evaluated within the specific context of the patient, their expectations and demands for care, and as part of their motivation to collaborate with the clinician to achieve the objectives of treatment. This process required several individual or combined strategies of reasoning. I identified “part-whole” reasoning as the dominant strategy, which helped to evaluate and address the contextual determinants of oral health. It also helped participants integrate other reasoning strategies as they moved back and forth between different layers of problems. This complicated interaction of participants with problems often required revisiting the diagnosis and treatment plan to ensure that all the relevant aspects of the problems had been identified and addressed through the selected treatment plan. Dental students and orthodontists alike used a mixture of analytical and non-analytical approaches for diagnoses. This necessitated a backward reasoning to identify specific problems, although most participants combined forward and backward reasoning strategies as they unraveled the problems before them.

Likewise, Crespo *et al.* (2004) found that dentists across all levels of expertise used a combination of forward and backward reasoning in diagnosis. I found also that most of the participants drew from their experiences to see patterns of diseases, and frequently they used illness scripts from previous attempts to resolve similar sets of problems. Dental students, for example, used scripts to confirm the presence of caries, as described by Bader and Shugars (1997). Maupome & Sheiham (2000) also identified pattern recognition and scripts as a non-analytical basis for diagnosing caries. Caries scripts were used by the participants in my UBC study to reveal "up-stream contributing" factors, such as psychosocial issues that initiate and sustain caries, as described by Baelum *et al.* (2006). This finding supports that approach to care in dentistry has evolved from a narrow focus on biological causes of diseases to adopting a more comprehensive biopsychosocial approach to clinical reasoning (Chapter. 1).

A significant aspect of diagnostic reasoning in general dentistry and in orthodontics involves visual information. Dental students and orthodontists alike used a combination of analytical and non-analytical reasoning to evaluate the visual information. Caries, periodontal diseases and oral lesions all involved pattern recognition. However, the dental students with limited experiences analyzed the situation in detail to confirm or reject an initial diagnostic hypothesis. Repeated analysis of radiographs by the experienced orthodontists led to scripts about a global impression (Engel, 2008) of the relationships between the different parts of the dentition and surrounding tissues. This was followed often by a quick

review of the numerical values derived from the analysis to confirm the accuracy of the diagnosis.

The more experienced clinicians used non-analytical approaches more frequently. Overall I found that almost everyone used both analytical and non-analytical reasoning depending on the nature of the problems and their personal experiences. This is consistent with the dual processing model of medical problem-solving as described by Norman (2009), and with the recommendation by medical educators to adopt a combined approach to improve accuracy of diagnostic decisions (Eva, 2005, Eva *et al.*, 2007).

5.2.2. Reasoning strategies

Seven reasoning strategies emerged either independently or integrated with other strategies. Here, I review each of them independently.

Descriptions of scientific reasoning such as the H-D reasoning refer mostly to the analytical process of diagnosis (Chapparo & Ranka, 2008, Fleming, 1991). I used this term to denote the strategies used by participants to support their reasoning with any kind of "evidence". Some orthodontists referred to the available scientific evidence as they tried to justify their reasoning for or against specific treatments. However, the limitation of "scientific" evidence was identified as a barrier, which prompted the need for either personal experiences or the argument of authority to arrive at a decision. Nonetheless, despite the growing interest in evidence-based dentistry and promoting "rational" decision-making (Matthews *et al.*, 1999), dentists do not seem to use the available scientific evidence routinely. Another study found that dental students and experienced dentists did not follow

Bayesian formulas even after they were instructed to do so and when evidence was provided (Chambers *et al.*, 2010). Apparently, they believed that it is difficult to estimate a probability for the presence or prognosis of a disease based on epidemiological data alone. The “causal web” models explains comprehensively how oral diseases occur (Baelum & Lopez, 2004), however, evidence for the effects of the up-stream causes (*i.e.,* psychosocial factors) is vague at best. My findings also highlight the limitations of scientific evidence as a basis. Clearly, reasoning in dentistry extends well beyond a purely scientific and biomedical discipline to involve a range of sophisticated practical and experienced-based sociocultural and historical phenomena, as suggested by Larson *et al.* (2008) for healthcare in general, and by MacEntee (2007) specifically for dentistry.

Uncertainty when addressing complex problems led to conditional reasoning by all participants regardless of their expertise. For example, evaluating the prognosis of certain conditions required an understanding of many factors involved in the initiation and progression of the condition. Unpredictable factors such as “growth” and “patient cooperation” led more experienced orthodontists to adopt flexible treatments to address problems as they arise. The same strategy is used by occupational therapists and physiotherapists as they anticipate the impact of their interventions (Chapparo & Ranka, 2008). Furthermore, one of the dominant applications of conditional reasoning by dental students was the condition set by financial status on the selection of a treatment plan. When financial constraints compromised the “ideal” treatment plan, the participants readily modified the plan so that it would be financially beneficial to the patient.

This financial discourse was dominant in the interviews with dental students, perhaps because the majority of patients attending a dental school clinic are financially poor. It could be due also to the wide range of options and costs available for restoring impaired dentitions. This study showed the significance of financial discourse when selecting among a wide range of treatment options in dentistry.

Collaborative reasoning helped to arrive at a shared understanding of problems and treatment objectives (Higgs & Jones, 2008). Communicating with patients and exploring their perception of problems also involved narrative reasoning (Fleming & Mattingly, 1994). Since my study did not involve real patients or role-playing with simulated patients, my descriptions of collaborative and narrative reasoning reflect the comments made about the use of those strategies only when a hypothetical situation demanded such communications. Loftus (2006) believes that communication and use of language are the essential aspects of clinical reasoning. He found that clinicians often use narratives about a patient's unique story of life and experience of disease to discuss their reasoning strategy with colleagues. My model illustrates the interaction between clinicians, patients and others (*e.g.,* parents, consultant specialists). As Loftus (2006) explains, these interactive and interpretive activities are impossible without language.

Ethical reasoning of dental students followed the top-down, bottom-up and combination approaches described by Edwards & Delany (2008) as the students struggled with the ethical dilemmas posed by the vignettes. The students assessed the situation and tried to adapt their own ethical principles to arrive at

reasonable and ethical decisions. Also, students referred to their previous experiences with similar problems and used their previous approaches as a guide to deal with these dilemma. I found that a deductive approach to ethical problems resulted in a faster decision, and students who used this approach seemed more certain and confident. However, a deductive approach involving two or more ethical principles caused uncertainty and confusion. Alternatively, students who moved back and forth between the inductive and deductive ethical reasoning could more easily justify their decisions on treatments. I did not create a specific scenario to evaluate ethical reasoning among the orthodontists, however, the conflict between respecting patient autonomy and providing the best care possible surfaced as some orthodontic participants justified their decisions for treatment. Bryant *et al.* (1995) asked dentists for examples of ethical dilemmas they faced when caring for institutionalized elders, and found that most of the dentists did not understand clearly what an ethical dilemma would entail. However, when the dentists were asked specifically to reflect on their experiences with frail elders, several ethical dilemmas surfaced in the interviews with the researchers, and it became apparent that dentists, like my participants, also applied principles of autonomy, beneficence, non-maleficence and justice.

Participants at UBC and the EDC both used pragmatic reasoning to address the problems inherent in the larger social, cultural, political and economic context of practice. Again, financial issues dominated the discourse about access to care for some patients. The dental students worried about their personal relationships

and teachers. Some of the issues seem to hinder their opportunities to engage in critical thinking or act on their beliefs about social responsibility to disadvantaged patients. Henzi *et al.* (2006) discovered similar issues among students in other North American dental schools where relationships with faculty, bureaucracy and pressures to become clinically competent occasionally compromised their ethical approach to care. The influence of these issues on students needs further exploration as they develop their professional identity and socialize into their professional roles.

I introduced "part-whole" reasoning as the dominant and effective reasoning strategy to integrate problems as the participants moved in and out of a comfortable frame of reference for considering the patients and others involved in care. This involved evaluating specific problems individually and in relation to other problems in the larger social, cultural, political and financial context. Application of this strategy by participants in both UBC and the EDC studies shows that clinical reasoning evolves in dentistry from the problem of disease to the person, and then on to the larger context of clinical practice (Chapter. 1). This core strategy helps integrate other strategies of clinical reasoning and supports a comprehensive plan to address the biopsychosocial factors that influence problems across different contexts.

The most recent model of clinical reasoning, introduced by Higgs and Jones (2008), highlights the interactive and contextual nature of this thought-process. Furthermore, Higgs and Loftus (2008) emphasize the need to develop discipline-specific models of clinical reasoning for research, practice and education. The

model of clinical reasoning I have constructed from my research in dentistry (Figure 5.1.) illustrates the dynamic interaction of these contexts, largely through the application of “part-whole” reasoning. Also, the model reflects the biopsychosocial nature of problems and approach to care in dentistry. I showed how application of conditional and pragmatic reasoning (*e.g.,* impact of the patient collaboration and their financial status on treatment decisions) requires moving out of the biological context of disease to the larger contex of the patients and the healthcare system. I showed also that the more experienced dental students and orthodontists alike often employ and integrate these strategies to address the pscychosocial factors that influence oral health-related problems.

5.2.3. Development of expertise

My studies confirm that repeated exposure to problems helps in developing a network of knowledge, experiences and beliefs about certain problems and respective approaches to care. This was evident in the reasoning of the more experienced dental students and orthodontists when they used diagnostic and treatment scripts to address common problems. However, less experienced students and orthodontic residents were frequently unsure of themselves. They failed to identify or interpret certain problems that they had not experienced previously. Limited knowledge of alternative treatment approaches and their respective outcome posed another situation of uncertainty to the inexperienced clinicians. Overall, clinical experience and exposure to problems seemed to be the dominant factor in developing the skills of clinical reasoning. Recent reports in medical education (Ericsson, 2004, Eva, 2005, Norman 2005a) endorse this

finding. Benner (1984) differentiated between five levels of expertise from novice to expert nurse. The reasoning of the junior students and residents in my study resembled the description of “novice” in Benner’s study in that they had limited knowledge from text books, course manuals and clinical experience. The senior students and residents resembled the nursing “advanced beginners” as they were able to identify aspects of the clinical situation based on some limited experiences with similar problems. The recent graduates from the orthodontic program reflected the level of “competents” in nursing who usually drew from their clinical experiences with similar problems. Finally, the experienced orthodontists represented the levels of “proficient” to “expert” nurse who can draw from an extensive stack of knowledge and experiences, seeing situations “as a whole”, knowing what to expect, and adopting a flexible approach to changing situations. However, experience alone does not ensure expertise. Expertise involves adaptive and reflexive reasoning skills that evolve as clinicians reflect on their repeated experiences with problems, evaluate the similarities and differences in the contextual factors influencing the problems, and arrive at creative and flexible strategies to address the problems (Mylopoulos & Regehr, 2007, Schmidt & Rikers, 2007).

The experienced clinicians in my study appeared to be more aware of the complicated interplay of factors that influence the outcome of their interventions. This helped them to recognize the pattern of certain problems and to foresee problems. They were more aware of the issues inherent in the larger social, economical and political environment of clinical practice. Similarly, Crespo *et al.*

(2004) noted that expert dentists demonstrated higher awareness of the contextual factors influencing clinical decision. However, they did not elaborate on the specific impact of contexts on clinical reasoning of experts.

In all, my findings demonstrate some of the key determinants of expertise in clinical reasoning including: 1) use of integrated networks of knowledge and experiences; 2) integrated use of reasoning strategies to relate the parts to the whole in each situation; 3) awareness of the contextual factors that influence problems and approach to care; 4) development of personal philosophy of care (*i.e.,* "way of doing things"); and 5) flexible and adaptive approaches to problems.

5.3. Rigor and limitations of the study

This research used similar methods in two different contexts that included important differences in location, clinical expertise and background of participants. The consistency in the findings from both studies strengthens the transferability of our findings to other contexts. I conducted several exploratory studies that involved observing dental students and their mentors for over three years as they engaged in discussions about clinical reasoning. I also informally interviewed several students and faculty at UBC about those discussions to explore further their approaches and opinions about problems in dentistry. These preparations refined my research questions and objectives and also served as additional information to triangulate my interpretation and descriptions of clinical reasoning.

Ultimately, I adopted a think-aloud method and used situational vignettes and diagnostic aids to simulate clinical encounters with problems. The ecological validity of my findings is compromised to some extent because the methods do not replicate the complexity of the "real world" in which clinicians typically interact with problems, patients and others (Arocha & Patel, 2008, Kirshner & Whitson, 1997). Therefore, I was not able to assess real communications between the participants and patients. Indeed some of the faculty members predicted that communication would be difficult to assess through the clinical scenario of a vignette.

I selected common, important and contentious problems in dentistry assuming that the selection would provoke a range of reasoning strategies that would be representative of oral heath-related problems. It is possible that other reasoning strategies are used in more complex and less frequently encountered cases.

I used the opinions of the nine members of faculty at UBC to validate the situational vignettes as an appropriate medium to prompt clinical reasoning of students. This proved to be an effective strategy ensuring that the vignettes presented information in a realistic way. However, I noticed that some of the terms I used as I developed and tested the vignettes were not consistently understood by faculty. For example, some did not understand what I meant by "awareness of the context of practice" and some struggled with relating ethics to clinical reasoning. This suggests that among faculty members there are different interpretations of about what is important in clinical reasoning.

Nonetheless, the findings from the interviews with faculty suggested that the combination of vignettes and diagnostic aids provided a reasonable range of interdisciplinary problems to prompt students to reason their way through most of the competencies that they are expected to master during their undergraduate education. I used the same method, without the same validation of vignettes, to study how orthodontists reason. Nonetheless, I believe that the vignettes provide a reasonable simulation of the diagnostic and treatment planning situations encountered by orthodontists. For example, they addressed the significance of interactions with patients and their parents to arrive at a shared understanding of problems and treatment objectives in orthodontics.

The UBC study only involved dental students at two stages of the program, which offered a limited opportunity to evaluate development of expertise in general dentistry as the participants were at best only at the levels of novice to barely competent. However, the EDC study involved orthodontists with a wide range of clinical experiences to ensure that I included participants from different levels of expertise. Recent concepts of expertise question the validity of the assumption that the number of years in practice ensures expertise (Mylopoulos & Regehr, 2007, Schmidt & Rikers, 2007). I did not label the levels of expertise and only present the major similarities and differences in reasoning of different groups of orthodontists. Yet, my findings show specific patterns in relation to reasoning capabilities of the less-experienced residents compared to the recent graduates and the more experienced orthodontists.

5.4. Implications and future directions

In this section, I offer recommendations for improving dental curriculum based on the findings of my study and current literature. I then discuss how my findings might direct future research about clinical reasoning in dentistry and healthcare.

Implications for dental education

I suggest that dentists, like other healthcare professions, do not employ H-D reasoning alone to identify and address problems. Instead, they adopt flexible reasoning strategies in relation to process (*i.e.*, analytical and non-analytical) and specific to the nature of the problems and contextual issues (*e.g.*, conditional, ethical, "part-whole"). PBL is the most dominant educational method in dentistry with claims to improving the problem-solving skills of dental students by focusing on the development of H-D reasoning process (Fincham & Shuler, 2001, Susarla *et al.*, 2004). A systematic review by Rochmawati and Wiechula (2010) found inconclusive evidence regarding the effectiveness of PBL in improving clinical reasoning. They acknowledged the diversity of PBL in different educational settings and called for further studies to explore the impact of PBL on how healthcare students reason. Charlin *et al.* (1998) compared the PBL practises within three Canadian medical programs and suggested that problems be used as media for applying and relating theoretical knowledge to practice. Also, like Eva (2005); Norman & Schmidt (2000) and Norman (2005a), they recommended that clinical problems be selected according to the specific educational objectives of each program. I will go further and recommend that dental educators select problems that require an integration of reasoning strategies that can address the

complexity imposed by the multitude of biopsychosocial determinants of oral health rather than focusing more narrowly on biological problems alone.

I show that clinical experience and exposure to problems develops and refines scripts for diagnosis and treatment planning. Consequently, dental educators could benefit students by adopting the concept of “deliberate practice” (Ericsson, 2004) to provide opportunities for students to develop the networks of knowledge and experience required for clinical reasoning. Such “deliberate practice” requires continuous exposure to problems and aims to improve clinical reasoning through repetition, reflection and feedback. However, I support the recommendations of Mylopoulos and Regehr (2007) that the objective of the “practices” should emphasize adaptive expertise rather than routine or ritualistic approaches to clinical problems. This requires a greater emphasis on reflection and feedback to ensure that the contextual aspects of problems are recognized and that the students have opportunities to reflect on their reasoning and compare it with the reasoning of their peers and more experienced clinicians (Ericsson, 2008, Rochmawati & Wiechula, 2010). I found important differences in the approach to problems within and across levels of expertise (Tables 4.1. and 4.2.). Perhaps reflection on clinical reasoning could be a routine exercise given to students following encounters with new clinical problems, possibly in the context of group discussions of real or fictitious patients. Reflections can be used as a topic for discussion in group seminars for students to compare their reasoning to their peers and mentors and be exposed to alternative frames of reference and interpretation of problems.

Currently, there are several computer programs available to develop virtual patients in medicine and dentistry (Huwendiek, de Leng, Zary & Fischer *et al.*, 2009, Poulton, Conradi, Kavia & Round *et al.*, 2009). They offer templates that could be used by instructors to incorporate clinical and diagnostic information of real patients in a virtual environment. Virtual patients do not offer the opportunity of interacting with peers and mentors in face-to-face seminars, but they provide a cost-effective alternative for small-group seminars (Huwendiek, Reichert, Bosse & de Leng *et al.*, 2009). They seem to be at least as effective as problem-based learning seminars in achieving educational objectives (Poulton *et al.*, 2009). Further studies are needed to evaluate their effectiveness in simulating clinical scenarios. The virtual patients could provide immediate and comparative feedback between students and experts. For example, after students complete the exercise of collecting clinical information for a diagnosis, they could compare their findings to those obtained by an expert. I discussed the limitations of using paper-based vignettes to simulate interactions with patients and other players in the healthcare environment. I believe that similar limitations apply to virtual patients as simulated clinical encounters. Considering these limitations, perhaps these educational methods can be used only as a tool for deliberate and reflective practice and not as substitutes for real clinical encounters with patients.

Dental educators would benefit from a larger involvement in community-based dental clinics as a supplement to the current dominance of experience in specialized university-based dental clinics (Brondani *et al.*, 2008, Formicola *et al.*, 2008). This model of education should provide a richer environment for students

to engage in a broader range of clinical decisions more in keeping with the expectations of the societies in which they will practice as dentists.

Implications for future research

My model of clinical reasoning can serve as a conceptual framework to assist future research in clinical reasoning in dentistry and in similar health-related disciplines. It illustrates how clinical reasoning extends beyond the cognitive context of a clinician to the broader healthcare environment in which clinicians interact with patients and others to identify, interpret and address problems. It shows the specific strategies used when dental students and clinicians address biopsychosocial determinants of oral health, and is in line with the evolution of clinical reasoning in dentistry from the problems of teeth to the patients and to the larger healthcare environment.

Of course each constituent of the model needs further exploration to clarify more precisely how it influences clinical reasoning. For example, the specific impact of financial issues on decision-making processes of dentists can be explored further or the impact of the patients' perceptions of problems on diagnostic or treatment decisions. The model can guide research that evaluates the effectiveness and validity of current educational and assessment methods in relation to developing clinical reasoning competences in dental education. Also, specific educational interventions can be developed and tested through experimental, survey or interpretive inquiry of their influences on clinical reasoning.

In conclusion, my model offers an empirical foundation for clinical reasoning in dentistry to guide future research, education and service. It is grounded in the

specific context of dentistry and reflects the evolving practice model of dentistry from a reductionist focus on diseases of the mouth to understanding oral health as a complicated biopsychosocial phenomenon (Locker, 1988, MacEntee, 2006).

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APPENDICES

Appendix 1. UBC dental curriculum

The UBC dental curriculum has undergone several changes over the course of my study. However, the following reflects the educational program offered at the time of my study.

Admission criteria for the DMD program

Each year, Faculty of Dentistry at UBC enrols 40 students in the Doctor of Dental Medicine (DMD) program. To be eligible for admission, applicants should complete 90 credits of the prerequisite courses at a recognized faculty at UBC or its equivalent. The courses include: English, Mathematics, Chemistry, Physics, Biology, Organic Chemistry, and Biochemistry. A Grade Point Average (GPA) of 70% is required for admission. All the applicants should also take the Dental Aptitude Test (DAT). The test is required for admission to any Canadian and US dental school. Since 1966, the Canadian Dental Association (CDA), in coordination with the American Dental Association (ADA), administers the DAT to test manual dexterity, natural sciences (including Biology and General Chemistry), perceptual ability, and reading. UBC uses three components of the DAT for admission purposes: academic average, perceptual test, and the carving test. Each year, the admission committee screens the applications and calls 80 candidates for a formal interview. Half of the applicants are selected to enter the program in the following academic year.

First Year (Junior Clerkship I)

The first year of the curriculum consists of four modules. The biomedical science module includes “Fundamentals of Body Design” and “Foundations of Medicine”. In the first 14 weeks, students learn about the normal biology and physiology of human body from cells to organs and systems. The Fundamentals of Body Design comprises three sub-blocks: P2P1 a (6 weeks), P2P1 b (4 weeks), and P2P1 c (4 weeks). The Foundations of Medicine includes several system blocks that are offered in a period of 55 weeks in the first and second year. The blocks are designed to help students develop an understanding of the biological, behavioural and population aspects of diseases and integrate the knowledge of the normal and abnormal structure and function of the body to diagnosis and treatment options. System blocks in First Year include: host defence and infection (5 weeks), cardiovascular (5 weeks), pulmonary (5 weeks), fluids, electrolytes, renal and genital urinary tract (5 weeks).

Each block is designed to horizontally and vertically integrate biological and clinical knowledge required to diagnose and manage clinical problems. Accordingly, faculties from several departments work in collaboration to write PBL cases and provide supplementary lectures and laboratories. Each week of the block starts with a PBL tutorial to present a clinical problem to the students. Tutorial groups consist of 8-9 students and a tutor to facilitate discussions. PBL cases are presented in 3 sessions over the week on Monday, Wednesday, and Friday mornings. The case provides the students with sequentially released information about the clinical problems. Each session presents segments of the

clinical problem that unfolds throughout the week and helps the students develop "learning issues" to understand and solve the problem. Lectures and labs supplement the discussions and direct students to develop knowledge about the learning objectives of the week. At the end of each academic term, students are assessed through multiple-choice written examinations.

In addition to the basic science blocks, there are three longitudinal courses in the first year: Interdepartmental Medicine (INDM 410: Introductory Clinical Skills and Systems I); Doctor/Dentist, Patient and Society (DPAS 410); and Dentistry I (DENT 410).

Communication Skill Course (INDM 410): The course is offered in a period of 14 weeks from September to December in Tuesday afternoons. Students receive two lectures on the topic and the remaining time is devoted to interviews with volunteer and standardized patients. Students attend small group discussions where they observe the interview process of their peers and with help of a mentor, provide feedback to the interviewers and generate discussions around the theme of the week. The interviews help students develop their communication skills (*i.e.* listen to the chief complaint of the patients and take histories to understand the psychosocial aspects of the patient's problem). At the end of the course, students are assessed through Objective Structured Clinical Examination (OSCE) and receive an evaluation report from their mentors.

Doctor/Dentist, Patient and Society (DPAS 410): DPAS is designed through multidisciplinary collaboration of the Faculties of Medicine, Dentistry, Anthropology and Sociology, and Healthcare and Epidemiology. The course aims

to help the students understand the changing healthcare system and their roles as healthcare professionals in its dynamic environment; the healthcare needs of the diverse Canadian society; and the knowledge and skills required to address the critical issues in relationships and communication with patients. The themes of the DPAS 410 include: social science and health (8 weeks), ethics (5 weeks), public health and community medicine (5 weeks), addiction medicine (5 weeks), evidence-based medicine (4 weeks), and sexual medicine (4 weeks). The course is offered weekly, every Wednesday afternoon, throughout the year. Each week, students attend a plenary session where they receive a lecture or participate in a discussion with a panel of guests. The session is followed by small group tutorials where 8-9 students meet with a tutor to discuss the theme of the week and present the required assignments. The students work on individual and group projects throughout the course. First, each individual should interview a patient with a chronic condition to explore the psychosocial impact of the chronic illness and disability on the lives of the patient and the family; identify the similarities and differences between acute and chronic health conditions; and recognize the social issues in providing healthcare needs of the patient. The second project is to analyze and discuss a complex ethical situation in the group and reflect on the various beliefs and ideas about the issue. Next, the group should develop a project and give a presentation about an infectious agent that is assigned to them by the course coordinators. During the course of addiction medicine and intercollegial responsibility, all the students should visit a community agency that provides alcohol and drug services and write a report of

their observation. Finally, the group should design a clinical trial to explore the impact of a multifactorial risk intervention on prevention of a disease and present the trial to the class. Students are assessed based on the collective scores of the assignments and the results of the final OSCE exam.

Dentistry I (DENT 410): Dental students spend half a day per week to participate in an introductory course of clinical dentistry. The course is offered every Monday afternoon in the Faculty of Dentistry and is designed and delivered by coordinators and instructors from the Faculties of Dentistry and Anatomy. The themes of the course include critical analysis (2 weeks), odontogenesis and dental morphology (5 weeks), ergonomics (2 weeks), infection control (3 weeks), head and neck anatomy (7 weeks), applied infection control (2 weeks), assessment of extra/intra oral landmarks (2 weeks), and assessment of periodontal structures (3 weeks). The course offers lectures, tutorials, laboratories, and clinical simulations where students perform oral examinations on the mannequin heads and their peers. At the end of the first term, the students complete a computer based exam for dental morphology. They also write a written exam on the head and neck anatomy and are assessed by their mentors after completing all the sections of the course.

DENT 410.3: After completing the final exams of the Foundation of Medicine, dental students take a supplement course in a period of 3 weeks in June. The themes of the three weeks include introduction to caries, periodontal diseases, and an introduction to dental pain. Each week starts with a PBL case, which is

supplemented by lectures and labs about the theme of the week. The students write a written exam and the tutors evaluate them at the end of each PBL case.

Second Year (Junior Clerkship II)

Second year of the program follows the same format of the first year. The Foundation of Medicine Module continues with the following blocks: musculoskeletal (4 weeks), blood and lymphatics (2 weeks), gastrointestinal (4 weeks), endocrine and metabolism (5 weeks), integument (1 week), brain and behaviour (9 weeks), reproduction (4 weeks), and growth and development (5 weeks).

DPAS 420: The themes of the course include social science and health (3 weeks), prevention and health promotion (3 weeks), causation (2 weeks), occupational health (2 weeks), domestic violence (2 weeks), complementary and alternative therapies (4 weeks), legal and ethical issues in prescribing (3 weeks), addiction medicine (1 week), and health policy, ethics, and law (9 weeks). The course is offered every Monday afternoon with a plenary session and the subsequent tutorials. Students have to complete three assignments for the course and an OSCE at the end of the year. For the first project, students should evaluate the social and epidemiological characteristics of a community and identify the health related needs of that community so they can learn about the local and regional health services in the province; conceptualize the scope of the problem; and identify the steps to take in the process of solving that problem. The next project is to collect information about a particular healing and alternative therapy and understand the underlying assumptions in application of the therapy.

The final project requires from students to critically appraise a therapeutic intervention based on the evidence-based publications about the therapy.

Dentistry II (DENT 420): The students attend lectures and clinic sessions every Thursday morning in the Faculty of Dentistry. The course is designed to prepare dental students for basic clinical procedures such as setting dental armamentarium in the clinic cubicles, keeping with the principles of infection control; adult patient assessment; learning the principal radiographic techniques and radiation protection; taking and pouring impressions; making and trimming study models; articulating the models; learning about the pharmacology of the local anesthetics, systemic and local complications of administering the anesthetics; and practicing different types of injections. The course is followed by several lecture, tutorials, and a laboratory session on primary teeth morphology, tooth development, craniofacial growth, and development of occlusion. Students take computer-based and written exams at the end of some sections. In addition, the tutors evaluate students' performance at the end of the course.

DENT 420.3: In June of the second year, dental students take an intense introductory course to practice psychomotor skills in operative dentistry and periodontics. The module includes lectures and clinical simulations where students practice instrument control; rubber dam placement; mechanical caries removal and pulp protection; composite resin placement and finishing; amalgam handling, placement, carving, and finishing; and conducting periodontal examination on mannequin heads. The course also includes a PBL case and

series of lectures on dental materials. At the end of the course, students should pass the psychomotor skills competency tests and an OSCE.

Third Year (Junior Clerkship III, Associate Clerkship)

Junior Clerkship III: The Third Year starts with a week of operative dentistry clinical simulations that continue over the course of the first term (two or one half-day per week). The first term also includes longitudinal weekly courses of occlusion, periodontics, endodontics, orthodontics, prosthodontics (including fixed and removable partial denture and complete denture), oral radiology, and oral surgery. Each course comprises lectures and clinical simulations. In addition, students attend PBL tutorials on weekly basis. PBL cases include prosthodontics (complete and partial denture), periodontics, endodontics (dental pain), and orthodontics.

Associate Clerkship: The students start a simulation course in pediatric dentistry and assist senior clerks in pediatric dentistry rotations in a community-bases care clinic off campus. They continue the fixed prosthodontics simulation module, and render dental care in ICC within the range of their competency. They receive series of lectures on biomaterials, preventive and community dentistry, critical thinking, local anesthesia and conscious sedation, and several discipline-based lectures. They also attend PBL tutorials on dental insurance plans, periodontics, pediatrics, endodontics, orofacial development, and critical thinking. In a period of three months from January to March, students attend diagnosis and treatment planning seminars. Third Year students should attend the seminars and

participate in group discussions. At the end of the course, they receive a lecture about diagnosis and treatment planning process in the ICC.

At the end of each term, students take oral, written, OSCE, and computer based exams. Simulation courses include competency exams at multiple stages of the course. Students are also evaluated for their attendance, participation, and preparation for PBL tutorials.

Forth Year (Senior Clerkship)

The Forth Year involves treatment planning and rendering care for complicated multidisciplinary cases. The students attend several community-based care sites in rotations including geriatrics, pediatrics, and dental care for disadvantaged population. The scope of the activities in rotations varies. However, the students are mainly responsible to observe and assist the UBC-affiliated dentists who render care for the patient on site. For some courses such as geriatrics, the students are responsible for providing a written report at the end of the course in which they reflect on their experience of attending the clinic or the long-term care facility in which care is rendered. They should also rotate in the ICC for screening patients and attend periodontics, oral surgery, orofacial pain, and oral medicine/oral pathology specialty clinics at UBC.

The students receive several discipline-based lectures and PBL tutorials. Most lectures and tutorials in the Forth Year are about oral medicine and oral pathology. PBL subjects include critical thinking, periodontics, dental trauma, and several oral medicine and oral pathology cases. In addition, senior clerks are responsible to give two presentations in the diagnosis and treatment planning

seminars. The first case involves presenting a “complex case” that they treatment planned in ICC and the second is to evaluate the outcome of a treatment plan that has been rendered at UBC. Mentors evaluate student’s presentations and assign their grades for the course.

Students take oral, written, and computer-based exams in December and March. They should also complete the National Dental Board Exam in March to become certified as a dentist.

Appendix 2. Vignettes for UBC study

Vignette 1

A 42-year old woman attends UBC dental clinic. She says: “I want to have new dentures. My old plate is not stable and is broken. I want to fix my teeth and take care of them.”

Vignette 2

After you present a treatment plan, she shows concerns about the cost of treatment. She asks you if you could extract all her teeth and make a set of dentures.

Vignette 3

You are at the end of 4th year and you need 2 more crowns to complete your “requirements”. The patient is reluctant to pay for the caries management program and is wondering if you can just make the RPD without the crowns.

Vignette 4

A 35-year old man comes to the clinic complaining of pain from broken anterior teeth. He says: “my front teeth are broken and they are hurting me, but the pain comes and goes. Also, my molar tooth is broken and I am not able to chew on both sides.”

Vignette 5

You consult your ICC instructor about the white lesion. The instructor believes that the lesion is leukoplakia and it should be monitored over time for change. You consult a periodontist on a different matter and he notices the white lesion in the patient's mouth. He believes that the lesion needs to be biopsied. He rebukes you for a 4th year for ignoring such an important issue, and is upset when you tell him, in your defence, that your ICC instructor doesn't agree with the biopsy option.

Vignette 6

As soon as you tell your instructor about the patient's smoking habit, he tells the patient to quite smoking right away otherwise the white lesion can become cancerous and kill him. The patient is quite upset about the way he was treated by your instructor and tells you that such an attitude would not help him to stop smoking. He asks you to schedule his appointments on the days when that instructor is not around.

Appendix 3. Letter of initial contact (UBC faculty)

Letter of Initial Contact

Study Title: Exploring clinical reasoning in a dental curriculum

Dear [Name of the participant],

I am contacting you to ask for your participation in a study of clinical reasoning in dental education. We are exploring when, where and how dental students acquire clinical reasoning skills. We have developed six situational vignettes representing various medical, psychosocial and ethical situations to explore how students evaluate the problems and make clinical decisions. We will ask you to participate in a 1-2 hour interview at your convenience to evaluate the appropriateness of the vignettes for exploring students' skills in clinical reasoning.

You were selected to participate because you have been closely involved in developing and delivering educational modules within the dental curriculum. Please be assured that you are completely free to decline this offer or to withdraw from the study at any time without concern or hindrance.

Shiva Khatami will conduct this study as a requirement for her PhD degree, so if you are willing to participate or would like more information about the study, please phone or email Shiva at 604-822-8879 or shivak@interchange.ubc.ca

I will be grateful if you will reply within the next week.

Yours sincerely,

Michael MacEntee, LDS(I); FRCD(C), PhD. Professor

Shiva Khatami, PhD Candidate

Appendix 4. Interview guide (UBC faculty)

Purpose:

The purpose of our study is to explore student's clinical reasoning. For that, we have developed several vignettes that include different problems. I would like to ask you to review the vignettes and tell me how in your view the problems in the vignettes could prompt students to reveal their skills in:

- Applying knowledge
- Communication
- Ethics
- Awareness of the psychosocial aspects of patients' conditions
- Awareness of prognosis of conditions and treatment options
- Awareness of the context of practice

Probing questions if necessary:

- How do you think the vignettes will help to explore a student's skills in applying scientific knowledge in diagnosis and treatment planning?

- How well will the vignettes prompt a student to reveal:
  - communication skills and abilities relating to treatment decisions?
  - awareness of ethical dilemmas?
  - awareness of the healthcare environment?
  - an understanding of prognosis and treatment planning?

Appendix 5. Consent form (UBC faculty)

CONSENT FORM

Title of Study: Exploring clinical reasoning in a dental curriculum

Principal Investigator: Michael MacEntee, Department of Oral Health Sciences, Faculty of Dentistry, 2199 Wesbrook Mall, Vancouver, BC, V6T 1Z3. 604 822-3562.

Graduate Student: Shiva Khatami, PhD Candidate, Department of Oral Health Sciences, Faculty of Dentistry, 2199 Wesbrook Mall, Vancouver, BC, V6T 1Z3. 604 822-8879.

Purpose: This study is designed to: 1) explore differences in clinical reasoning skills among dental students; 2) explain how the skills develop in an undergraduate dental program; and 3) provide guidelines for education and clinical reasoning in dentistry.

Selection and Participation: You were selected to participate because of your involvement in designing and delivering teaching modules within the dental curriculum at UBC. You know that you can decline to participate and withdraw from the study at any time without consequences.

Study procedures: You will be asked to assess six situational vignettes for exploring clinical reasoning by dental students, and your assessment will be audiotaped during the course of one- hour open-ended interview. The interview recordings will be transcribed and analyzed systematically by the investigators to document your assessments, recommendations, and opinions about the vignettes.

Risks: There is no foreseen risk associated with this study.

Confidentiality: Your identity and personal information collected during the study will be strictly confidential and you will be identified only by a code number. All records will be kept in a locked filling cabinet or stored securely on a computer protected by a password. The code will be held only by Shiva Khatami. She will conduct this study as a

requirement for her PhD degree and the information you provide will appear in the content of her doctoral thesis without revealing your identity.

Contact information: You can contact the investigators or Ms. Judy Laird, CDA, Clinical Research Coordinator at 604 822-5064 if you have questions or desire further information. You can contact also the Research Subject Information Line (PHONE: 604 822-8598) in the UBC Office of Research Services if you want information about your rights as a research subject.

Consent: Your participation in this study is entirely voluntary and you may refuse to participate or withdraw from the study at any time without concern or hindrance of any kind.

You have received a copy of this consent for your own records.

Participant Signature:_____ Date: _____/_____/_____

Participant Name (Please print) _____

You agree to have your interview tape recorded

Participant Signature:_____ Date: _____/_____/_____

Participant Name (Please print) _____

You do/do not give permission for the principal investigator to use the information you are providing as part of a larger study focused on the same issue.

Participant Signature:_____ Date: _____/_____/_____

Participant Name (Please print) _____

Appendix 6. Letter of initial contact (UBC students)

Letter of Initial Contact

Study Title: Exploring clinical reasoning in a dental curriculum

Dear [name of the student],

I am contacting you to ask for your participation in a study of clinical reasoning in dental education. We are exploring when, where and how dental students acquire clinical reasoning skills. We have developed six situational vignettes representing various medical, psychosocial and ethical situations to explore how students evaluate the problems and make clinical decisions. We will ask you to participate in a 1-hour interview at your convenience to consider the clinical vignettes, to identify the problems they represent, and to suggest treatment for the problems. We will ask you to "think out loud" as you think about each vignette so that we can follow clearly how you evaluate the situations and solve the problems.

Please be assured that you are completely free to decline this offer or to withdraw from the study at any time without concern or hindrance, and in no way will your participation or refusal to participate influence your standing as a student within the Faculty of Dentistry or the university.

Shiva Khatami will conduct this study as a requirement for her PhD degree, so if you are willing to participate or would like more information about the study, please phone or email Shiva at 604-822-8879 or shivak@interchange.ubc.ca

I will be grateful if you will reply within the next week.

Yours sincerely,

Michael MacEntee, LDS(I); FRCD(C), PhD. Professor

Shiva Khatami, PhD Candidate

Appendix 7. Consent form (UBC students)

CONSENT FORM

Title of Study: Exploring clinical reasoning in a dental curriculum

Principal Investigator: Michael MacEntee, Department of Oral Health Sciences, Faculty of Dentistry, 2199 Wesbrook Mall, Vancouver, BC, V6T 1Z3. 604 822-3562.

Graduate Student: Shiva Khatami, PhD Candidate, Department of Oral Health Sciences, Faculty of Dentistry, 2199 Wesbrook Mall, Vancouver, BC, V6T 1Z3. 604 822-8879.

Purpose: This study is designed to: 1) explore differences in clinical reasoning skills among dental students; 2) explain how the skills develop in an undergraduate dental program; and 3) provide guidelines for education and clinical reasoning in dentistry.

Selection and Participation: You were selected to participate because you responded to the letter of initial contact about this study. You know that you can decline to participate and withdraw from the study at any time without consequences.

Study procedures: You have been advised that you will be asked to review six clinical vignettes and related diagnostic aids to identify the problems they represent, and to suggest treatment for the problems. You will be asked to “think out loud” as you think about each vignette and your thoughts and comments will be audiotaped during the course of one-hour open-ended interview so that the investigators can analyze them carefully and in detail.

Risks: There is no foreseen risk associated with this study.

Confidentiality: Your identity and personal information collected during the study will be strictly confidential and you will be identified only by a code number. All records will be kept in a locked filling cabinet or stored securely on a computer protected by a password. The code will be held only by Shiva Khatami. She will conduct this study as a

requirement for her PhD degree and the information you provide will appear in the content of her doctoral thesis without revealing your identity.

Contact information: You can contact the investigators or Ms. Judy Laird, CDA, Clinical Research Coordinator at 604 822-5064 if you have questions or desire further information. You can contact also the Research Subject Information Line (PHONE: 604 822-8598) in the UBC Office of Research Services if you want information about your rights as a research subject.

Consent: Your participation in this study is entirely voluntary and you may refuse to participate or withdraw from the study at any time without concern or hindrance of any kind.

You have received a copy of this consent for your own records.

Participant Signature:_____ Date: _____/_____/_____

Participant Name (Please print) _____

You agree to have your interview tape recorded

Participant Signature:_____ Date: _____/_____/_____

Participant Name (Please print) _____

You do/do not give permission for the principal investigator to use the information you are providing as part of a larger study focused on the same issue.

Participant Signature:_____ Date: _____/_____/_____

Participant Name (Please print) _____

Appendix 8. Instruction for Think-aloud Method

Purpose: This study explores clinical reasoning of dental students in the beginning and end of the 4th Year. I want you to review vignettes about two patients and tell me what you would do so I can hear how you address each vignette. Please note that this is not a test of your clinical knowledge or of treatment planning, but rather my attempt to understand how you think when you encounter a clinical situation. At any point during this interview, if you think that you need any additional information, please ask for it. Any further information will be provided to you only if you think that is needed.

Appendix 9. A segment of a table comparing reasoning process of students

Colour coding for this table: Orange stands for Pragmatic Reasoning; Pink for Conditional Reasoning and Green for Collaborative Reasoning.

JSB	JSC	SSE	SSG
If I just met her I would say Hi. [I would] get to know her a bit. . . .Here at UBC, we like to get Med Hx and then Dent Hx. . . .	I would start off by getting a general med Hx, dental Hx: when she got the denture, why she lost teeth, clarify what part is broken, what she means by "[denture] not stable". . . .	First explore the chief complaint: see why the denture is unstable and if it can be repaired, look to see if she really needs a new denture . . .	[I want to] know more about the patient and denture. [I] take a routine approach and don't jump into chief complaint. . . .
I don't know what kind of denture she is talking about . . . need to do odontogram . . . do dental exam. . . . [take] dental Hx . . .	[I would then do the] extra-oral, intra-oral exam: look at existing teeth, look at the denture, see what's wrong, look for other information, then discuss Tx options. . . .	Look at other teeth, caries and see if there is underlying problem: why she has caries or plate, she is young for a plate, why denture and broken teeth. . . .	[I take Medical and] dental Hx: when the denture was made, had it given trouble to her before. Why did it break. . . .
[Need to] gather data: X-ray. . . . after collecting all data, [I would] do Tx plan: ask about chief complaint, which is old plate unstable and broken . . . but [I need to] know if there is anything else (maybe that's just her biggest problem). . . .	[Looking at photos I see] missing teeth on upper, sore on the lip, fractured off crown, filling, deep bruises and stains. . . . [I] want to see how much residual ridge is preserved for stability of denture. [I want to] see X-rays of the area where she has teeth left. . . . [I see] tipped tooth, might have canine guidance on excursion.	[looking at photos I see] Cl V lesions. Hygiene seems ok, but there should be a reason why she lost teeth. . . . [I] want to know why she lost teeth, she is only 42.	She says denture is not stable. [I would] ask what she means by that, [because] people have different expectations of stable [dentures] Sometimes you can please patient with little work. . . .. she says she wants to take care of them. [I would] ask her to say what she means [by that] and if you can take [care of] the patient or it is out of your means. . . .
[Looking at photos, I see which] teeth [are] present . . . broken tooth, active decay, may be she lost teeth because of decay, looking at the grooves, dark underneath enamel. . . . soft tissue looks OK, nothing red or inflamed looking . . . good ridge on the front, not resorbed. . . .	[Looking at the radiographs, I] look at the surrounding structures first: sinuses, density of the bone, horizontal and vertical defect, look at it segmentally from one side and then go across, look at the bone around the apical of teeth, see if there is radiolucency, something around the incisor. . . . in radiology they teach us to go through and look like a check-list at all of the different structures. . . .	[I] need to know about the reasons for tooth loss in relation to [her] dental IQ . . . if [we are] investing time and money, [I] need to know how successful I am going to be. . . . if she will have proper oral home care and attempt to do some work at home . . . [I] need to know why she lost teeth . . . maybe she didn't care about them before and now that they are gone, she values them more and wants to take care of them.	[I will] then [do the] extra and intra-oral exam. . . see the denture in the mouth, see if she can still wear it, assess the denture, take records and models, get radiographs from previous dentist, [I] like to start from a baseline. . . .

Appendix 10. Vignettes for EDC study

Vignette 1

A 14-year old patient attends EDC orthodontic clinic. His chief complaint states: “My teeth are not straight”.

Vignette 2

A 17- year old patient attends EDC orthodontic clinic. His chief complaint states: “I don’t like my smile”.

Appendix 11. Letter of initial contact (EDC participants)

Letter of Initial Contact

Study Title: Clinical Reasoning in Orthodontics

Dear [name of the participant],

We are contacting you to ask for your participation in a study of clinical reasoning in orthodontics. We are exploring how orthodontists from different levels of expertise approach orthodontic problems. We have developed several situational vignettes representing some of the common and important problems related to craniofacial growth and malocclusion to explore how orthodontists evaluate the problems and make clinical decisions. We will ask you to participate in a 1-hour interview at your convenience to consider the clinical vignettes, to identify the problems they represent, and to suggest treatment for the problems. We will ask you to "think out loud" as you think about each vignette so that we can follow clearly how you evaluate the situations and solve the problems.

Please be assured that you are completely free to decline this offer or to withdraw from the study at any time without concern or hindrance, and in no way will your participation or refusal to participate influence your standing as a resident or faculty within the Department of Orthodontics at the Eastman Dental Center.

Shiva Khatami will conduct this study as a requirement for her certificate program in orthodontics, so if you are willing to participate or would like more information about the study, please phone or email Shiva at 585-301-5157 or shivak@interchange.ubc.ca

I will be grateful if you will reply within the next week.

Yours sincerely,

Marshall Deeney, DDS

Shiva Khatami, DDS

Appendix 12. Consent form (EDC participants)

CONSENT FORM

Title of Study: Clinical Reasoning in Orthodontics

Principal Investigator: Marshall Deeney, DDS, Department of Orthodontics, Eastman Dental center, 625 Elmwood Avenue, Rochester, NY, 14620.

Graduate Student: Shiva Khatami, DDS, Department of Orthodontics, Eastman Dental center, 625 Elmwood Avenue, Rochester, NY, 14620, 585-301-5157.

Purpose: This study is designed to: 1) describe the process of clinical reasoning in orthodontics; 2) explore the similarities and differences in reasoning of orthodontists across different levels of expertise; and 3) define competency in clinical reasoning in orthodontics to provide guidelines for assessment and curriculum development in graduate orthodontic education.

Selection and Participation: You were selected to participate because you responded to the letter of initial contact about this study. You know that you can decline to participate and withdraw from the study at any time without consequences.

Study procedures: You have been advised that you will be asked to review two clinical vignettes and related diagnostic aids to identify the problems they represent, and to suggest treatment for the problems. You will be asked to “think out loud” as you think about each vignette and your thoughts and comments will be audiotaped during the course of one-hour open-ended interview so that the investigators can analyze them carefully and in detail.

Risks: There is minimal foreseen risk associated with this study.

Confidentiality: Your identity and personal information collected during the study will be strictly confidential and you will be identified only by a code number. All records will be

kept in a locked filling cabinet or stored securely on a computer protected by a password. The code will be held only by Shiva Khatami. She will conduct this study as a requirement for her certificate program in Orthodontics and the information you provide will appear in the content of any publication of this study without revealing your identity.

Contact information: You can contact the investigators at 585-301-5157 if you have questions or desire further information.

Consent: Your participation in this study is entirely voluntary and you may refuse to participate or withdraw from the study at any time without concern or hindrance of any kind.

You have received a copy of this consent for your own records.

Participant Signature:_____ Date: _____/_____/_____

Participant Name (Please print) _____

You agree to have your interview tape recorded

Participant Signature:_____ Date: _____/_____/_____

Participant Name (Please print) _____

Appendix 13. Behavioural Research Ethics Board approval

The University of British Columbia
Office of Research Services
Behavioural Research Ethics Board
Suite 102, 6190 Agronomy Road, Vancouver, B.C. V6T 1Z3

CERTIFICATE OF APPROVAL- MINIMAL RISK RENEWAL

PRINCIPAL INVESTIGATOR:	DEPARTMENT:	UBC BREB NUMBER:
Michael I. MacEntee	UBC/Dentistry/Oral Health Sciences	H06-80058

INSTITUTION(S) WHERE RESEARCH WILL BE CARRIED OUT:

Institution	Site
UBC	Vancouver (excludes UBC Hospital)

Other locations where the research will be conducted:
N/A

CO-INVESTIGATOR(S):
Joanne N. Walton
Daniel Pratt
Joan L. Bottorff
Shiva Khatami
John Collins

SPONSORING AGENCIES:
UBC Hampton Research Endowment Fund - "Searching for Clinical Reasoning in Dentistry"

PROJECT TITLE:
Searching for Clinical Reasoning in Dentistry

EXPIRY DATE OF THIS APPROVAL: January 23, 2009

APPROVAL DATE: January 23, 2008

The Annual Renewal for Study have been reviewed and the procedures were found to be acceptable on ethical grounds for research involving human subjects.

Approval is issued on behalf of the Behavioural Research Ethics Board

University of Rochester Research Subjects Review Board

Letter of Exemption

To: Marshall Deeney

Re: RSRB00026038

Study Title: Clinical Reasoning in Orthodontics

The RSRB has reviewed this study and determined that it meets federal and University criteria for exemption for the following reason:

Study is exempt from federal regulation under the following category (45 CFR 46.101)
Category 2:Survey/interview/observational research

Study is exempt from federal regulation under the following category (45 CFR 46.101)
Category 4:Secondary use of pre-existing data

- Investigators are required to submit any changes (amendments) to a study prior to implementation to ensure that the conditions for exemption continue to be met.
- An exemption means that you do not need to submit for continuing review.
- Exemptions are not allowed in Categories 1-6 if the study involves prisoners.
- By University of Rochester policy, studies involving subjects under the age of 18 years must include parent/guardian permission. Exceptions to this policy are delineated under Consent Issues in Research Involving Minors and may be found on the web at: http://www.urmc.rochester.edu/rsrb/pdf/minor.pdf
- Studies involving surveys or interviews with subjects under the age of 18 years generally are not exempt under Category 2.
- Investigators must protect the rights of subjects enrolled in exempt activities by applying the principles put forth in the education program for human subject protection (EPRP or HSPP).

This research meets HIPAA regulations by:

De-identification

Jeanne Grace, Chair, Research Subjects Review Board Date: 12/12/2008

The Department of Health and Human Services has approved a Federalwide Assurance (FWA) with the University of Rochester (FWA9386), which is in effect through September 27, 2010.