AN INVESTIGATION IN THE PREVALENCE OF CO-AXIAL MISALIGNMENT OF SURGICAL LOUPES AMONGST BC DENTAL PROFESSIONALS

by

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B.Sc, The University of British Columbia, 2008

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A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF

THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE

in

THE FACULTY OF GRADUATE AND POSTDOCTORAL STUDIES

(Craniofacial Science)

THE UNIVERSITY OF BRITISH COLUMBIA

(Vancouver)

April 2016

Abstract

Dental surgical loupes have been increasingly popular among dental professionals over the last decade for their visual and postural benefits. In the province of British Columbia, over 60% of dental clinicians practice with surgical loupes and many dental educational institutions have made surgical loupes mandatory for all pre-clinical and clinical students. However, dental professionals will only receive the full benefits of surgical loupes if the loupes are adjusted to fit the individual needs of each clinician. This study examines the co-axial alignment of surgical loupes, one of the three critical criteria for the proper adjustment of these optical systems. A simple quantitative co-axial alignment measurement tool was first developed and then tested for reliability and repeatability. The researcher then measured co-axial alignment of surgical loupes among 97 practicing dental professionals in British Columbia and 23 UBC Dentistry students who currently practice with surgical loupes. The participants were also asked to complete a survey on clinical practice patterns. The results demonstrated that 1) there is a high prevalence (82.5%) of co-axial misalignment of surgical loupes among dental professionals surveyed; 2) dental professionals wearing Front-lens Mounted surgical loupes with full vertical adjustability (FLM w/FVA), Front-lens Mounted surgical loupes with limited adjustability (FLM w/LVA) and Through-the-Lens (TTL) surgical loupes are equally likely to be out of co-axial alignment; 3) FLM w/ FVA are the only loupes that can be adjusted to achieve full co-axial alignment and 4) dental professionals' perception of their own visual acuity and quality of care are the same for dental professionals using aligned surgical loupes and for those using misaligned surgical loupes. The results from this study establishes a solid foundation for larger-scale studies in the field of surgical magnification and helps the dental communities make informed decisions about their equipment, and will guide surgical loupes manufacturers to develop more evidence-based products.

Preface

This thesis is an original intellectual product of the author W.M.Wen. UBC Behavioural Research Ethics Board approved the study ethics which was covered under Research Ethics Board Number: H14-01945, entitled “Dental Loupes.”

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List of Abbreviations

BC: British Columbia

BCDA: British Columbia Dental Association

BCDHA: British Columbia Dental Hygienists' Association

CDHBC: College of Dental Hygienists of British Columbia

CDSBC: College of Dental Surgeons of British Columbia

DA: Declination Angle

DHDP: Dental Hygiene Degree Program

DMD: Doctor of Dental Medicine

FLM: Front-Lens-Mounted

FVA: Full Vertical Adjustability

JBM: John B. MacDonald building

LVA: Limited Vertical Adjustability

MSD: Musculoskeletal Disorder

OHC: Oral Health Clinic

RDH: Registered Dental Hygienist

SCARL: Statistical Consulting and Research Laboratory

TTL: Through-The-Lens

UBC: University of British Columbia

US: United States

VCC: Vancouver Community College

WD: Working Distance

Acknowledgements

I offer my enduring gratitude to the faculty, staff and my fellow students at UBC, who have inspired me to continue my work in this field. I owe particular thanks to my supervisor Dr. L. M. Rucker, who was not only a teacher but also a good friend. I am also very appreciative of my knowledgeable and open-minded committee members Prof. Z. Kanji and Dr. D. Laronde.

I thank Dr. B. Shariati for answering my endless questions in statistics, UBC SCARL for professional statistical consulting, and Dr. C. Beattie for his expertise in ophthalmology.

Special thanks are owed to my parents, whose knowledge and support have inspired me over the years and will continue to inspire me for the years to come.

Dedication

For my parents Jing Feng Wen and Dong Wu

Chapter 1: Introduction

Surgical telescopes, or "surgical loupes", are magnification devices worn by dental and medical professionals that allow the clinician to observe structures not easily visible to the naked eye.(1,2) Surgical loupes usually consist of frames and carrier lenses similar to that of regular glasses or protective goggles, with binocular magnifying lenses either mounted on the frames or fixed in the carrier lenses (Figure 1.1). Since the 1920s, surgical loupes have been used in a variety of medical procedures, long before they became popular in modern dentistry.(3) Currently, surgical loupes and surgical microscopes are widely used in surgeries involving fine anatomical structures, such as treatment of birth defects in infants, removal of tumours in the nerve, or repairing pancreatic ducts.(4–6) Some advocate that surgical loupes should be made mandatory for all microsurgeries for quality assurance purposes, as the human eye is limited at discriminating delicate but potentially important anatomical structures. (1,7)

Comparing to medicine, surgical loupes' popularity in modern dentistry is more recent but rapidly growing.(8,9) In the past two decades, the use of surgical loupes has been documented in a plethora of dental procedures, such as endodontics, orthodontics, dental hygiene treatments, general restorative dentistry and complex oral surgery.(10–18) Similar to microsurgery, dental procedures also involve a small and delicate part of the human body and success is measured in millimeters. For example, the average adult human mouth can only open to approximately 45-50 millimeters, and the average crown length of an adult maxillary molar is approximately 13 millimeters. (19,20) Therefore, the surgical loupes used in dentistry are typically between 2.5x to 4.5x magnification, as this range of magnification allows enlarged images of tooth structures without significantly limiting field of vision of the dental professional.(8,21) It is important to note that using magnification in dentistry is not "the higher the better", as there is a lack of evidence supporting implementing higher magnification for dental procedures.(8,14) Only a small number of publications by a single author suggested using higher magnification (6.0x to 8.0x) surgical loupes for scaling, root planing, prophylaxis, crown/post and partial fixed dental prosthesis. The author suggests that higher magnifications will help dental professionals better

visualize the tooth structures and surfaces.(15–18,22,23) However, these articles were based only on clinical observations and lacked any large-scale studies to support their claims.

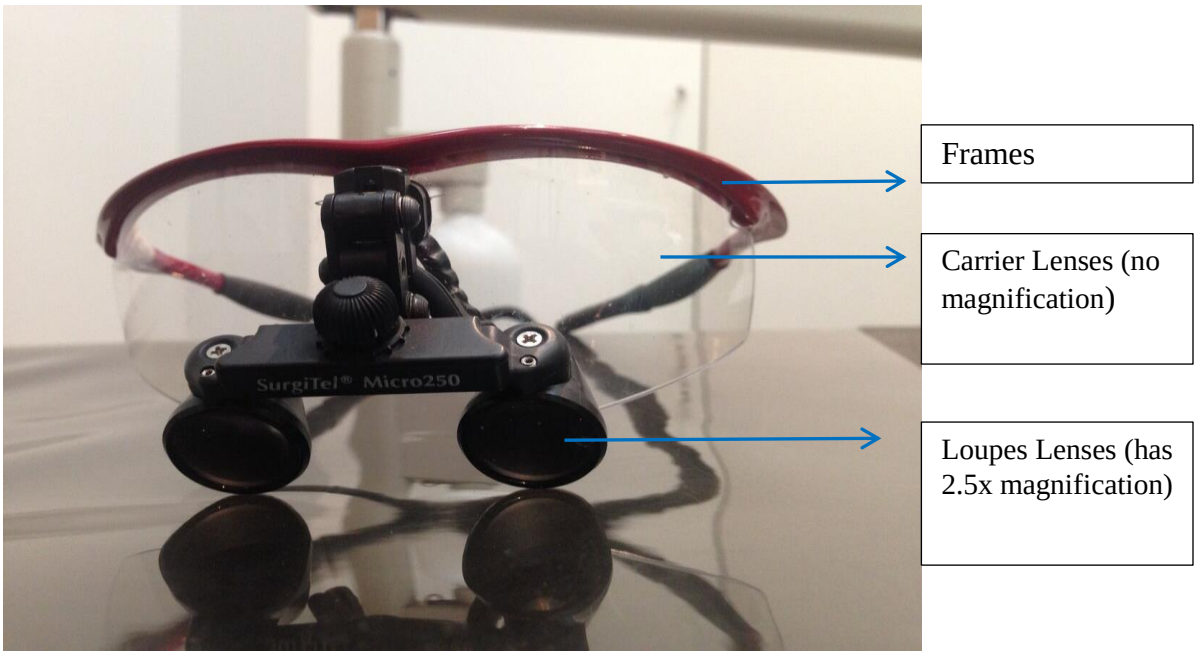


Figure 1.1 A pair of surgical loupes commonly used in dental practices.

The image shows surgical loupes at 2.5x magnification. The surgical loupes are of the mounted design where the loupes lenses are mounted onto the carrier lenses. The image was taken by the researcher.

Globally, there has been growing popularity for surgical loupes among both practicing professionals and students. In the province of British Columbia, over 60% of dental professionals practice with surgical loupes, while dental educational institutions such as the University of British Columbia (UBC) and Vancouver Community College (VCC) have made surgical loupes mandatory for all pre-clinical and clinical dental and dental hygiene students.(24) Surgical loupes are also highly recommended for dental hygiene students at Camosun College, Vancouver Island University, and Vancouver College of Dental hygiene. Similar trends are observed in the U.S. where two thirds of dental hygiene students reported instruction on surgical loupes as a regular curriculum component, although not all institutions that inform students about surgical loupes have required students to purchase them.(25) Among practicing dental professionals in the U.S, a survey study of 868 practicing dental hygienists shows that approximately 60% of the participants used surgical loupes.(26) Surgical loupes have also gained popularity in Europe, where 64% of Swiss dentists reported using surgical loupes and 83.6% of dental students in the

UK identified interest in purchasing surgical loupes.(27,28) Sales representative from surgical loupes manufacturers can now be seen at dental conventions and trade shows around the world, where a pair of surgical loupes can be purchased for between $250 and $2500 Canadian dollars.(29,30) However, the use of surgical loupes in dentistry remains well documented but thinly researched(31); there is an overall paucity of research about surgical loupes in dentistry.

1.1 Benefits of Using Surgical Loupes

As previously mentioned, despite the growing market demand of using surgical loupes in dentistry, the existing body of research evidence on the benefits of surgical loupes has been rather thin with mixed results.(9) The majority of current research on the benefits of surgical loupes focuses on two aspects: 1) establishing balanced posture for dental professionals to prevent musculoskeletal disorders; and 2) enhancing the quality of care. Both aspects will be thoroughly explored in the following sections.

1.1.1 Musculoskeletal Disorders and Surgical Loupes

Current research demonstrates that dental professionals are at high risk of developing musculoskeletal disorders (MSD's).(32–34) MSD's describe a number of injuries affecting different parts of the body, such as muscles, joints, nerves and tendons.(35) Some of these injuries develops over time and can impair daily functions, as well as causing long-term pain and disability.(36) Globally, it is reported that 64 - 93% of dental professionals experience MSD's at some stage of their career; and up to 78% of dental professionals reported experiencing musculoskeletal pain and discomfort over a period of 12 months.(33,37,38) Both dentists and dental hygienists are at risk of developing MSD's, and symptoms of MSD's can surface very early in one's career.(32) For instance, a survey study conducted among 216 dental hygiene programs in the United States revealed that more than half of the participating programs had students who experience MSD's while in school.(39)

For dental professionals, some of the most affected parts of the body include lower back, neck, shoulders, hands, wrists, and lower extremities.(33,34) Lower back pain appears to be the most reported MSD among all dental professionals.(32,33)A study among dental professionals in

Queensland, Australia reported that 53% of participants suffered from lower back pain.(40) Similar observations were made in a U.S study among 5000 dental professionals, where over 60% of dentists and dental hygienists reported incidences of lower back pain.(41) Neck and shoulder pain and discomfort have also been shown to be very prevalent, with approximately 29% - 63% of dental professionals reporting neck pain, shoulder pain, or both.(41,42) A Swedish study even found that as high as 81% of dental professionals experienced pain in the neck and shoulder region.(43) The increase prevalence of MSD's in the upper body could be due to the recent shift from "stand-up" dentistry to "sit-down" dentistry.(34) One Polish study found that 47.8% of dental professional experienced leg pain when they perform dental procedures standing up, while similar studies conducted in the U.S revealed that only 6.3% - 8.3% of dentists and dental hygienists in the U.S experienced similar issues when dentistry is mostly performed in the sitting position.(41,44)

Comparably, MSD's in the hands and wrists appear to be particularly prevalent and severe among dental hygienists. In a survey study among 95 U.S dental hygienists, 93% of participants reported pain and limited functionality in either their wrists or hands.(45) Similarly, Akesson et al. found that 64% of dental hygienists experienced hand and wrist pain over 5 years, a prevalence much higher than that of dentists or dental assistants.(38) Such symptoms not only appear in practicing hygienists, but also in dental hygiene students.(46,47)

Many factors contribute to MSD's in dental professionals. Unbalanced posture at work has been identified as a major contributor to MSD's, along with repetitive motions, prolonged static positions and increased use of vibratory instruments.(43,48–50)Working in unbalanced postures over an extended period of time can impose tension on the muscles much higher than that of daily activities. Such "muscle overload" prevents blood circulation and causes increased pressure on the surrounding body structures, resulting in pain, discomfort and limited functionality in the affected individuals. (51,52)

Rucker *et al.* identified a number of postural challenges faced by dental professionals, including twisted torsos, raised elbows and tipped shoulders during patient care.(48) Similarly, a U.S.

study focusing specifically on neck, shoulder and lower back pain found that over a period of 4 hours, both dentists and dental hygienists in this study twisted their torsos at least 30 degrees more than 50% of the time. Moreover, their necks were bent at least 30 degrees 85% of the time, and their shoulders were raised and rotated at least 30 degrees more than 50% of the time.(53) Dental specialists appear to experience postural challenges as well. A study on the posture and muscle activities of endodontists revealed that a number of muscles in the neck, shoulder and wrists of the clinicians were under elevated stress during patient care.(54) Similar observations were also reported for orthodontists and pediatric dentists.(55,56) Due to the smaller sizes of their patients, pediatric dentists face additional postural challenges such as lack of leg space under the patient chair, creating more stress on their lower backs and legs.(56)

Working in unbalanced postures not only creates physical pain and loss of function but also causes significant social, psychological, and economic stress for dental professionals. A Greek study among 430 dentists found that 16% of the dentists surveyed suffered from loss of work due to pain and discomfort; and 32% sought medical treatment to relieve work related MSD's.(57) Since dental professionals in many parts of the world are compensated on a fee-for-service basis instead of a fixed salary, this loss of work might have significant impact on their income and financial status.(58) The medical treatments may be out-of-pocket expenses for some dental professionals as well, creating even more financial and economic instability. (59)

People who suffer from chronic pain and loss of function tend to experience more mental stress as well. Costello *et al.* identified that chronic pain can lead to higher risks of depression and anxiety.(60) A dental professional who suffer from MSD's may also experience stress and anxiety because they are unable to meet work demands and feel that they have little control over the work they can and cannot perform due to pain.(61) In a series of studies conducted among Swedish dental professionals, it was found that the relationship among poor posture, pain and mental stress can be inter-related. In other words, a dental professional who works in unbalanced postures is subject to more pain, and more pain in turn leads to more stress and loss of work. The increased stress levels may cause more musculoskeletal pain in the dental professional, who may choose to work even in more compromised postures as a result. Such negative feedback cycles

may have significant long term impact on the quality of life and overall wellbeing of dental professionals. (42,61,62)

The use of surgical loupes has been suggested as an intervention strategy to improve the posture of dental clinicians, thus decreasing work-related musculoskeletal disorders, pains, and stress. (24,63) However, over the past decade, only a limited number of studies have been conducted to specifically investigate the effect of surgical loupes on clinician posture and work-related MSDs. In a case-study, Branson *et al.* described the experience of one dental hygiene student integrating surgical loupes into practice.(9) Using self-reflective journals and instructor's observations, the same student's posture was recorded and assessed for one week without surgical loupes and then for three weeks with surgical loupes. Both the student's self-assessment and the instructor report demonstrated improvements in the student's posture when using surgical loupes. Similarly, a study involving 19 dental hygiene students demonstrated positive changes in the students' posture when working with surgical loupes compared to the control group without surgical loupes.(31) However, both studies were based on rather small sample sizes; thus, the findings may not be generalizable.

Comparably, a study at Dalhousie University on 35 dental hygiene students observed similar trends. Each student was assessed while hand-scaling with and without surgical loupes.(64) The students were assessed at different time points for a variety of postural components, including posture of the head and neck, shoulders and arms. The result showed significant improvement in posture when using surgical loupes ($p<0.001$). This study also suggested that these improvements were significantly more pronounced for students who started using surgical loupes immediately after entering the program compared to those who integrated surgical loupes into their care at a later date ($p<0.1$), when poor postural habits may have already developed prior to introduction of surgical loupes.

A larger-scale survey study on 421 dentists and 170 dental hygienists was conducted in British Columbia.(49) This survey study asked a variety of questions on practice ergonomics and management issues, as well as control of work environment, lifestyle and symptoms of

musculoskeletal disorders. This study found that a strong negative correlation exists between surgical loupes use and lower back problems, one of the most prevalent MSD's for dental professionals.(33) This negative correlation was found for both dentists ($P = 0.034$) and dental hygienists ($P < 0.001$), suggesting that surgical magnification is an effective intervention strategy of musculoskeletal disorders for dental professionals of various clinical responsibilities. This study is also one of the foundational research evidences that supported the mandatory or highly recommended use of surgical loupes in all dental and dental hygiene programs in British Columbia.(24)

Not all studies found surgical loupes improved posture. Hayes *et al.* found that the effect of using surgical loupes on musculoskeletal disorders to be rather mixed.(52) This Australian study compared upper-body musculoskeletal function of 12 practicing dental hygienists with 17 final-year dental hygiene students. The practicing dental hygienists were given surgical loupes and the students were not. Both self-assessed and objective measurements of musculoskeletal functions were recorded at baseline and then at 6 months after surgical loupes were introduced. The study demonstrated no significant differences between the two groups with regards to objective measurements on musculoskeletal functions, and results on self-assessed musculoskeletal functions were mixed. However, some of the mixed results could be due the study design. This study compared dental hygiene students with practicing dental hygienist, where differences in age, gender and work experience between these two samples were not accounted for. The study also had a limited sample size which may affect the statistical power of its results.

Although overall evidences on the effect of surgical loupes on clinician posture and work-related MSDs have been positive, studies investigating surgical loupes and postural interventions are generally limited by their study design. As describe above, existing studies on the relationship between surgical loupes and clinician posture often involve small sample sizes and frequently are restricted to educational settings with only student subjects. There is a paucity of research in this area with larger sample sizes, more longitudinal studies, and standardized research techniques.(32)

1.1.2 Quality of Care and Surgical Loupes

Similar to studies on postural benefits of surgical loupes, research on quality of care with surgical loupes faces similar challenges: the studies were predominantly conducted with small sample sizes, among students in simulated clinic environments or *in vitro* with extract teeth. Current studies on effects of surgical loupes on quality of care have focused on visual acuity, diagnostic abilities and treatment outcomes.

1.1.2.1 Visual Acuity

It has been identified that dental clinician's visual acuity is enhanced with surgical loupes. Perrin *et al.* and Eichenberger *et al.* compared visual acuity of dentists with and without surgical loupes in simulated clinical settings.(65,66) Despite the variation in age and natural vision, visual acuity was significantly improved with surgical loupes for dentists of all ages. Perrin *et al.* also identified that with surgical loupes, dental professionals could identify structures as small as 0.05mm at the root surface, a significant improvement over natural, unaided human vision.(66)

Similar trends were observed in the U.S among dental hygiene students. In a study with 19 dental hygiene students, Branson *et al*. reported that 95% of the students experienced improvement in visual acuity with surgical loupes.(31) Moreover, a pilot study with 14 U.S dental hygiene students focused specifically on indirect vision with surgical loupes. The participants were asked to identify marked dots on a phantom head using indirect vision, and the number of correctly identified dots and the time it took to identify the dots were recorded. 72% of the students self-assessed that that they experienced enhanced visual acuity using surgical loupes.(67) However, both studies were limited by its small sample size and low statistical power; their findings may not be generalizable to bigger populations of all dental professionals.

Eichenberger *et al*. further examined the relationship between self-assessed visual acuity and objective measurements on visual acuity with a slightly bigger sample size. In this study, 69 Swiss dentists were asked to complete a self-assessment questionnaire on visual acuity using surgical loupes, followed by an objective measurement on visual performance.(28) Although surgical loupes improved visual acuity for all dentists, the correlation between the self-assessed

and the objective visual acuity of the dentists was weak, indicating that dental professionals may not always be aware of their own visual performance and limitations.(28)

Not all dental professionals found the enhanced visual acuity of surgical loupes helpful. It has been documented that many dental professionals experience an "adjustment period" when they first started using surgical loupes.(26,68,69) In a small study involving 12 dental hygienists, 75% of the participants experienced nausea, headaches and vertigo with surgical loupes.(68) Similarly, a bigger study involving 116 dental students showed that 20% of the students had difficulty adapting to surgical loupes after the first year.(69) In a large survey study among 868 dental hygienists, up to 50% of surgical loupes users identified that the adjustment period is the biggest disadvantage of using surgical loupes; and 20% of the participants who used surgical loupes experienced headaches and general discomfort with surgical loupes.(26)

1.1.2.2 Diagnostic Abilities

Surgical loupes have also been reported to have positive effects on the diagnostic abilities of dental professionals; although the majority of current research is limited to root canals therapy in endodontics. There has also been limited evidence of using surgical loupes to aid caries detection and removal.

Surgical loupes have been demonstrated to enhance diagnostic abilities in endodontic treatments. Hasan *et al.* demonstrated that when wearing surgical loupes, the second mesiobuccal canal (MB2 canal) of maxillary first molars was identified 50.9% of the time, a success rate much higher than with the naked eye at 32.5%.(12) A larger scale American study examined 312 cases of root canal therapy on maxillary first and second molars. Participants who used surgical loupes located the MB2 canal 55.3% of the time, a success rate significantly higher than those using no magnification at 18.2% of the time ($P < 0.01$).(70) This study also showed that there was no significant difference between using surgical loupes and using surgical microscopes in successfully locating the MB2 canal, suggesting that surgical loupes might be just as effective at locating the MB2 canal in root canal therapy as surgical microscopes.

However, not all studies found surgical loupes were able to enhance diagnostic abilities in root canal therapy. Smadi *et al.* attempted to locate the MB2 canal in 100 extracted maxillary first molars with natural vision and then with surgical loupes, the findings were rather inconclusive. (10) The number of canals was first located visually and then confirmed using staining with a coloured dye. The study revealed that although using surgical loupes helped the examiner achieve a higher rate of success in identifying the canals, the results were not statistically significant across all cases of root canal therapy.(10) One reason for this non-significant result could be because this study was conducted *in vitro* using extracted teeth. In other words, the teeth used in this study may not be able to fully simulate the teeth of healthy adult populations. In fact, approximately 16% of the teeth used in this study were extracted due to trauma or poor restorative work, making it difficult to identify the MB2 canals.

Comparably, the studies on using surgical loupes to aid detection and removal of dental caries have been rather mixed. Whitehead and Wilson asked dentists to identify caries and the need of restoration on 100 extracted teeth, and then the same process was repeated with the aid of surgical loupes.(71) Both the identification of caries and the decision to restore those teeth were greatly improved using surgical loupes.(71) However, other studies have demonstrated different results. A study asking 10 experienced dental school faculty to identify marginal discrepancy of restorations found no significant differences with and without surgical loupes. This lack of statistical significance could be due to the limited sample size of the study.(72) A similar study asking 2 examiners to identify incipient occlusal caries on 60 extracted teeth and determine the need for restoration also demonstrated inconclusive results with and without surgical loupes, indicating that further studies in this field are needed. (73)

1.1.2.3 Outcomes of Treatment

Current reports on using surgical loupes to improve outcomes of dental and dental hygiene treatments have generally been very positive, with similar trends being observed across different dental procedures.

Dental hygienists wearing surgical loupes have reported improved outcomes of treatment for periodontal therapy, such as scaling and root planing. Hayes *et al.* identified that dental hygiene students were more confident in calculus removal when wearing surgical loupes to enhance their vision.(68) Similarly, Branson *et al*. compared the clinical performance of 19 dental hygiene students with and without surgical loupes, and found that students with surgical loupes scored significantly higher. (31) Another larger-scale study used scanning electron microscopy to evaluate the outcomes of scaling and root planing and found positive changes with surgical loupes.(74) Ninety human teeth scheduled for extraction were scaled and root planed prior to extraction; and the teeth were then prepared to be viewed under an electron microscope. The electron microscope images (3200x magnification) showed that teeth scaled/root planed with surgical loupes contained significantly less debris on the root surfaces than the teeth scaled/root planed without surgical loupes ($P<0.001$).(74)

For both dental students and practicing dentists, surgical loupes were reported to improve outcomes of treatment and student performance. A study at the University of Pennsylvania provided 116 dental students with surgical loupes and compared their clinical performances with students from the previous year without surgical loupes. The study concluded that the group with surgical loupes completed more clinical tasks, worked faster per procedure and required less assistance, therefore achieving greater overall performance than the group without surgical loupes.(69) However, this study did compare student performances from two different years, thus not considering intrinsic variations between different years of students. In other words, the student group with surgical loupes could have just been a stronger cohort of students even if they were not using surgical loupes. To address this limitation, Narula *et al.* asked 40 dental students from the *same* year to prepare two mandibular molars in the same phantom head for composite restoration. The molar preparation with surgical loupes was performed first, followed by the preparation without surgical loupes. The study demonstrated that tooth preparation was better with surgical loupes despite the students having less practice with this preparation.(75) In non-educational settings, a study by Frankenberger *et al.* found that when performing occlusal-distal restorations, using surgical loupes was beneficial for reducing marginal overhangs up to

40%.(76). Similarly, Forgie *et al*. evaluated cases of replacing old restorations and found that preparations made with surgical loupes required removal of less tooth structure. (77)

There has been limited evidence on treatment outcomes among dental specialists wearing surgical loupes, but existing research appears positive.(70) In a 4-year retrospective study with endodontists, it was reported that the outcomes of root canal therapy was improved when surgical loupes were used. (78) For orthodontics, a study examined 22 orthodontics patients to evaluate adhesive removal with and without the use of surgical loupes.(13) The study made models of the patients' teeth after brackets were removed and examined the models under electron microscope. Electron microscopic images (50× magnification) of 394 models of buccal enamel surfaces were evaluated and the results showed less enamel damage and fewer adhesive residues when surgical loupes were used during removal of orthodontic brackets.(13)

1.2 Selection of Surgical Loupes

Rucker and Sunell suggested that for dental clinicians to fully receive the postural and visual benefits of surgical loupes, the surgical loupes need to be adjusted to fit the specific and individual needs of each clinician.(79) Specifically, three critical criteria must be met to ensure the safe and effective use of surgical loupes: working distance, declination angle, and co-axial alignment.(79–81)

1) Appropriate Working Distance (WD). Working distance is the distance between the eyes of the clinician and the mouth of the patient when the clinician sits down comfortably to work. The working distance of a pair of surgical loupes should match the anatomical and optimal working distance requirements for the individual clinician. If the surgical loupes' working distance do not match that of the clinician, the clinician might need to bend excessively forwards or backwards for their surgical loupes to stay in focus, thus compromising the posture of the clinician (Figure 1.2 a and 1.2 b).

a) b)

Figure 1.2 Working distance of a dental clinician.

Panel a (left) shows a dental clinician whose surgical loupes have the appropriate working distance for the clinician. Panel b (right) shows a dental clinician whose surgical loupes have a working distance too short for the clinician, causing the clinician to bend forward. Both images were taken by the researcher and permission to use has been granted by the subjects.

2) Appropriate Declination Angle (DA). Declination angle is the angle to which the dental clinicians can comfortably lower their eyes when working on a patient (Figure 1.3). The surgical loupes a clinician chooses need to carefully match the declination angle of the clinician. (79) Figure 1.4a shows a dental clinician wearing surgical loupes that match his declination angle, and Figure 1.4b shows a dental clinician whose declination angle is steeper than what his surgical loupes could provide. Wearing surgical loupes with improper declination angles may cause the clinician to bend his neck unnecessarily to look through the magnifying lenses of the surgical loupes, resulting in neck pain, eye strain, muscle fatigue and other postural challenges.(79)

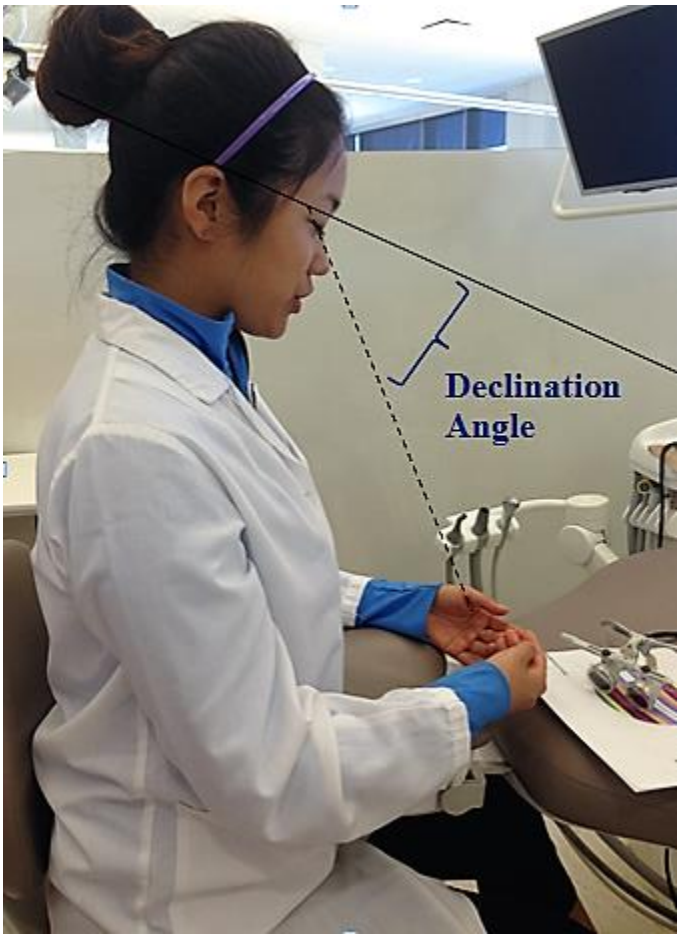
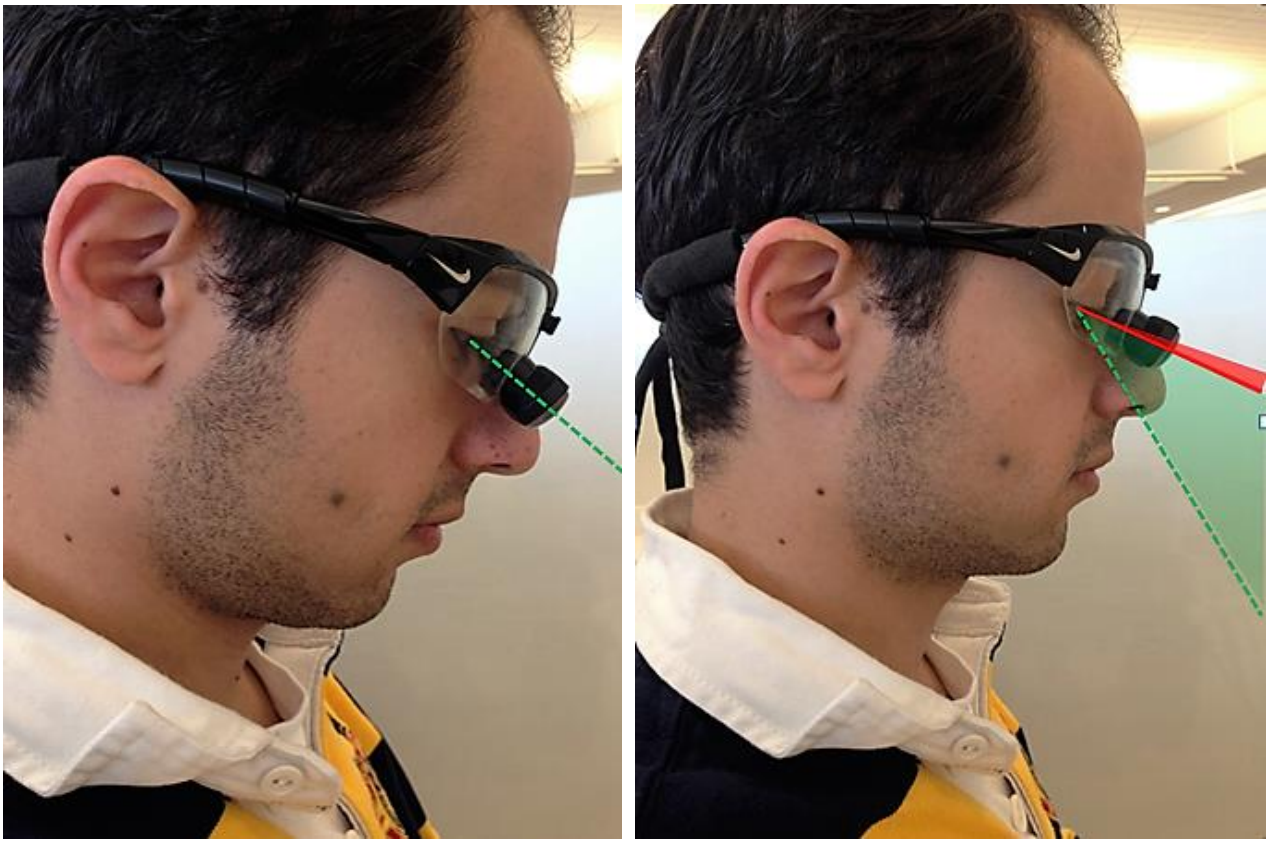


Figure 1.3 Declination angle of a dental clinician.

The image was taken by the researcher and permission of use has been granted by the subject.



a) b)

Figure 1.4 Appropriate and inappropriate declinations angles.

Panel a (left) shows a dental clinician whose surgical loupes have the appropriate declination angle for the clinician. Panel b (right) shows a dental clinician whose declination angle (as denoted by the green zone) is much steeper than what the surgical loupes can provide (as denoted by the red zone). This clinician would have to bend his neck excessively in order to look through the magnifying lenses of his surgical loupes. Both images were taken by the researcher and permission to use has been granted by the subject.

3) Correct Co-axial Alignment. Co-axial alignment refers to the vertical alignment between the magnification lenses of the surgical loupes and the eye line of the clinician. In other words, when a clinician looks through the magnification lenses of the surgical loupes, the magnified image through the surgical loupes should be in alignment with actual object being looked at (Figure 1.5). Co-axial alignment of surgical loupes can be detected by placing a straight instrument (*e.g.* a pencil or a scaler) into the clinician's magnified field of view (Figure 1.6).

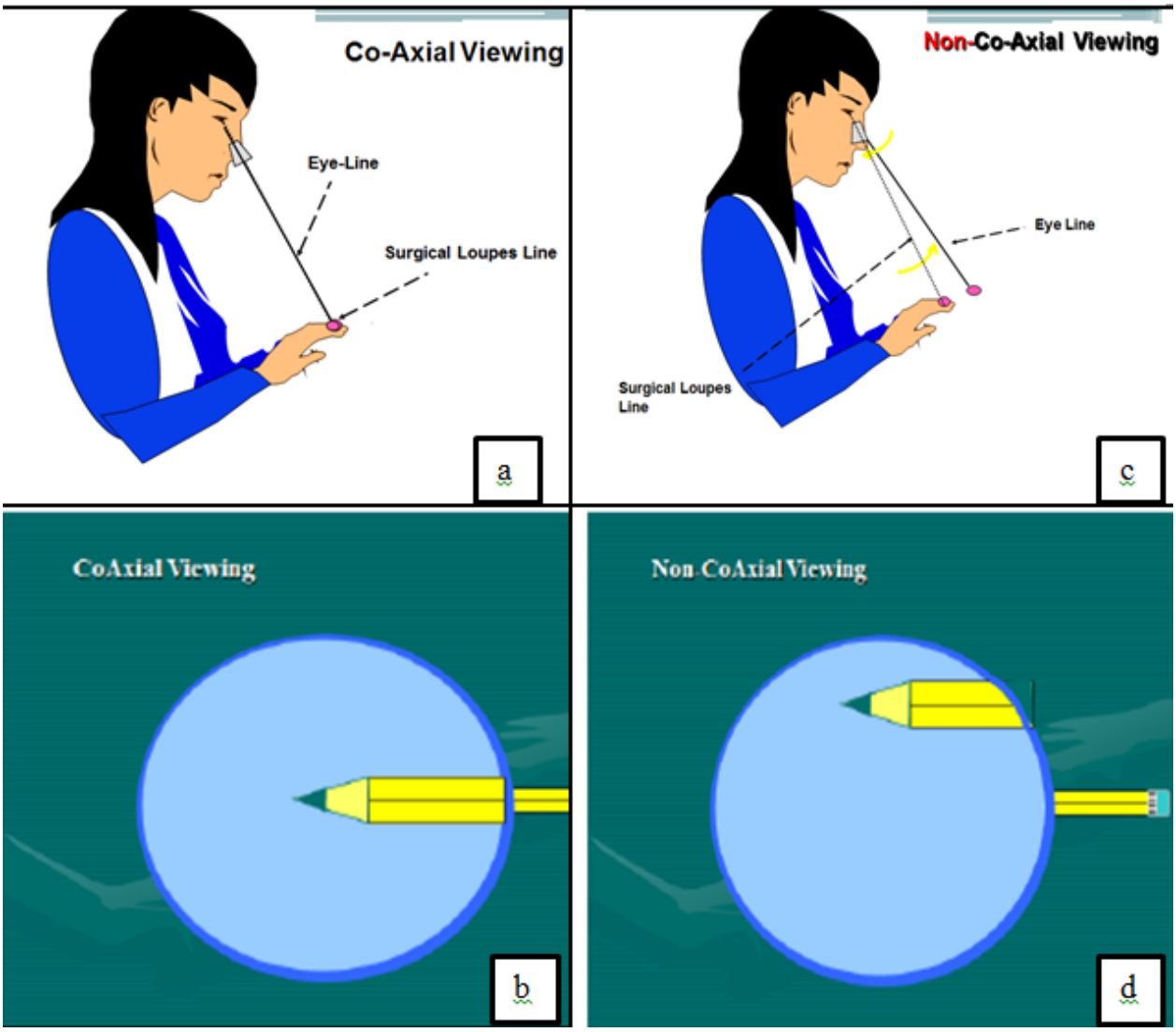


Figure 1.5 Co-axial vs. Non-co-axial viewing

Panel a and b show the clinician's view when the surgical loupes are in co-axial alignment with the eye line of the clinician. Panel c and d show the clinician's view when the surgical loupes are in co-axial misalignment with the eye line of the clinician. Permission to use this image has been granted.

When a dental clinician looks at a straight instrument (i.e. a pencil) through surgical loupes that are in co-axial alignment with the eye line (Figure 1.5a), the magnified image of the pencil is in alignment with the unmagnified pencil itself (Figure 1.5b). However, when a dental clinician looks at the pencil through surgical loupes that are not aligned co-axial to the eye line (Figure 1.5c), the magnified image of the pencil is not aligned to the unmagnified pencil itself, creating a

discrepancy between the magnified image through the surgical loupes and the actual object being looked at (Figure 1.5d).

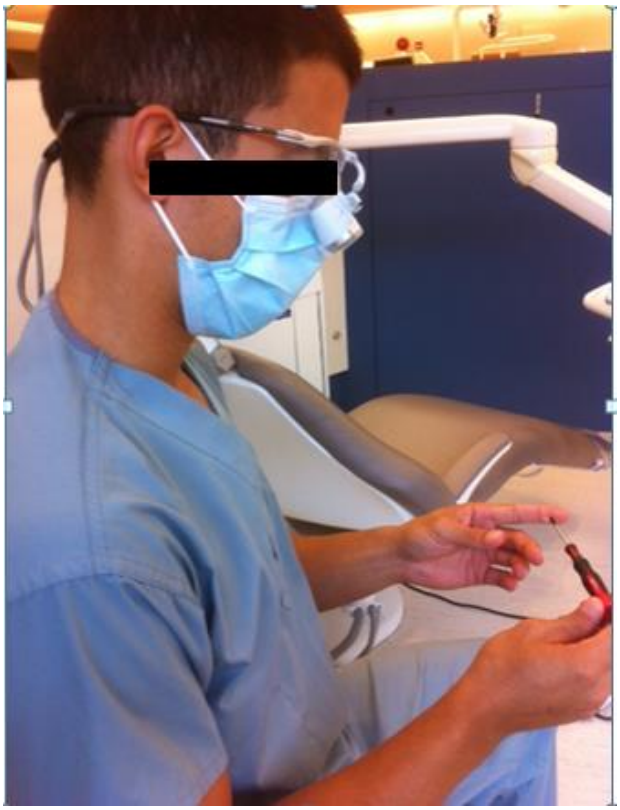


Figure 1.6 A dental clinician assessing the co-axial alignment of surgical loupes.

The image above shows a dental clinician assessing the co-axial alignment of surgical loupes by placing a straight instrument into his magnified field of view. The image was taken by the researcher and permission to use has been granted by the subject.

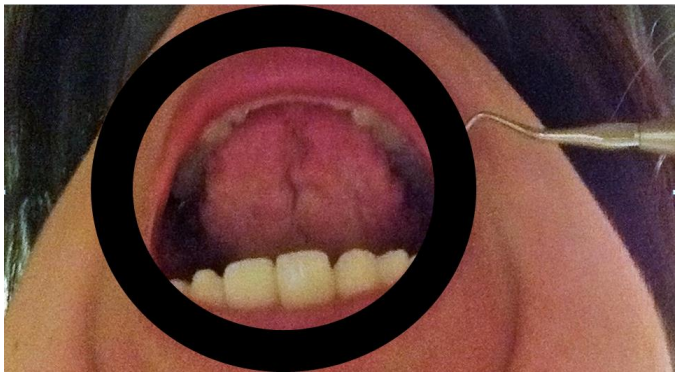
Previous work by Rucker and Sunell suggest that not all surgical loupes on the market satisfy the three criteria for optimal postural and visual support of dental clinicians.(80) The first criterion, working distance (WD), can be achieved by careful selection on the part of the clinician at the time of purchase. The second criterion, declination angle (DA), can also be measured and calculated at the selection stage, as well as by careful adjustment after the clinician receives his surgical loupes. (79,81,82) However, significant challenges continue to exist for achieving and maintaining the third criterion, correct co-axial alignment, which will be explained in detail the following section.

1.3 Practicing with Co-axially Misaligned Surgical Loupes

1.3.1 Visual Discrepancy

The most pronounced effect of wearing co-axially misaligned surgical loupes is the visual discrepancy created by the misalignment. When a dental clinician brings an instrument into his magnified field, he will first encounter a scotoma zone, or a "visual blind zone", before the instrument becomes visible in the magnified field of view.(24) In other words, the dental clinician will not be able to see the tip of his instrument immediately before and after the instrument enters his magnified field. Figure 1.7a shows a periodontal scaler before it enters the visual scotoma zone (the black circle). Figure 1.7b shows the sharp tip of the periodontal scaler disappearing into scotoma zone. Figure 1.7c shows the sharp tip of the periodontal scaler reappearing in the clinician's magnified field. If the surgical loupes are co-axially aligned, the magnified image of the periodontal scaler will be in a straight line with the unmagnified image of the scaler (Figure 1.7c).

a)



b)

c)

Figure 1.7 The scotoma a dental clinician experiences while bringing a periodontal scaler into the magnified field of surgical loupes.

Panel a. (top) shows a periodontal scaler before it enters the visual scotoma zone. Panel b. (middle) shows the sharp tip of the periodontal scaler disappearing into scotoma zone. Panel c. (bottom) shows the sharp tip of the periodontal scaler reappearing in the clinician's magnified field of view. All images were taken by the researcher and the subject of the images is the researcher so no additional permission is needed.

However, if the surgical loupes are co-axially misaligned, instruments that are carried or passed into the magnified field of operation may arrive at an unexpected position, either too high (Figure 1.8a) or too low (Figure 1.8b).

a)

b)

Figure 1.8 The discrepancy between the magnified view and the unmagnified view when a dental clinician wears co-axially misaligned surgical loupes.

Panel a. (top) shows the magnified image of a periodontal scaler higher than the actual object due to co-axial misalignment of surgical loupes. Panel b. (bottom) shows the magnified image of a periodontal scaler lower than the actual object due to co-axial misalignment of surgical loupes. All images were taken by the researcher and the subject of the images is the researcher so no additional permission is needed.

1.3.2 Chromatic Aberrations

In addition to the previously mentioned concerns, clinicians wearing misaligned surgical loupes might experience chromatic aberrations of the magnified image. Chromatic aberrations occur when the magnifying lenses are either unable to bring all colours to the same focal plane, and/or when different colours are focused at different positions in the focal plane.(83) As a result, the dental clinician might experience bright sparks of different colours in his magnified view (Figure 1.9).

a) b)

Figure 1.9 Chromatic aberrations.

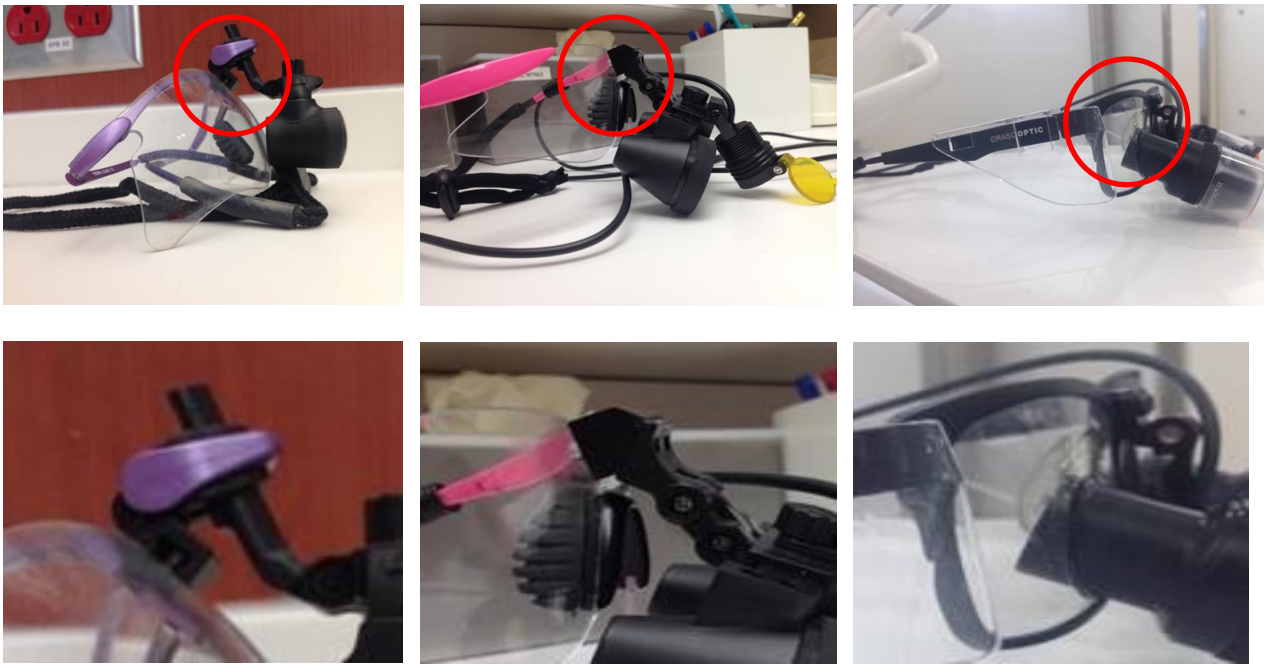
Panel a. (left) shows a magnified image of lower anterior teeth without chromatic aberrations. Panel b. (right) shows a magnified image of lower anterior teeth with chromatic aberrations. Both images were taken by the researcher and permission of use has been granted by the subject.

Working with such visual discrepancies and colour aberrations might impose a variety of risks and challenges to the dental clinician. In an attempt to compensate for the misalignment, the affected clinician will purposefully "aim high" or "aim low" as the instrument enters the magnified field. Alternatively, the clinician might tilt and crane his head and neck excessively in order to "find" the magnified view prior to commencing operation with the instrument. Since the human oral cavity is only 45-55mm in size, such attempts to compensate for visual discrepancies greatly increase the potential for losing control of the instruments near and inside the patient's

mouth, resulting in patient injuries. The constant tilting and craning of the head and neck might also expose the clinician to higher risks of musculoskeletal stress and pain.(82) Lastly, the colour aberrations might further compromise the clinician's visual acuity and clinical decision making, as well as cause nausea and eye strain to the clinician. (82)

1.4 Current Surgical Loupes in Use

The two major groups of surgical loupes currently in use are Front-Lens-Mounted (FLM) and Through-The-Lens (TTL). FLM surgical loupes are further divided into FLM with Full Vertical Adjustability (FLM with FVA) systems and FLM with Limited Vertical Adjustability (FLM with LVA) systems. As illustrated in Figure 1.10, FLM with FVA surgical loupes have a centre slide that allows full vertical movement of the mounted magnifying lenses. FLM with LVA surgical loupes rely on bending the hinges between the magnifying lenses and the frames for vertical adjustability, but this design does not allow the full range of vertical movement as experienced with FLM with FVA surgical loupes. Lastly, TTL surgical loupes have the magnifying lenses fused directly into the lenses of the frames, allowing no vertical adjustability besides slight bending of the frames and nosepieces.



a) FLM w/ FVA b) FLM w/ LVA c) TTL

Figure 1.10 The three systems of surgical loupes.

Panel a. (left) shows Front-Lens-Mounted surgical loupes with Full Vertical Adjustability (FLM with FVA). Panel b. (centre) shows Front-Lens Mounted surgical loupes with Limited Vertical Adjustability (FLM with LVA) and panel c. (right) shows Through-the-Lens (TTL) surgical loupes. All images were taken by the researcher.

Most surgical loupes manufacturers produce both FLM and TTL systems and offer various levels of magnification. However, not all manufactures produce FLM systems with full vertical adjustability. The FLM surgical loupes with FVA are very adjustable for declination angle and co-axial alignment. FLM with LVA surgical loupes can have some adjustability for declination angle but does not allow full vertical adjustability to meet the needs for co-axial alignment. Comparably, TTL systems only allow very slight vertical adjustability through manipulation of the frames and nose pieces. In other words, if a pair of TTL loupes does not meet the clinician's needs for declination angle or co-axial alignment, the clinician won't be able to fully adjust the surgical loupes himself. However, TTL systems are more popular among dental professionals for their lighter weight and "custom made" appeal.(82)

The aforementioned studies performed by Rucker and Sunell addressed the concerns regarding working distance and declination angle of surgical loupes.(79,81,84) However, current research on the co-axial misalignment of surgical loupes remains very minimal. The challenge, especially for the TTL loupes, is that coaxial alignment is not measurable directly from the surgical loupe device independent of the designated clinician. The alignment is entirely related to the physical spatial relationship of the loupes lenses to the clinician; hence, issues of facial structure, inter-pupillary distance and clinician declination angle preference can mean that a single pair of surgical loupes could be set in fine coaxial alignment for one clinician but would be out of alignment at the same setting for another clinician. The crucial determination of correct co-axial alignment can only be made by the clinician himself for any given pair of surgical loupes.

1.5 Research Rationale

Currently to the best of the researcher's knowledge, there is an absence of research regarding the prevalence of co-axial misalignment of surgical loupes among dental professionals. Unlike the two other critical criteria, working distance and declination angle, there has been no established method to reliably measure co-axial alignment quantitatively. Consequently, there is little understanding of the prevalence or severity of co-axial misalignment among dental professionals, the factors associated with co-axial misalignment, as well as clinical and ergonomic implications of practicing with co-axially misaligned surgical loupes. For instance, there has been no research to determine if clinicians with different types of surgical loupes (ie. FLM or TTL) are equally likely to experience co-axial misalignment. There also has not been any research on whether co-axial misalignment affects a clinician's perception of visual acuity and quality of care with surgical loupes. In other words, do dental clinicians with co-axially aligned and misaligned surgical loupes both feel that they can see well with surgical loupes and provide good quality of care with surgical loupes, or there will be a difference in their responses? This study aims to address some of these gaps in current research and understanding among dental professionals in British Columbia.

1.6 Research Question

What is the prevalence of practicing with co-axially misaligned surgical loupes amongst B.C dental professionals?

The specific aims include:

1. To develop a simple, quantitative tool to measure co-axial alignment of surgical loupes;
2. To determine if dental clinicians with FLM surgical loupes vs. clinicians with TTL surgical loupes are equally likely to be out of alignment;
3. To determine if practicing with co-axially misaligned surgical loupes affects the clinicians' perception of visual acuity and quality of care using surgical loupes.

Chapter 2: Materials and Methods

2.1 Development of the Co-axial alignment Measurement Tool

2.1.1 Early Designs

Prior to this investigation, co-axial alignment of surgical loupes had been estimated by placing a straight instrument into the clinician's magnified field of view, then asking the clinician whether the magnified image of the instrument is "in a straight line" with the unmagnified image of the instrument (Figure 1.5 & 1.6).(81) However, this method does not allow the dental clinician to tell how much "out of alignment" the surgical loupes are, and the results could easily be affected by variations in shape, length or width of the "straight instrument" of choice. Based on these observations, an early version of the co-axial alignment measurement tool was drafted by the researcher (Figure 2.1).

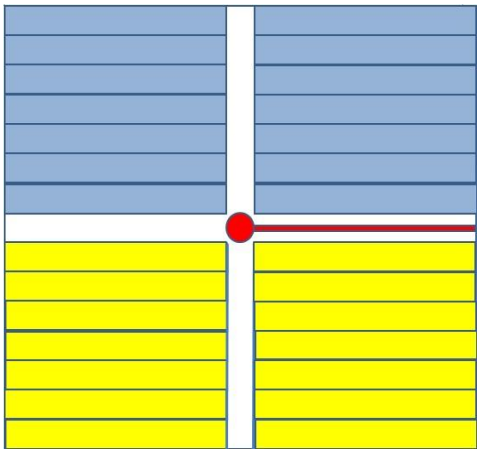


Figure 2.1 Early version of the co-axial alignment measurement tool.

This image represents an early version of the co-axial alignment measurement tool as drafted by the researcher. The red dot and red line were to mimic a straight instrument and the blue and yellow-coloured grids were to guide a clinician to place the red line in the centre of his magnified view while wearing surgical loupes.

As shown in Figure 2.1, the early version of the co-axial alignment tool demonstrated the following features: 1) a red dot at the centre of the measurement tool and a straight red line extending from the centre to mimic a "straight instrument"; 2) the red line was of set length and width to avoid any variations and 3) blue and yellow-coloured grids above and below the red line

to help the dental clinician place the red dot in the centre of his magnified field of view. In other words, a dental clinician would know the red dot was at the centre of his magnified field view if he saw equal numbers of blue and yellow grids above and below the red line. However, this initial design presented a number of shortfalls. Firstly, it might be difficult for a dental clinician to count the coloured grids while also looking at the red line. Secondly, the appropriate dimensions of the co-axial alignment measurement tool were unknown. In other words, the scale of the measurement tool had to be determined, it had to be clearly visible under 2.5x -3.5x magnification, and the dimensions of the coloured grids were needed to make this tool quantitative.

2.1.2 Determination of Appropriate Dimensions

To determine the appropriate dimensions for the co-axial alignment measurement tool, 11 pairs of surgical loupes were obtained from 5 major manufacturers: Heine, Designs for Vision Inc., Orascoptic™, Surgitel® and Q-optics. The surgical loupes were between 2.5x – 3.0x magnification and included all 3 systems: front-lens-mounted (FLM) with full vertical adjustability, front-lens-mounted (FLM) without vertical adjustability, and through-the-lens (TTL).

As explained in section 1.4.1, when a dental clinician brings an instrument into his magnified field, the clinician will first encounter a scotoma zone, or a "visual blind zone", before the instrument becomes visible in the magnified field (where the image of the instrument becomes magnified). Therefore, every pair of surgical loupes was examined to determine the dimension of the scotoma zone and the dimension of the magnified field. On History® grid paper, the researcher marked the borders of the magnified field and the scotoma zone for each pair of surgical loupes using a red pen (an example is shown in Figure 2.2). Out of the 4 TTL systems, 2 pairs were excluded from the study as they were too misaligned for the researcher to see a clear image through the magnifying lenses. All surgical loupes at 2.5x - 2.75x magnification scored approximately 7 grids (from the centre) for the radius of the magnified field and approximately 12 grids (from the centre) for the border of the scotoma zone. The 3.0x surgical loupes had a slightly smaller magnified field, scoring 5-6 grids for the radius of magnified field, but the

border of the scotoma zone remained at 12 grids. Each grid was 6.5mm in length on the History® grid paper.

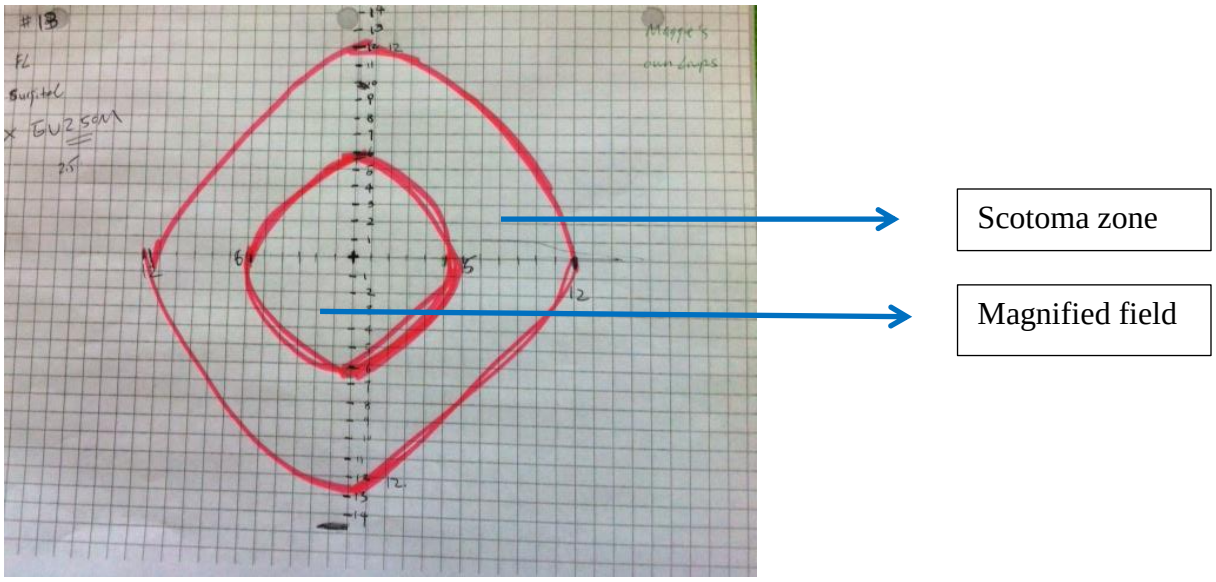


Figure 2.2 Scotoma zone and magnified field of a pair of surgical loupes.

The image shows History® grid paper with the scotoma zone (visual blind zone) and the magnified field marked by the researcher when wearing a pair of 3.0x surgical loupes.

2.1.3 Final Design of the Co-axial Alignment Measurement Tool

Based on observations above, the co-axial alignment measurement tool was redesigned to a customized shaped grid as shown in Figure 2.3. Grid-based tools are commonly used in ophthalmology; for instance, tools such as the Amsler grid are used to assess and detect visual disturbances (*e.g.* image distortions, dark spots) caused by changes in the retina.(85)

As shown in Figure 2.3, the new design on History® grid paper included 9 grids above and below the red line to ensure its appropriate dimensions for different levels of magnification. The mirroring colour bands were incorporated to help the clinician centre the red line, and the colour bands were arranged that clinicians who suffer from colour-blindness will still be able to distinguish the colour bands.

Two columns of units were added to the right hand side, and sufficient distance was kept between the column and the colour bands to ensure that the columns will not fall into the magnification scotoma (blind zone) of the surgical loupes. The two columns of units were "upside down" from each other to address the issue of left and right dominant eye: some clinicians will need to rotate the paper 180^{o} and have the columns on their left hand side instead of right hand side.(86) Each unit remained at 6.5 mm (the width of the grid on commercially available grid paper).

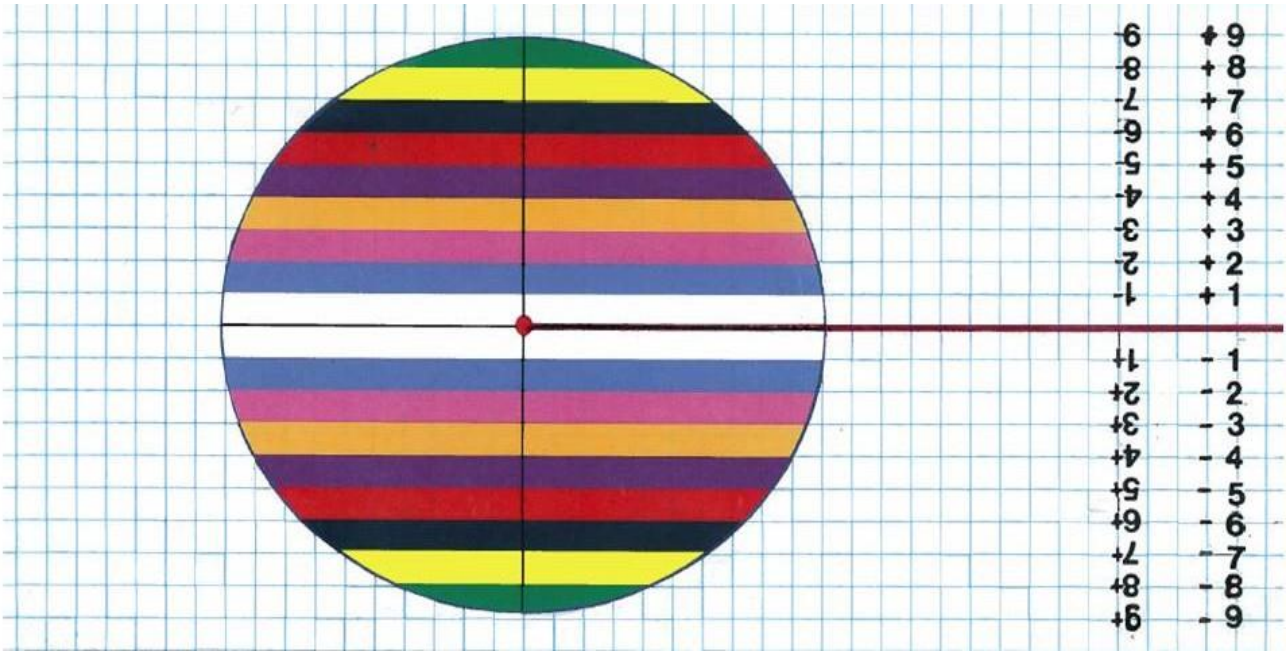


Figure 2.3 The co-axial alignment measurement tool for surgical loupes.

2.2 How to Use the Co-axial Alignment Measurement Tool

To measure the co-axial alignment of a given pair of surgical loupes, a participating dental clinician is asked to perform the following steps:

1) Don the surgical loupes;
2) Look at the Co-axial Alignment Measurement Tool through the surgical loupes, and align the view so that the red dot is positioned/located at the centre of the magnified field of view;
3) Use the colour bands to ensure the red dot is truly vertically centred (ie. the clinician needs to see the same colour band on the top and bottom borders of the magnified view);
4) Check whether the long red line extending from the red dot is "broken" or "continuously aligned" between the magnified view and the unmagnified view;
5) If the red line appears straight, the surgical loupes are co-axially aligned for the individual clinician; if the red line is broken, the surgical loupes are co-axially misaligned (Figure 2.4). The units on the right indicate units of misalignment. The clinician is asked to identify the number of units (to the nearest 0.5 unit) of misalignment for their surgical loupes. In the case shown in Figure 2.4b, the clinician's surgical loupes have a misalignment of +2.5 units.

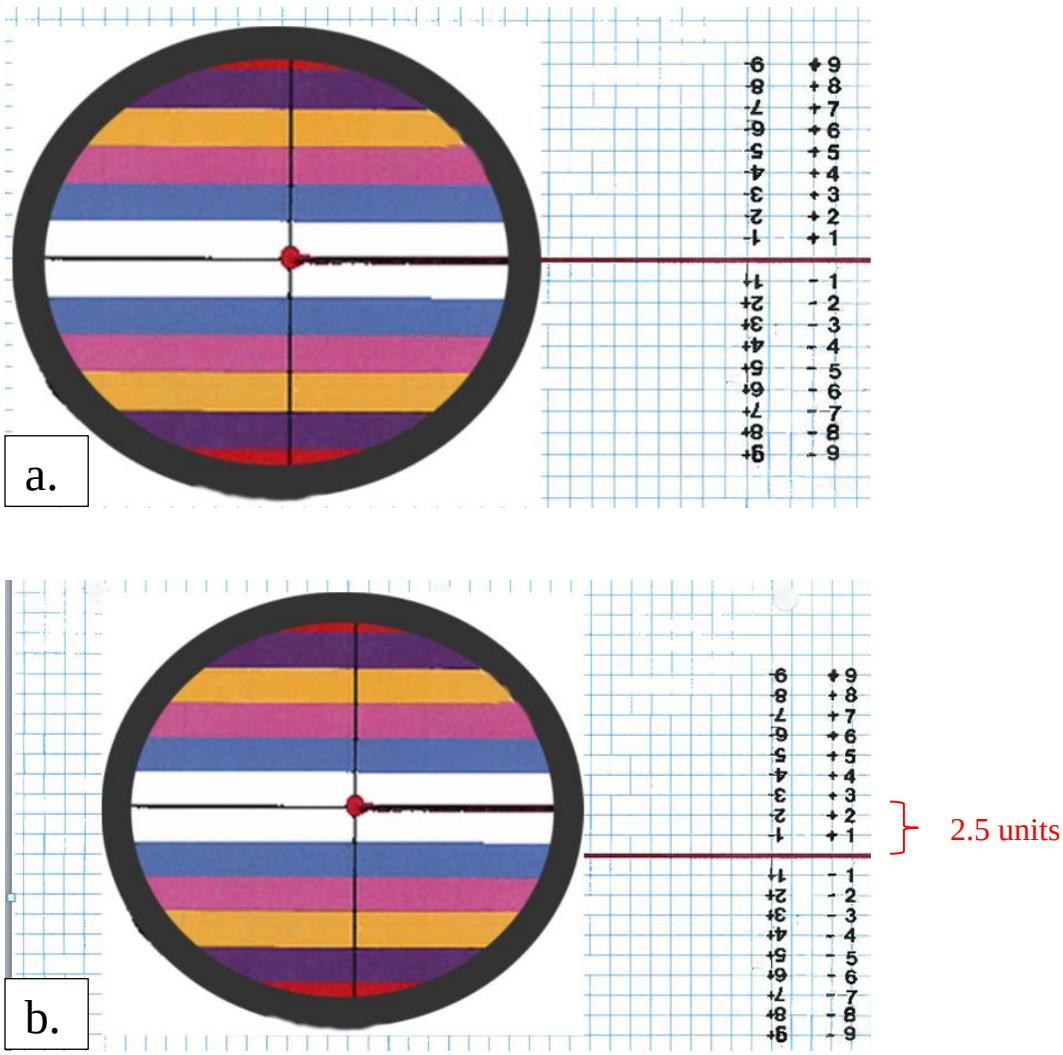


Figure 2.4 Co-axial aligned and misaligned view on the measurement tool.

Panel a (top) shows co-axially aligned view. Panel b (bottom) shows co-axially misaligned view of 2.5 units using the measurement tool.

2.3 Reliability Testing of the Co-axial Alignment Measurement Tool

To test the reliability of the co-axial alignment measurement tool and to validate the clinical practice pattern survey questionnaire (Appendix A), two rounds of pilot studies were conducted.

2.3.1 Pilot Study #1:

The purpose of pilot study #1 was to check 1) if the co-axial alignment measurement tool can produce consistent measurements on the *same* pair of surgical loupes on two *separate* measurements on the *same* day with the *same* clinician; and 2) if the clinical practice pattern questionnaire is being read the same way as the researchers intended.

Eleven third-year DMD student volunteers (2 males and 9 females) from UBC Faculty of Dentistry were recruited through posters in the JBM and OHC buildings and via e-mail broadcasts sent from student program assistants. All participants were instructed to: 1) measure the co-axial alignment of their own surgical loupes using the co-axial alignment measurement tool; 2) complete the written clinical practice pattern questionnaire and 3) repeat the co-axial alignment measurements after they completed the written survey.

2.3.2 Pilot Study #2:

The purpose of pilot study #2 was to check if the co-axial alignment measurement tool can repeatedly produce consistent measurements on the *same* pair of surgical loupes on *different* days with the *same* clinician.

Six Faculty volunteers (2 males, 4 females) from UBC Faculty of Dentistry were recruited via e-mail. All participants were instructed to: 1) measure the co-axial alignment of 5 different pairs of fixed position surgical loupes (with no built-in prescription) using the co-axial alignment measurement tool; and 2) repeat the co-axial alignment measurements on 4 different, non-consecutive days.

2.4 The Main Study

The main study examined two separate populations: practicing dental professionals in British Columbia and students at the University of British Columbia. The details on recruitment, sampling, the study process, ethical considerations and statistical analysis are discussed in the following sections.

2.4.1 Recruitment

2.4.1.1 Practicing Dental Professionals in British Columbia

Participants were recruited through information posters at UBC Faculty of Dentistry, e-mail messages to all part-time clinical instructors at UBC Dentistry, and e-mail messages to all members of BCDA and BCDHA. The information posters were posted in UBC Faculty of Dentistry between November 2014 and May 2015 by the researcher. The e-mail recruitment messages were sent by third-party administrative staff at UBC dentistry, BCDA and BCDHA in November and December 2015. None of the third-party administrative staff were involved in the research. Snowball sampling was also employed as participants were encouraged to circulate the recruitment e-mail among their own professional circles. Snowball samples are efficient, easily accessible and cost effective, all of which are suitable for the purpose of this study.(87) The interested persons contacted the researcher directly to arrange 15-minute appointments. The researcher then travelled to a location of the participant's choice (either at the UBC OHC clinic or the private practice of the participant) to meet the participant and conduct the study.

The inclusion criteria were the participating clinician must be: 1) a dental professional (general dentist, dental specialist or dental hygienist); 2) practicing in the BC Lower Mainland; and 3) currently working clinically with surgical loupes. All participants were fully informed and consented to participate on a signed form in accordance with the guidelines of the UBC Behavioural Research Ethics Board.

2.4.1.2 Students at the University of British Columbia

A convenience sample of UBC DMD/DHDP students were recruited through e-mails sent to them via their program assistants, and the interested students contacted the researcher directly. The researcher met the students at an operatory of their choice within UBC OHC to conduct the 15-minute study.

The inclusion criteria were the participating student must be 1) A third or fourth-year DMD/DHDP student at UBC; and 2) currently working with surgical loupes. The exclusion criterion was "any current student of the researcher" to avoid any issues of coercion during recruitment. All participants were fully informed, and gave consent on a signed consent form for their participation in accordance with the guidelines of the UBC Behavioural Research Ethics Board.

2.4.2 Sampling

2.4.2.1 Practicing Dental Professionals in British Columbia

A total of 101 dental professionals answered the recruitment messages. Of 101 dental professionals, 2 were excluded because they did not yet own surgical loupes, and 2 participants never arranged to meet the researcher due to time constraints.

Therefore, a total of 97 practicing dental professionals in the BC lower mainland were surveyed using the co-axial alignment measurement tool and the clinical practice pattern survey. This sample size was calculated based on proportion estimates by UBC SCARL (Statistical Consulting and Research Laboratory) using a sample size calculator (http://homepage.stat.uiowa.edu/~rlenth/Power/) and the following facts: **1)** there are approximately 3000 dentists (including dental specialists) and 3000 hygienists registered with CDSBC and CDHBC, thus the total number is approximately 6000 within the province(88,89); **2)** previous research showed 60% of dental professionals practice with surgical loupes in BC(49); therefore, approximately 3600 dentists and hygienists practice with surgical loupes in BC; **3)** since the

prevalence of co-axial misalignment was unknown, an estimated proportion of 50% was used to obtain the most conservative sample size, Confidence Interval (C.I.) was 95% .

Of 97 practicing dental professionals, 53 were dentists and 44 were hygienists.

2.4.2.2 Students at the University of British Columbia

A total of 25 UBC DMD/DHDP students answered the recruitment message, and 23 students were surveyed using the co-axial alignment measurement tool and the clinical practice pattern survey. Two students were excluded as they never arranged to meet the researcher after initial contact due to time constraints. Of 23 students, 12 were DMD students and 11 were DHDP students.

2.4.3 The Survey Study

During the survey study, all participants (both practicing professionals and students) were asked to 1) measure co-axial alignment of their surgical loupes using steps outlined in "2.2 – how to" of this chapter, and complete a 4-page questionnaire on their clinical practice patterns (Appendix A). This survey took approximately 10-15 minutes for each participant to complete.

For participants with misaligned surgical loupes, the researcher had offered to adjust their surgical loupes and determine if the surgical loupes could be aligned co-axially to the clinician after the adjustment. This service was offered to all participants with misaligned surgical loupes, including those with TTL models (by manipulating the frames and nosepieces). Only participants who consented for the adjustment had their surgical loupes adjusted and the adjustment only took place after the survey was completed and all data recorded. Both the number of participants who accepted the offer and how many surgical loupes were successfully adjusted to achieve full co-axial alignment were recorded and reported in the Results sections.

2.4.4 Ethical Considerations

Ethical approval for the conduct of this study was obtained through the Behavioural Research Ethics Board at the University of British Columbia. Participants were provided with a letter of

introduction which included information on the participant selection criteria, data collection methods, expected time commitment to the study, confidentiality considerations, and a request to participate (Appendix B). Once participants agreed to be included in the study, they were provided with an informed consent form (Appendix C). This consent form was sent to the potential participant at least one week prior to the survey to ensure sufficient time was given to the participant to review the form, to ask questions if needed, and to decide whether or not to participate. To ensure that this consent form had been read and understood by the participant, it was reviewed and signed in person immediately prior to the start of the survey. The researcher avoided using coercive or persuasive language in both the introductory letter and the consent form. If the participant was a current faculty member at the Faculty of Dentistry at the University of British Columbia, choosing or refusing to participate in this study would not affect his/her employment status. The recruitment messages were distributed by administrative staff not involved in the research at UBC Dentistry, BCDA or BCDHA.

Strategies were implemented to ensure anonymity. The participants of this study were informed that the study was completely voluntary and they were free to withdraw from the study at any time. They had the right to refuse to answer any questions, to request to stop the survey at any time and to withdraw any information they do not wish to be included in this study. Should they withdraw, the information they had provided up to the point of withdrawal will not be used in the data analysis, unless they consent to have it included.

This survey did not record any information that may lead to the identification of the individual participant (e.g. ethnicity, license/student number, name of practice). Each completed survey was assigned a case number with all personal identifiers removed. All data were stored in a password-protected computer. Upon completion of the study, the data gathered were turned over to the principal investigator where they will be stored for the required minimum of five years at a UBC locked facility. After this five year period, the data will be shredded to ensure that confidentiality will not be breached.

The participants were informed that information shared in this study was to be used in the graduate student's thesis and, thus might also be published in journal articles, seminars and conferences. All information generated in this study would remain anonymous to all outside of the research team.

2.4.5 Statistical Analysis:

The data collected were entered into Microsoft ® Excel 2010. The data were interpreted using the IBM® Statistical Package for Social Sciences (SPSS) software (version 20) and Epi Info ™ 7. The statistical analysis was performed in consultation with Dr. B. Shariati and the UBC Statistics Department and its Statistics Consulting and Research Library (SCARL). For the pilot studies, an intra-class correlation analysis was conducted to determine consistency among measurements on the same pair of surgical loupes on multiple days with the same clinician. For the main study, categorical data such as: gender, profession, manufacturer, model of surgical loupes, perception (visual acuity, quality of care) and frequency of surgical loupes use were analyzed using the Fisher's exact test. Fisher's exact test was chosen over the Pearson Chi Square test due to the small sample size. For continuous data such as clinician's age and number of years in practice, the Wilcoxon-Mann-Whitney test was used. All the tests were two-sided and the results are considered statistically significant $P < 0.05$. Additionally, post-hoc statistical power was calculated using OpenEpi, which is open source software found on: www.openepi.com. The assumption used for post-hoc power calculation was with the alpha set to 0.05 and power was considered sufficient if it were to reach 80% or greater. Overall, the power for this study was deemed to be low throughout.

Chapter 3: Results

3.1 Reliability of the Co-axial Alignment Measurement Tool

Pilot Study #1

The goal of pilot study #1 was to determine if the co-axial alignment measurement tool was able to produce consistent measurements on the *same* pair of surgical loupes on two *separate* measurements on the *same* day with the *same* clinician. As shown in Table 3.1, all eleven UBC DMD student volunteers were able to report the same units of misalignment over 2 separate measurements on the same pair of surgical loupes. 1 unit = 6.5mm. The two measurements were taken 20 minutes apart. All eleven participants reported that they were able to distinguish the colour bands from each other, indicating that the width of the colour band (6.5mm) was sufficient.

Participant #	Units of Misalignment (1st Measurement)	Units of Misalignment (2nd Measurement)
1	-1.5	-1.5
2	-4.5	-4.5
3	1.5	1.5
4	1.0	1.0
5	-4.0	-4.0
6	-4.0	-4.0
7	-3.0	-3.0
6	-3.0	-3.0
9	1.0	1.0
10	-1.0	-1.0
11	1.0	1.0

Table 3.1 Pilot study #1.
The same participant is able to report the same units of misalignment the same day over 2 measurements.

Pilot Study #2

The purpose of pilot study #2 was to check if the co-axial alignment measurement tool can repeatedly produce consistent measurements on the *same* pair of surgical loupes on *different* days with the *same* clinician. As highlighted in Table 3.2, the co-axial alignment measurement tool can reliably produce measurements within 0.5 units of each other on the same pair of "fixed-position" surgical loupes over 4 different, no-consecutive days. This observation was repeatable for all 6 UBC Dentistry Faculty volunteers using 5 pairs of "fixed position" surgical loupes (except for one occurrence where a pair of surgical loupes was accidentally dropped to the floor, inadvertently changing the position and alignment of the loupes for that one measurement). The intra-class correlation analysis showed an intra-class correlation coefficient of 0.997, indicating high consistency among all the measurements.(90)

Therefore, in all subsequent chapters, "co-axial alignment" for surgical loupes was defined as any surgical loupes that measured equal to or less than **± 0.5** units from the centre red line of the measurement tool". "Co-axial misalignment" was hence defined as surgical loupes that measured greater than **±0.5 units** from the centre red line.

Loupes #	Participant 1 Daily measurements				Participant 2 Daily measurements				Participant 3 Daily measurements				Participant 4 Daily measurements				Participant 5 Daily measurements				Participant 6 Daily measurements			
1	-9.5	-9.0	-10.0	-9.5	-5.0	-4.5	-4.5	-5.0	0.0	0.0	0.5	0.0	5.0	5.0	5.0	5.0	-4.5	-5.0	-5.0	-5.0	2.5	2.5	2.0	2.0
2	-6.0	-5.5	-5.0	-5.0	-2.0	-2.0	-2.0	-2.0	-0.5	-1.0	-1.0	-1.0	2.0	2.0	2.0	2.0	-8.0	-9.0	-8.5	-8.0	-3.0	-3.0	-3.0	-3.0
3	-6.5	-7.0	-7.0	-6.0	1.0	1.5	1.0	1.0	-0.5	-1.0	-0.5	-0.5	2.0	2.0	1.5	2.0	-0.5	-1.0	-1.0	-1.0	3.0	3.0	3.0	3.0
4	-5.5	-5.5	-6.0	-6.5	-1.5[1]	0.5	1.0	0.5	2.0	2.0	1.5	2.0	1.5	1.0	1.5	1.0	-7.5	-7.0	-6.5	-7.5	-0.5	-0.5	-1.0	-0.5
5	-6.5	-7.0	-7.0	-7.0	-2.0	-2.0	-2.5	-2.0	-1.0	-1.0	-1.0	-1.0	0.0	0.0	0.0	0.5	-8.0	-8.0	-8.5	-9.0	-2.0	-2.0	-2.5	-2.0

Table 3.2 Pilot study #2.

The co-axial alignment measurement tool can reliably produce a measurement within 0.5 units on the same 5 pair of surgical loupes over 4 different days with 6 participants.

[1] For participant #2, the researcher had accidentally dropped loupes #4 to the floor after the initial measurement, resulting in a 2.0-unit difference between the initial measurement and all subsequent measurements. However, all 3 subsequent measurements fell within 0.5 units of each other.

It is important to note that since co-axial alignment is unique to each individual, two *different* participants will be unlikely to get the *same* measurement on the *same* pair of surgical loupes. The two pilot studies also revealed that working distance appears to play a role in co-axial alignment measurements. While co-axially aligned surgical loupes will remain aligned throughout the working distance of the clinician, co-axially misaligned surgical loupes could have some variation in units of misalignment throughout the clinician's working distance. This observation does not mean that a given clinician's surgical loupes will change between "misaligned" and "aligned" by simply changing the working distance. A pair of surgical loupes in misalignment will remain in misalignment throughout the working distance of the clinician, but the units of misalignment will slightly vary depending the distance at which the clinician was measured. Therefore, to ensure that this study captures the "true" units of misalignment for dental clinicians at work, all participants in this survey study were measured at their own, self-derived working distance (working distance that they actually work at when treating patients). The working distance at which each participant was measured was recorded as well.

3.2 The Study among Practicing Dental Professionals

3.2.1 Prevalence of Misalignment among Practicing Dental Professionals

Figure 3.1 shows that from the 97 participants surveyed, only 17 (17.5%) were practicing with co-axially aligned surgical loupes. 82 (82.5%) were practicing with co-axially misaligned surgical loupes. Therefore, the prevalence of co-axial misalignment of surgical loupes among all BC dental professionals can be estimated to be between 75% - 90% (the 95% confidence interval was calculated to be 7.5% at the sample size of 97 participants, thus 82.5% ±7.5% is 75% - 90%)

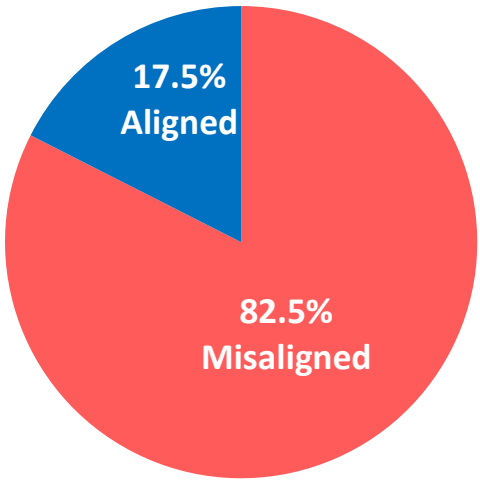


Figure 3.1 Prevalence of co-axially misaligned surgical loupes among 97 practicing dental professionals in BC.

Figure 3.2 below shows how the units of misalignment are distributed among 97 participants. Two units of misalignment appear to be the most common with 17 participants, followed by 1 units of misalignment and 3 units of misalignment (both at16 participants). On the other extreme, 3 participants practiced with surgical loupes that were 9 units or over out of alignment.

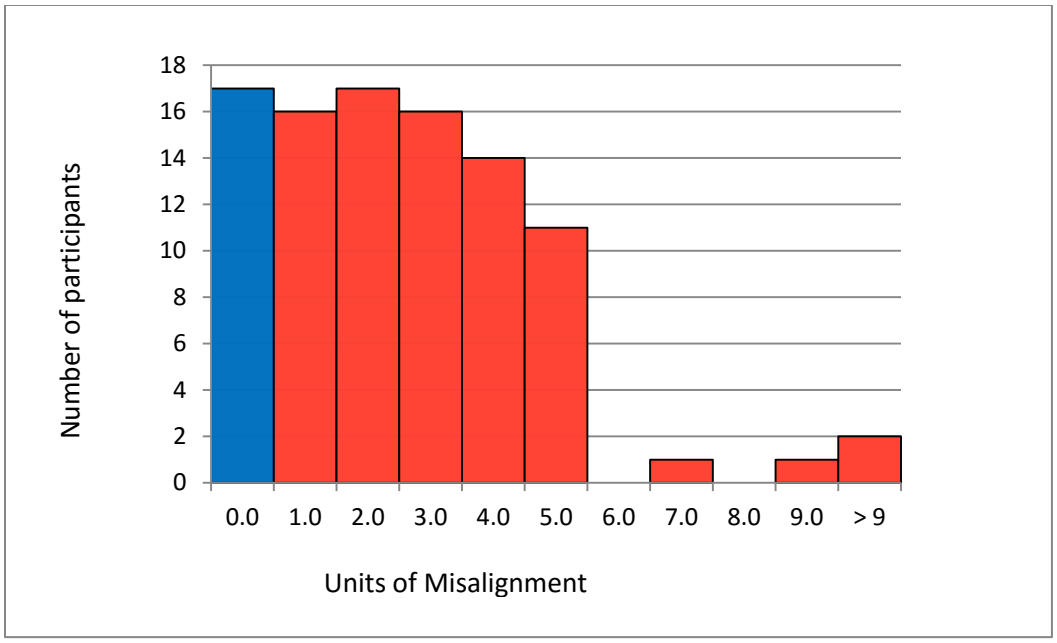


Figure 3.2 Distribution of co-axial misalignment among 97 practicing dental professionals in B.C.
Blue = aligned; Red = misaligned

Given that each unit = 6.5mm, Figure 3.3 illustrates what each unit of misalignment appears to be in relation to the human oral cavity and common dental instruments. The average adult human oral cavity can open to approximately 45-50mm length, or 7-8 units on the co-axial alignment measurement tool. The working end length of a periodontal probe is just under 4 units, as is a Cavitron ultrasonic scaler tip. The portion of the Cavitron tip that actually contacts the tooth surfaces during calculus removal is even smaller, at approximately 1 unit in length.
In other words, the severity of misalignment that many of the participants were experiencing would correspond to the entire working length of a sharp dental instrument, and in some cases, this visual discrepancy will be equivalent to a patient's entire oral opening.

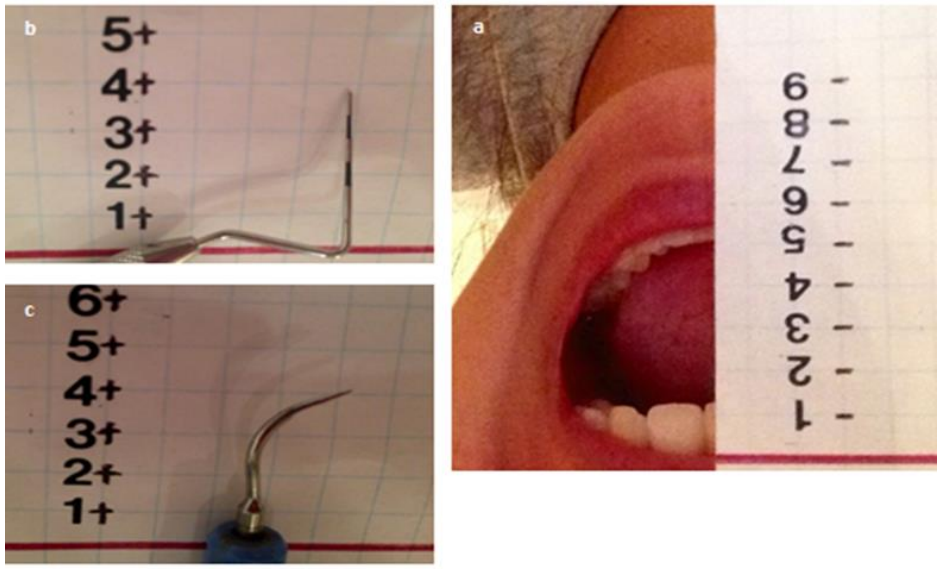


Figure 3.3 The length of each co-axial misalignment unit in relation to the human oral cavity and common dental instruments.

Panel a (right) shows an adult human oral cavity next to the co-axial alignment measurement tool. Panel b (top left) shows a periodontal probe and Panel c (bottom left) shows a Cavitron ultrasonic scaler tip next to the co-axial alignment measurement tool.

3.2.2 Demographic Variables of Practicing Dental Professionals

Table 3.3 shows the demographic variables of all 97 participants. Overall, 34 (35%) participants were male and 63 (65%) were female. The mean and median age was 43 years old (S.D = 13 years). 53 (55%) participants were dentists and 44 (45%) were dental hygienists. The mean years in practice was 17 years (S.D = 13 years). From the 97 participants, 45 (46%) were faculty members of a dental educational institution.

As summarized in table 3.3, male and female dental professionals are equally likely to practice with co-axially misaligned surgical loupes (P = 0.781). There are no significant differences between dentists and dental hygienists (P = 0.792) or between faculty and non-faculty members of dental educational institutions (P = 0.937). Further, clinician's age and number of years in practice are not good predictors of the co-axial alignment of their surgical loupes (P = 0.227 and P = 0.500 respectively).

	All	Aligned (%)	Misaligned (%)	*P* value
Total	97 (100%)	17 (18%)	80 (82%)	
Gender				
Male (%)	34 (35%)	5 (15%)	29 (85%)	0.781
Female (%)	63 (65%)	12 (19%)	51 (81%)	
Age in Years (Mean + S.D)	43±13	46±11	43±14	0.227*
Years in Practice (Mean + S.D)	17±13	19±12	16±13	0.500*
Role in Dental Practice				
Dentist (%)	53 (55%)	10 (19%)	43 (81%)	0.792
Hygienist (%)	44 (45%)	7 (16%)	37 (84%)	
Faculty				
Yes (%)	45 (46%)	7 (16%)	38 (84%)	0.937
No (%)	52 (54%)	10 (19%)	42 (81%)	

Table 3.3 Demographic variables of all 97 participants in relation to co-axial alignment of their surgical loupes.

*The Wilcoxon-Mann-Whitney test was used for continuous variables such as Clinician's Age and Years in Practice and Fisher's exact test was used for all categorical variables such as Gender and Role in Dental Practice.

3.2.3 Front-Lens-Mounted (FLM) vs. Through-the-Lens (TTL) Surgical Loupes

Among 97 participants, 54 (56%) owned TTL surgical loupes and 43 (44%) owned FLM surgical loupes. From the 43 participants with FLM surgical loupes, 32 participants had FLM surgical loupes with full vertical adjustability (referred to as "FVA" below) and 11 participants had FLM surgical loupes with limited vertical adjustability (referred to as "LVA" below).

3.2.3.1 Manufacturing Companies

Table 3.4 categorizes the different types of surgical loupes by manufacturer. Among the 97 participants, the three most popular manufacturing companies were SurgiTel®, Orascoptics™ and Designs for Vision, Inc. Together, these three companies accounted for 77 pairs of surgical loupes surveyed. SurgiTel® had the largest number of FLM surgical loupes with full vertical adjustability (26 pairs), whereas all of the Designs for Vision surgical loupes found in this study were TTL (23 pairs). Interestingly, 2 out of 97 participants reported that their surgical loupes were of "unknown" manufacturers, as these participants simply purchased their surgical loupes from online stores who did not disclose the name of the manufacturer. There were no identifying markings on these two pairs of surgical loupes.

Manufacturer	FLM		TTL	Total
	w/ FVA	w/ LVA		
SurgiTel ®	26	0	1	27
Orascoptic™	2	2	23	27
Designs for Vision, Inc.	0	0	23	23
Heine	2	3	0	5
Q-optics	2	0	1	3
Zeiss	0	2	0	2
ExamVision™	0	0	2	2
Univet®	0	0	1	1
Other[1]	0	2	3	5
Unknown[2]	0	2	0	2

Table 3.4 The three different types of surgical loupes (FLM with full vertical adjustability, FLM with limited vertical adjustability, and TTL) listed by manufacturer.

[1] "Other" includes Rose Micro Solutions (2 pairs), Snap On Optics™ (1 pair), SheerVision® (1 pair) and Brasseler USA® (1 pair).
[2] The participants purchased these surgical loupes from online stores and did not know the name of the manufacturer.

Table 3.5 summarizes the number of co-axially aligned and misaligned surgical loupes for each manufacturer, starting with companies with the most number of aligned surgical loupes to companies with the least number of aligned surgical loupes. The % of misaligned surgical loupes per manufacturer is only calculated for the top three manufacturers, as the total counts are too small for all other manufacturers for the data to make a fair statistical representation of their products. Even then, there was not enough statistical power for the 3 categories. While a greater proportion of Designs for Vision, Inc. surgical loupes were misaligned than the other 2 top manufacturers, the results were not statistically significant among the top three companies regarding number of co-axially aligned surgical loupes (P = 0.214).

Manufacturer	Total	Aligned (%)[1]	Misaligned (%)[2]	P value[3]	Range of Misalignment (units)
SurgiTel ®	27	7 (26%)	20 (74%)		1.0-10.0
Orascoptic™	27	7 (26%)	20 (74%)	0.214	1.0-5.5
Designs for Vision, Inc.	23	2 (9%)	21 (91%)		1.0-7.0
Zeiss	2	1	1		2.0
Heine	5	0	5		2.0-3.0
Q-optics	3	0	3		2.0-4.0
ExamVision™	2	0	2	N/A	2.0-15.0
Univet®	1	0	1		2.0
Other	5	0	5		2.0-5.0
Unknown	2	0	2		5.0

Table 3.5 The number of co-axially aligned and misaligned surgical loupes for each manufacturer.

[1,2] The % aligned and % misaligned were only calculated for the top three manufacturers, as the total count is too small for all other manufacturers.

[3] The P-value is only calculated for the top three manufacturers, as the total count is too small for all other manufacturers.

3.2.3.2 Front-Lens Mounted (FLM) vs. Through-the-Lens Systems

Table 3.6 and Figure 3.4 show the number of participants wearing co-axially aligned and misaligned surgical loupes for each system of surgical loupes: FLM with FVA, FLM with LVA, and TTL. While participants wearing FLM with FVA had the most number of surgical loupes in alignment (28%), there are no statistically significant differences among the three different systems with regards to prevalence of misalignment (P = 0.167).

Pre-Adjustment	Aligned (%)	Misaligned (%)	P Value
FLM (FVA)	9 (28%)	23 (72%)	0.167
FLM (LVA)	1 (9%)	10 (91%)	
TTL	7 (13%)	47 (87%)	

Table 3.6 Number and percent of participants with aligned and misaligned surgical loupes for each system of surgical loupes.

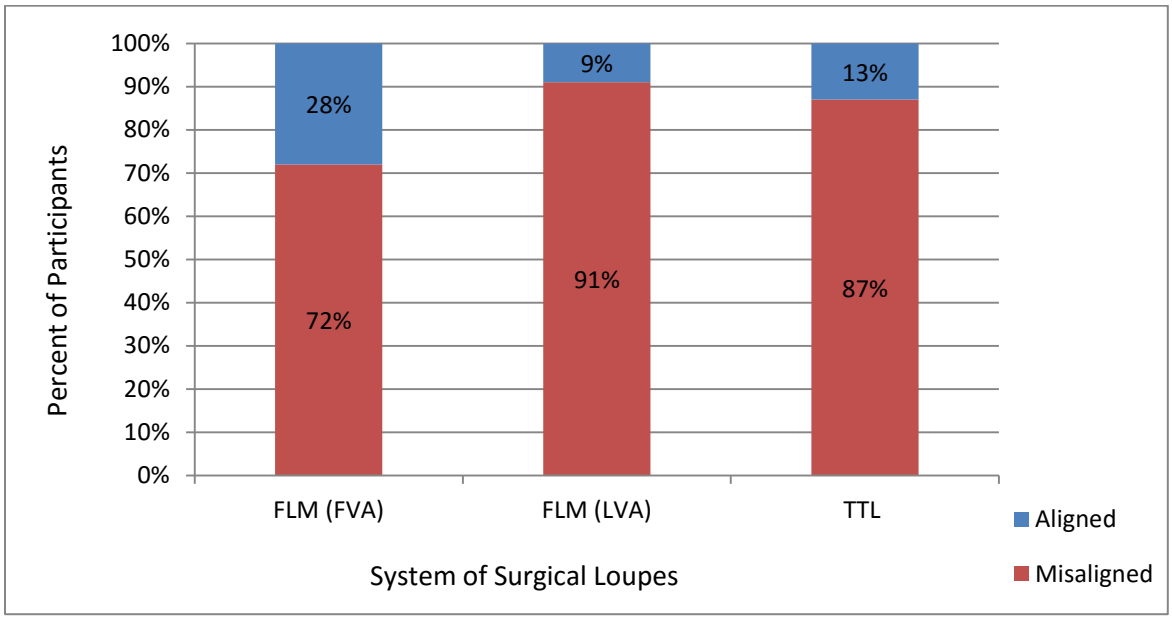


Figure 3.4 Percent of participants with aligned and misaligned surgical loupes for each system of surgical loupes (P = 0.167).

As described in Chapter 2 (section 2.4.3), out of the 80 participants who had co-axially misaligned surgical loupes, 26 participants (32.5%) consented to have their surgical loupes

adjusted by the researcher to see if their surgical loupes could become co-axially aligned to the participants. Out of the 26 participants who consented to have their surgical loupes adjusted, 18 were able to achieve full co-axial alignment with their surgical loupes after the adjustment: 17 pairs of these fully adjusted surgical loupes were FLM with FVA, 1 pair were TTL and 0 pairs were FLM with LVA. The remaining 8 participants have experienced 0.5-3.0 units of reduction in misalignment, but their surgical loupes could not achieve full co-axial alignment post adjustment.

Table 3.7 and Figure 3.5 show the total count of aligned and misaligned surgical loupes post-adjustment. FLM with FVA are significantly more likely to be adjustable to full co-axial alignment than FLM with LVA or TTL systems ($P < 0.05$).

Post-Adjustment	Aligned (%)	Misaligned (%)	P Value
FLM (FVA)	26 (81%)	6 (19%)	0.000
FLM (LVA)	1 (9%)	10 (91%)	
TTL	8 (15%)	46 (85%)	

Table 3.7 Number and percent of participants with aligned and misaligned surgical loupes for each system of surgical loupes *post-adjustment*.

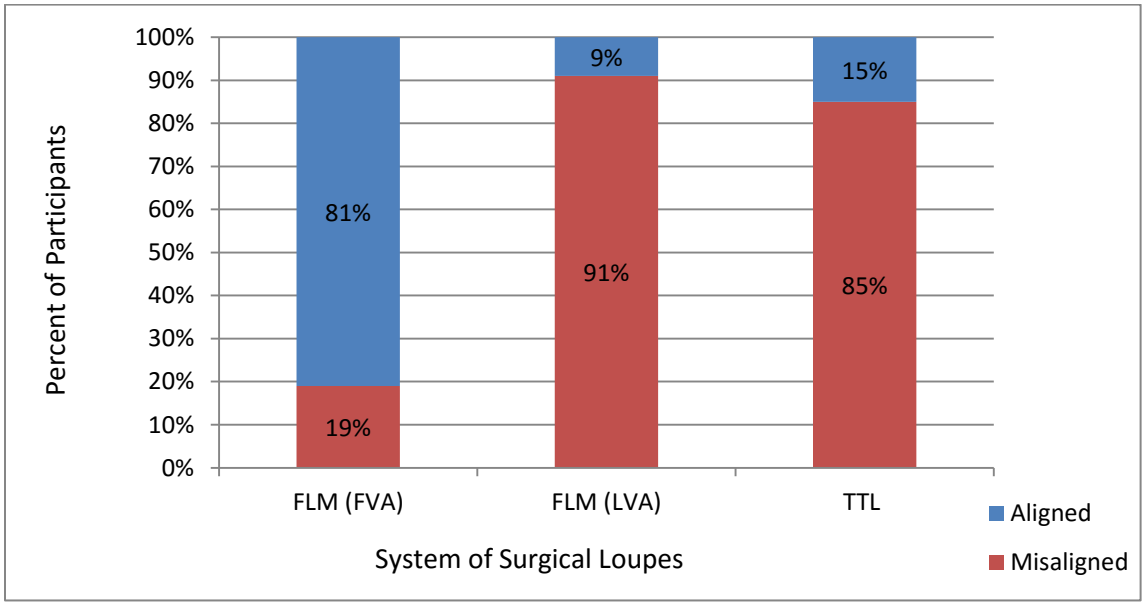


Figure 3.5 Percent of participants with aligned and misaligned surgical loupes for each system of surgical loupes *post-adjustment* ($P = 0.000$).

3.2.4 Perception of Surgical Loupes Use

3.2.4.1 Perceived Visual Acuity

Figure 3.6 compares responses to the statement "I feel that I can see well wearing my surgical loupes" between participants wearing co-axially aligned surgical loupes and those wearing misaligned surgical loupes *prior to* any adjustment by the researcher. Despite the high prevalence of co-axial misalignment, there are no significant differences between participants with co-axially aligned and misaligned surgical loupes in relation to perceived visual acuity (P = 0.528). Combining the responses into 3 categories of "agree, neutral, disagree" did not produce statistically significant results either. In other words, similar proportions of participants with aligned surgical loupes and misaligned surgical loupes "agreed to strongly agreed" with this statement. Lastly, no participants strongly disagreed with this statement and only a few participants with misaligned surgical loupes disagreed or were neutral towards this statement.

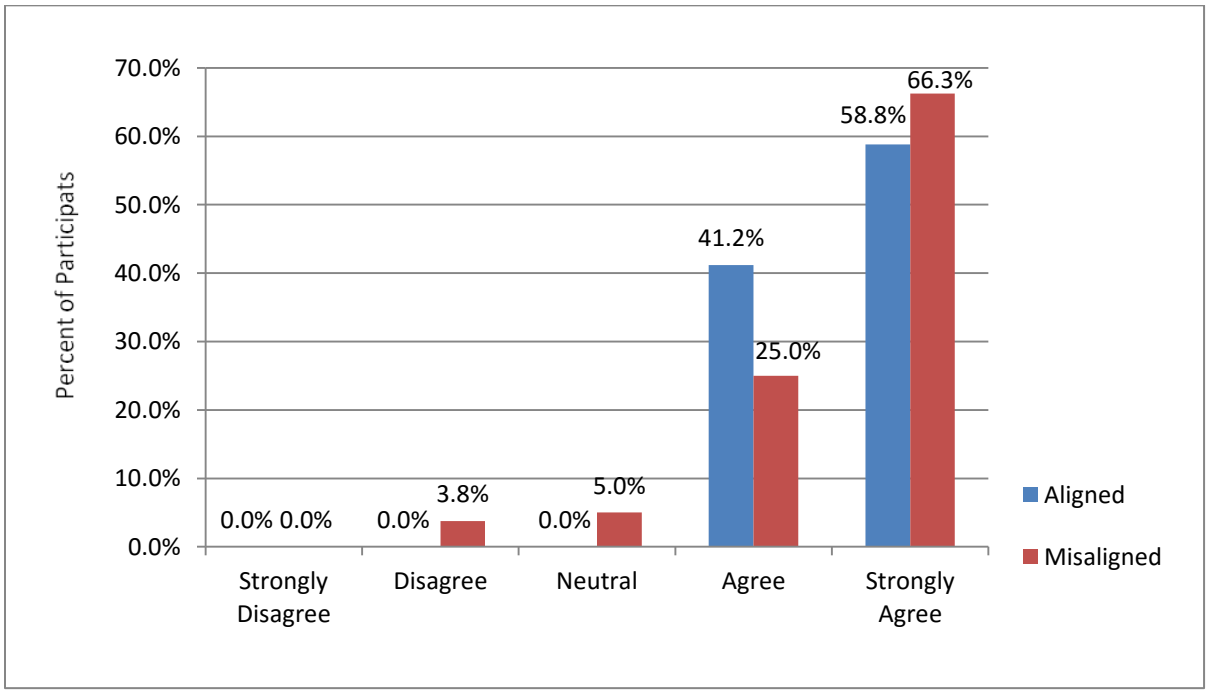


Figure 3.6 Participants' perceived visual acuity with their own surgical loupes in response to the statement "I feel that I can see well wearing my surgical loupes".
There are no significant differences between participants with co-axially aligned and misaligned surgical loupes (P = 0.528).

3.2.4.2 Perceived Quality of Care

Figure 3.7 compares responses to the statement "I feel that I can provide improved quality of care wearing my surgical loupes" between participants wearing co-axially aligned surgical loupes and those wearing misaligned surgical loupes *prior to* any adjustment by the researcher. There are no significant differences between participants with co-axially aligned and misaligned surgical loupes in relation to perceive quality of care (combining the responses into 3 categories of "agree, neutral, disagree" did not produce statistically significant results either.) Similar proportions of participants with aligned surgical loupes and misaligned surgical loupes "agreed to strongly agreed" with that statement. Lastly, no participants strongly disagreed with this statement and only a few participants with misaligned surgical loupes disagreed or were neutral towards this statement.

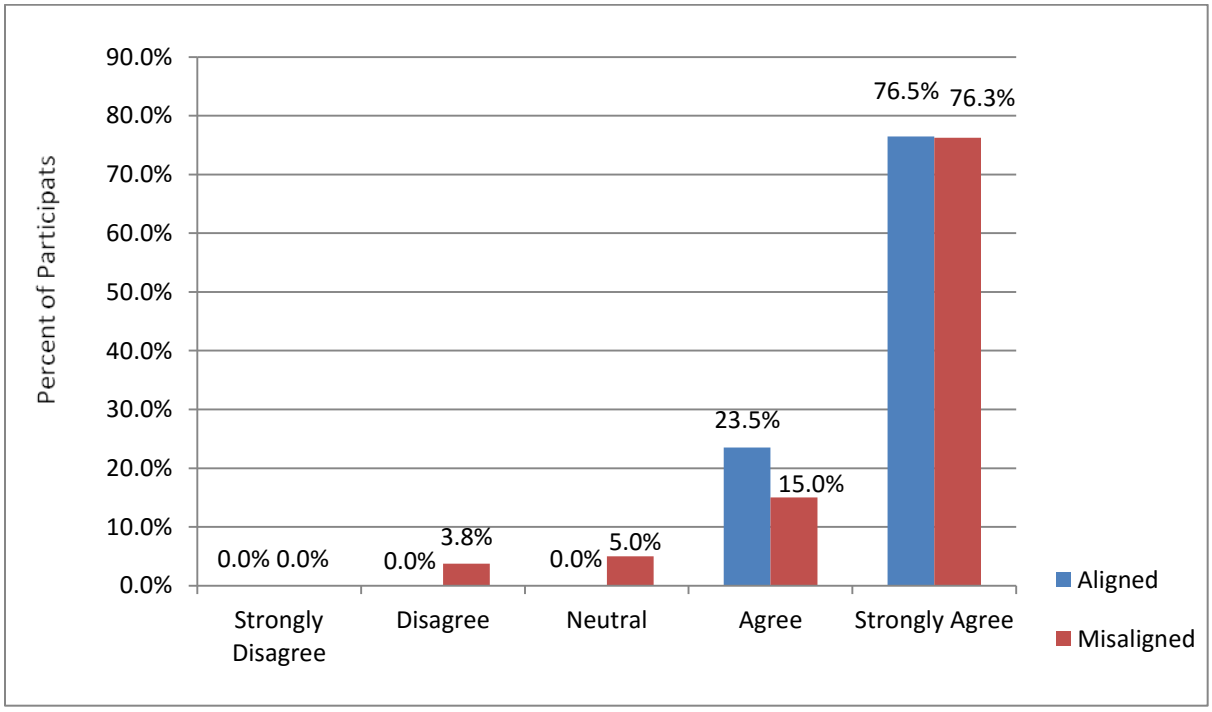


Figure 3.7 Participants' perceived quality of care with their own surgical loupes in response to the statement "I feel that I can provide improved quality of care wearing my surgical loupes". There are no significant differences between participants with co-axially aligned and misaligned surgical loupes (P = 0.755).

3.2.5 Practice Patterns with Surgical Loupes

3.2.5.1 Frequency of Surgical Loupes Use

Figure 3.8 compares responses to the question "how often do you wear your surgical loupes while working in a dental situation?" between participants wearing co-axially aligned surgical loupes and those wearing misaligned surgical loupes. Despite the high prevalence of co-axial misalignment, there are no significant differences between participants with co-axially aligned and misaligned surgical loupes (combining the responses into 3 categories of "never to rarely", "occasionally", "frequently to always" did not produce statistically significant results either). Slightly more participants with aligned surgical loupes identified that they use surgical loupes "rarely", "occasionally" or "frequently" than participants with misaligned surgical loupes, however the results are not significant.

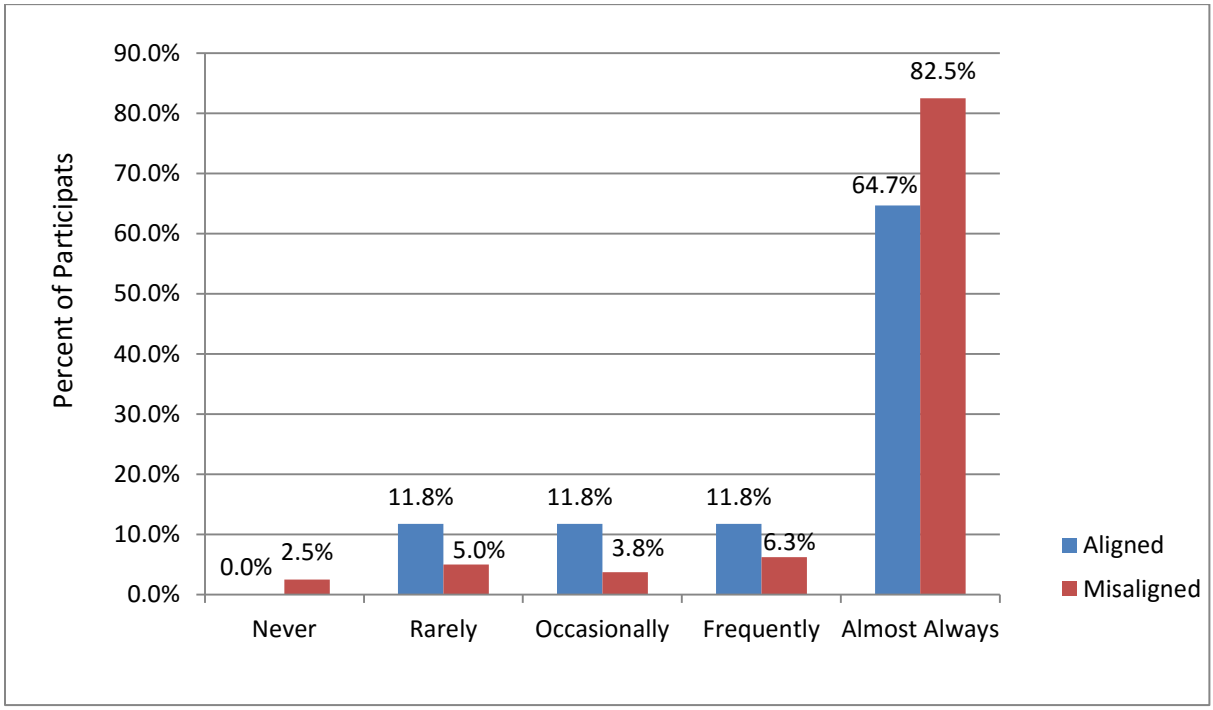


Figure 3.8 Frequency of surgical loupes use in a dental setting in response to the question "how often do you wear your surgical loupes while working in a dental situation?"
There are no significant differences between participants with co-axially aligned and misaligned surgical loupes (P = 0.200).

3.2.5.2 Procedures Performed with Surgical Loupes among Dental Hygienists

From the 97 participants, 44 were dental hygienists. Table 3.8 summarizes the procedures for which dental hygienists wear surgical loupes while practicing. “Yes” means that the dental hygienist performs this procedure *with* surgical loupes; “No” means that the dental hygienist performs this procedure *without* surgical loupes. Dental hygienists who did not perform a given procedure at all in practice were not included in this table. Out of 44 dental hygienists surveyed, 7 were wearing co-axially aligned surgical loupes and 37 were wearing co-axially misaligned surgical loupes.

The procedures performed were examination (includes extra-oral, intra-oral and dental exams), radiographic interpretation, periodontal assessments (includes probing, measurement of recession, identification of furcations and other mucogingival defects), scaling/root planing and polishing. As shown in Table 3.8, there appears to be no statistically significant differences between the aligned group and the misaligned group for all the procedures listed. Although dental hygienists with aligned surgical loupes are more likely to use surgical loupes for radiographic interpretation (42.9%) and scaling/root planning (100%) than dental hygienists with misaligned surgical loupes (29.5% and 91.1%, respectively), the results were not significant.

Procedure Performed[1]	Aligned (%)	Misaligned (%)	P-Value
Examination[2] (N=42)			
No	2 (33.3%)	8 (22.2%)	0.616
Yes	4 (66.7%)	28 (77.8%)	
Radiographic Interpretation (N=41)			
No	4 (57.1%)	24 (70.5%)	0.659
Yes	3 (42.9%)	10 (29.5%)	
Periodontal Assessments[3] (N=44)			
No	1 (14.3%)	4 (10.8%)	1.000
Yes	6 (85.7%)	33 (89.2%)	
Scaling/Root Planing (N=44)			
No	0 (0.0%)	3 (8.1%)	1.000
Yes	7 (100.0%)	34 (91.9%)	
Polishing (N=42)			
No	3 (42.9%)	10 (28.5%)	0.656
Yes	4 (57.1%)	25 (71.5%)	

Table 3.8 The procedures for which dental hygienists wear surgical loupes while practicing.
There are no significant differences between dental hygienists wearing aligned surgical loupes and dental hygienists wearing misaligned surgical loupes regarding procedures performed.

[1] Participants who do not perform this procedure at all in practice are not included.
[2] Examination includes extra-oral, intra-oral and dental exams
[3] Periodontal Assessments include probing, measurement of recession, identification of furcations and other mucogingival defects.

3.2.5.3 Procedures Performed with Surgical Loupes among Dentists

Of the 97 participants, 53 were dentists. Table 3.9 summarizes the procedures for which dentists wear surgical loupes while practicing. “Yes” means that the dentist performs this procedure *with* surgical loupes and “No” means that the dentist performs this procedure *without* surgical loupes. Dentists who did not perform a given procedure at all (e.g. orthodontics) are not included in this table. Out of 53 dentists surveyed, 10 were wearing co-axially aligned surgical loupes and 43 were wearing co-axially misaligned surgical loupes. However, one dentist with misaligned surgical loupes was excluded from this part of the results because he chose not to answer this section of the survey.

Additional to all procedures answered by dental hygienists, the 52 dentists surveyed also performed direct restorations, crown/bridge, simple extractions, complex oral surgery and orthodontics. Similar to the dental hygienists surveyed, there appears to be no significant differences between dentists wearing aligned surgical loupes and dentists wearing misaligned surgical loupes regarding procedures performed with surgical loupes. Although slightly more dentists with aligned surgical loupes are more likely to use surgical loupes for direct restoration (100%) and crown/bridge (100%) than dentists with misaligned surgical loupes (97.5%), the results were not significant.

Procedure Performed[1]	Aligned (%)	Misaligned (%)	P-Value
Examination[2] (N = 50)			
No	1 (11.1%)	5 (12.0%)	1.000
Yes	8 (89.9%)	36 (88.0%)	
Radiographic Interpretation (N = 49)			
No	5 (62.5%)	24 (58.5%)	0.722
Yes	3 (37.5%)	17 (41.5%)	
Periodontal Assessments[3] (N = 50)			
No	2 (20.0%)	6 (14.3%)	0.623
Yes	7 (70.0%)	35 (83.3%)	
Scaling/Root Planing (N = 37)			
No	1 (14.3%)	4 (13.3%)	1.000
Yes	6 (85.7%)	26 (86.7%)	
Polishing (N = 36)			
No	2 (40.0%)	8 (25.8%)	0.603
Yes	3 (60.0%)	23 (74.2%)	
Direct Restoration (N = 52)			
No	0 (0.0%)	1 (2.4%)	0.808
Yes	10 (100.0%)	41 (97.6%)	

Procedure Performed[1]	Aligned (%)	Misaligned (%)	P-Value
Crown and Bridge (N = 49)			
No	0 (0.0%)	1 (2.5%)	1.000
Yes	9 (100.0%)	39 (97.5%)	
Simple Extraction (N = 46)			
No	3 (37.5%)	10 (26.3%)	0.669
Yes	5 (62.5%)	28 (73.7%)	
Complex Oral Surgery (N =42)			
No	1 (11.1%)	4 (12.1%)	1.000
Yes	8 (88.9%)	29 (87.9%)	
Orthodontics (N = 19)			
No	3 (60.0%)	7 (50.0%)	1.000
Yes	2 (40.0%)	7 (50.0%)	

Table 3.9 The procedures for which dentists wear surgical loupes while practicing.
There are no significant differences between dentists wearing aligned surgical loupes and dentists wearing misaligned surgical loupes in relation to procedures performed.

[1] Participants who do not perform this procedure at all in practice are not included.
[2] Examination includes extra-oral, intra-oral and dental exams
[3] Periodontal Assessments include probing, measurement of recession, identification of furcations and other mucogingival defects.

3.3 The Study among UBC Dentistry Students

Twenty-three dental and dental hygiene students at the University of British Columbia also participated in this study (12 DMD and 11 DHDP, 8 male and 15 female). The trends observed among students are comparable to that of practicing professionals despite the small sample size.

3.3.1 Prevalence of Misalignment among UBC Dentistry Students

Figure 3.9 shows that out of 23 participants surveyed, only 5 (21.7%) were practicing with co-axially aligned surgical loupes. Eighteen (78.3%) were practicing with co-axially misaligned surgical loupes.

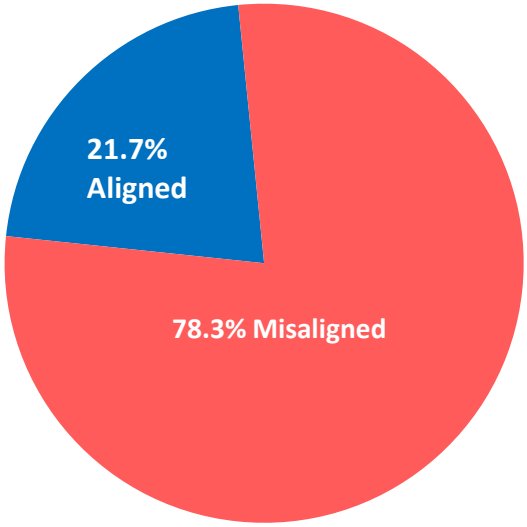


Figure 3.9 Prevalence of co-axially misaligned surgical loupes among 23 dental and dental hygiene students at the University of British Columbia.

Figure 3.10 shows how the units of misalignment are distributed among 23 participants. Most participants (6) had surgical loupes that were 1 unit out of alignment; followed by 4 participants at 2 units. One participant practiced with surgical loupes that were 8 units out of alignment.

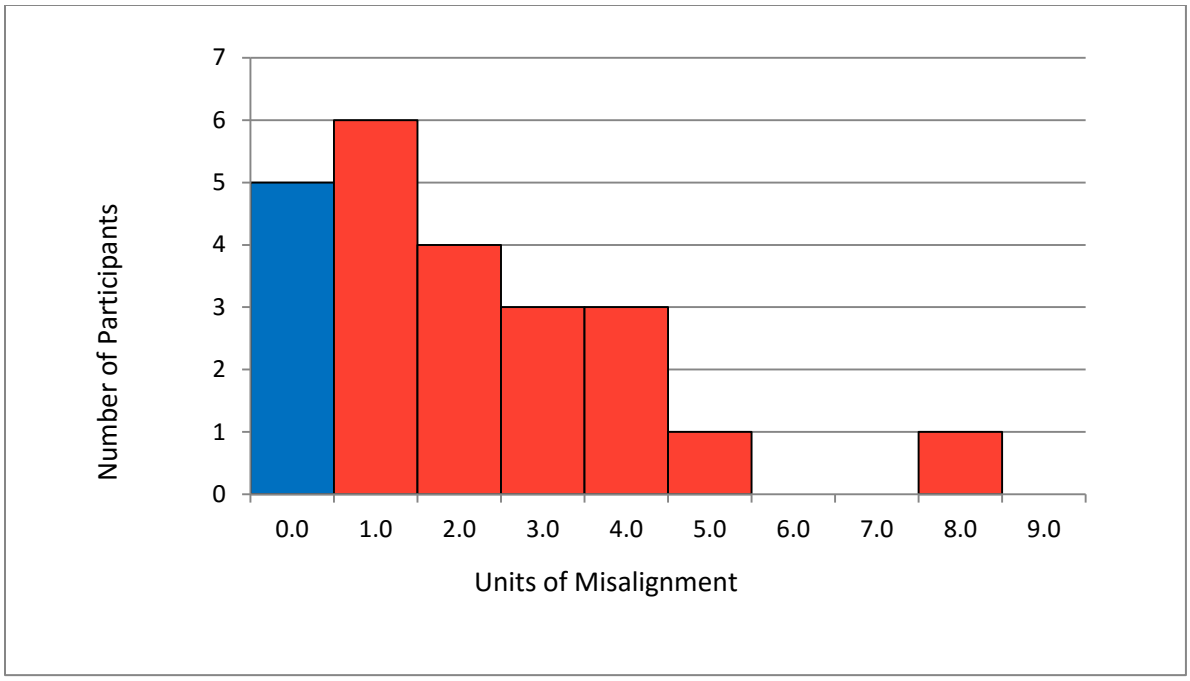


Figure 3.10 Distribution of co-axial misalignment among 23 dental and dental hygiene students at the University of British Columbia.
Blue = aligned; Red = misaligned

3.3.2 Demographic Variables of UBC Dentistry Students

Table 3.10 shows the demographic variables of all 23 participants. Overall, 8 (35%) participants were male and 65 (65%) were female. The mean and median age were younger than that of the practicing professionals at 25 years old (S.D = 3 years). Twelve (52%) participants were dental (DMD) students and 11 (48%) were dental hygiene (DHDP) students. Fourteen (61%) participants were in the third-year of their studies and 9 (39%) students were in the fourth year of their studies. Both DMD and DHDP programs are four years long.

The results show more male students have misaligned surgical loupes than female students, although the results were not significant. There are no significant differences between DMD and DHDP students. Lastly, student's age and year of program are not good predictors of the co-axial alignment of their surgical loupes in this sample.

	All	**Aligned (%)**	**Misaligned (%)**	***P* value***
Total	23 (100%)	5 (21.7%)	18 (78.3)	
Gender				
Male (%)	8 (35%)	1 (12.5%)	7 (87.5%)	0.621
Female (%)	15 (65%)	4 (26.7%)	11 (73.3%)	
Age in Years (Mean + S.D)	25±3	25±3	25±3	0.339*
Program Year				
Third Year (%)	14 (61%)	3 (21.4%)	11 (78.6%)	1.000
Fourth Year (%)	9 (39%)	2 (22.2%)	7 (77.8%)	
Program Type				
DMD (%)	12 (52%)	3 (25%)	9 (75%)	1.000
DHDP (%)	11 (48%)	2 (18.2%)	9 (81.8%)	

Table 3.10 Demographic variables of 23 students in relation to co-axial alignment of their surgical loupes.
*The Wilcoxon-Mann-Whitney test was used for continuous variables such as Clinician's Age and Fisher's exact test was used for all categorical variables

3.3.3 Front-Lens-Mounted (FLM) vs. Through-the-Lens (TTL) Surgical Loupes

Among the 23 participants, 7 (30%) had TTL surgical loupes and 16 (70%) had FLM surgical loupes. From the 16 participants with FLM surgical loupes, 15 had FLM with FVA systems and 1 had FLM with LVA system.

3.3.3.1 Manufacturing Companies

Table 3.11 breaks down the different types of surgical loupes by manufacturer. The three most popular manufacturing companies among the 23 participants were Q-optics (7 pairs), SurgiTel® (5 pairs) and Designs for Vision, Inc. (4 pairs). All Q-optics and SurgiTel® surgical loupes were FLM with FVA and all Designs for Vision, Inc. surgical loupes founded in this study were TTL. Table 3.11 also summarizes the number of co-axially aligned and misaligned surgical loupes for each manufacturer. The % of misaligned surgical loupes, range of misalignment and associated P-values was not calculated for the student group because the total count for each manufacturer is too low to make a statistically significant representation of their product.

Manufacturer	FLM		TTL	Aligned (%)	Misaligned (%)	Total
	w/ FVA	w/ LVA				
Q-optics	7	0	0	1 (14%)	6 (86%)	7
SurgiTel ®	5	0	0	1 (20%)	4 (80%)	5
Designs for Vision, Inc.	0	0	4	0	4 (100%)	4
Heine	3	0	0	0	3 (100%)	3
Orascoptic™	0	0	2	2 (100%)	0	2
Perioptix	0	1	0	1 (100%)	0	1
Univet®	0	0	1	0	1 (100%)	1

Table 3.11 Surgical loupes and status of co-axial alignment listed by manufacturer.

3.3.3.2 Front-Lens Mounted (FLM) VS. Through-the-Lens Systems

Table 3.12 and Figure 3.11 show the number of participants with co-axially aligned and misaligned surgical loupes for each system of surgical loupes: FLM with FVA, FLM with LVA, and TTL. There are no significant differences among the three different systems with regards to prevalence of misalignment (P = 0.139).

Pre-Adjustment	Aligned (%)	Misaligned (%)	P Value
FLM (FVA)	2 (13%)	13 (87%)	0.139
FLM (LVA)	1 (100%)	0 (%)	
TTL	2 (29%)	5 (71%)	

Table 3.12 Number and percent of participants with aligned and misaligned surgical loupes for each system of surgical loupes among 23 UBC dentistry students.

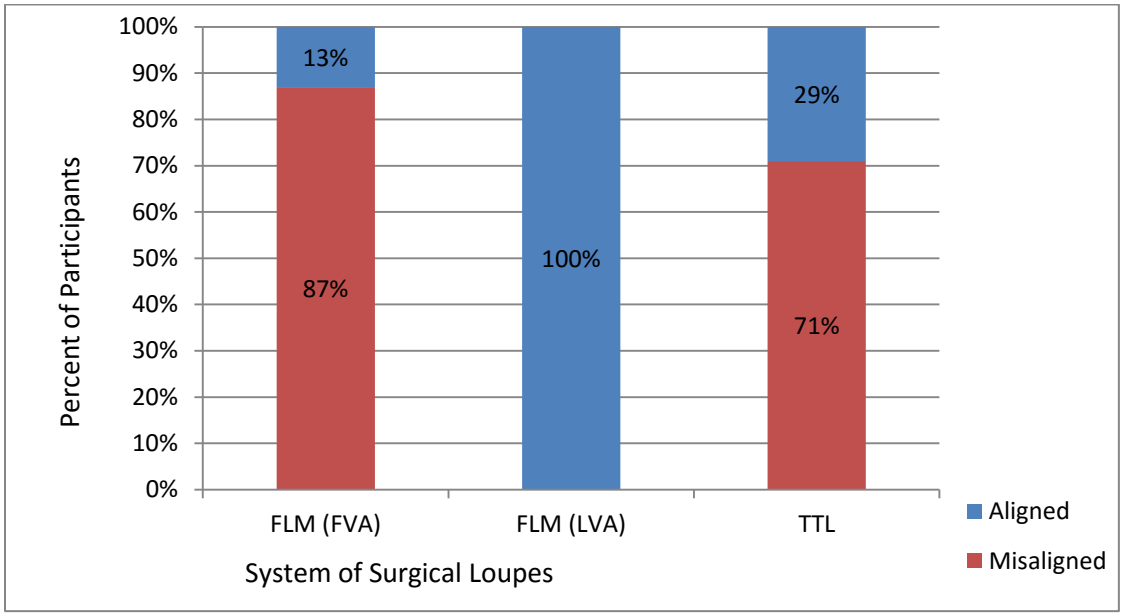


Figure 3.11. Percent of participants with aligned and misaligned surgical loupes for each system of surgical loupes among 23 UBC dentistry students (P = 0.139).

As described in Chapter 2 (section 2.4.3), out of the 18 students who had co-axially misaligned surgical loupes, 14 (78%) students consented to have their surgical loupes adjusted by the researcher. Among the 14 consenting participants, 12 were able to achieve full co-axial

alignment with their surgical loupes after the adjustment; all 12 pairs of surgical loupes were FLM with FVA.

Table 3.13 and Figure 3.12 show the total count of aligned and misaligned surgical loupes post-adjustment. Again, FLM with FVA are significantly more likely to be adjusted to full co-axial alignment than FLM with LVA or TTL systems ($P < 0.05$).

Pre-Adjustment	**Aligned (%)**	**Misaligned (%)**	**P Value**
FLM (FVA)	14 (93%)	1 (7%)	0.003
FLM (LVA)	1 (100%)	0 (%)	
TTL	2 (29%)	5 (71%)	

Table 3.13 Number and percent of participants with aligned and misaligned surgical loupes for each system of surgical loupes among 23 UBC Dentistry students (*post-adjustment*).

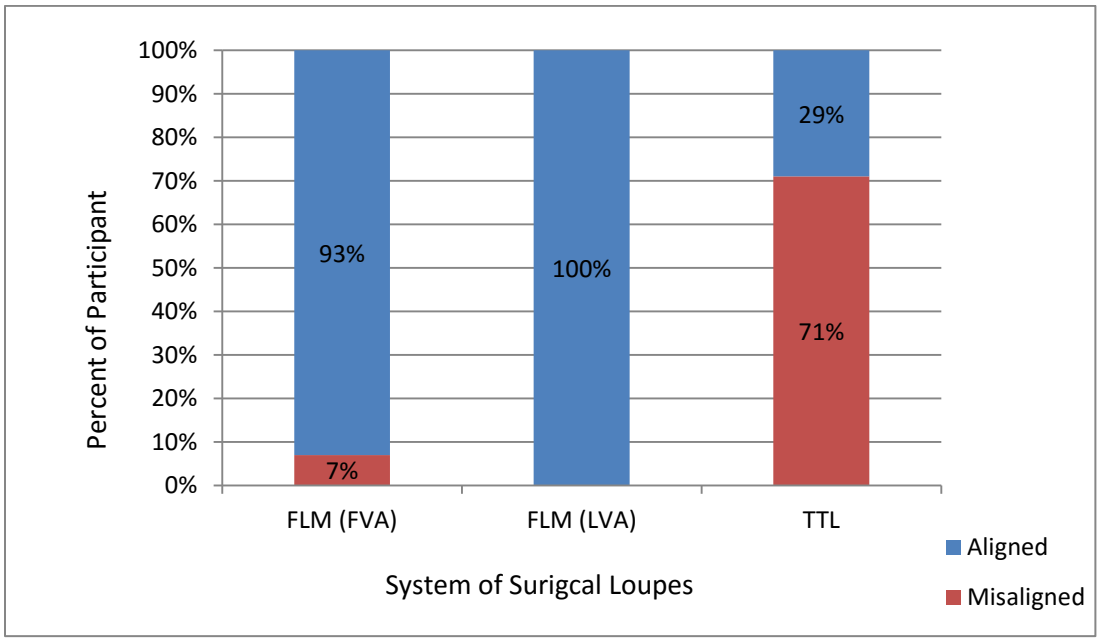


Figure 3.12 Number of aligned and misaligned surgical loupes for each system of surgical loupes among 23 UBC Dentistry students *post adjustment* ($P = 0.003$).

3.3.4 Perception and Practice Patterns among UBC Dentistry Students

With regards to perception of using surgical loupes, Figure 3.13 summarizes the students' responses to the statements "I feel that I can see well wearing my surgical loupes". There were no statistical significance in the student responses due to the small sample size (combining responses into 3 categories of "strongly disagree to disagree", "neutral", "agree to strongly agree" produced no significance either). While more students with aligned surgical loupes (60%) agreed with this statement than students with misaligned surgical loupes (38.9%), the results were not significant. Also, while none of the students with aligned surgical loupes strongly disagree, disagree or were neutral to this statement, 5.6% of students with misaligned surgical loupes disagreed to this statement and 22.2% of students felt neutral to this statement.

Similarly, Figure 3.14 summarizes the students' responses to the statement "I feel that I can provide improved quality of care wearing my surgical loupes". There were no statistical significance in the student responses due to the small sample size (combining responses into 3 categories of "strongly disagree to disagree", "neutral", "agree to strongly agree" produced no significance either). While more students with aligned surgical loupes (60%) agreed with this statement than students with misaligned surgical loupes (22%), the results were not significant statistically. Also, while none of the students with aligned surgical loupes strongly disagree, disagree or were neutral to this statement, 5.6% of students with misaligned surgical loupes disagreed to this statement and 16.7% felt neutral to this statement.

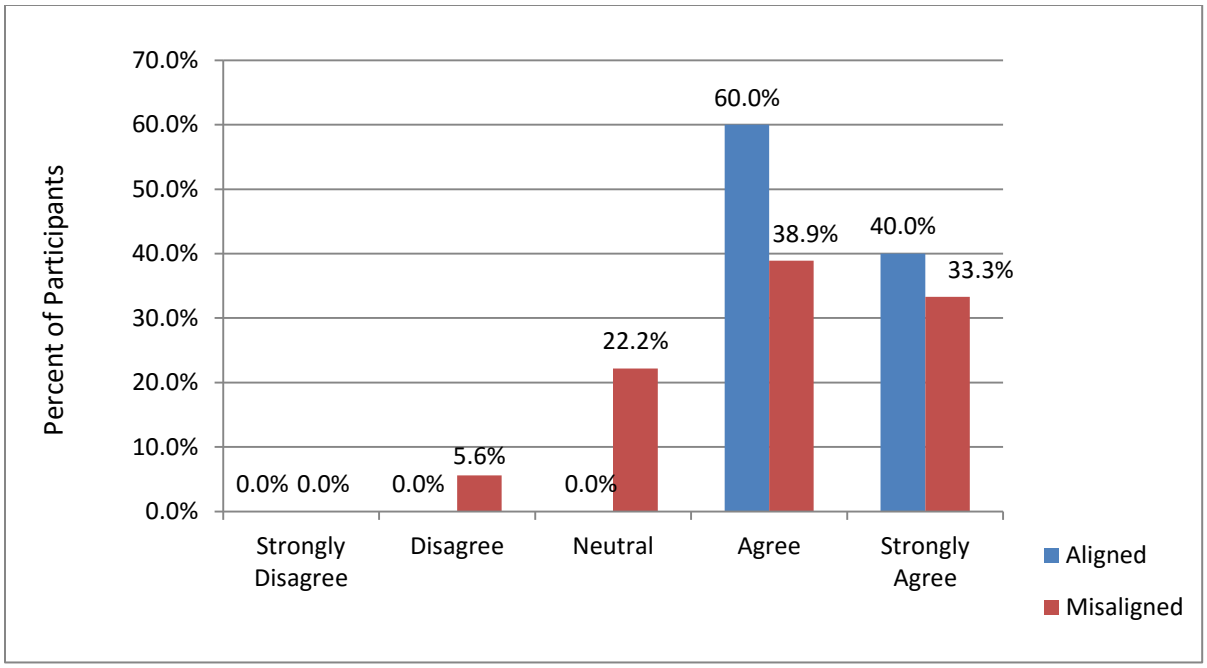


Figure 3.13 Students' perceived visual acuity with their own surgical loupes in response to the statement "I feel that I can see well wearing my surgical loupes".
There are no significant differences between participants with co-axially aligned and misaligned surgical loupes (P = 0.736).

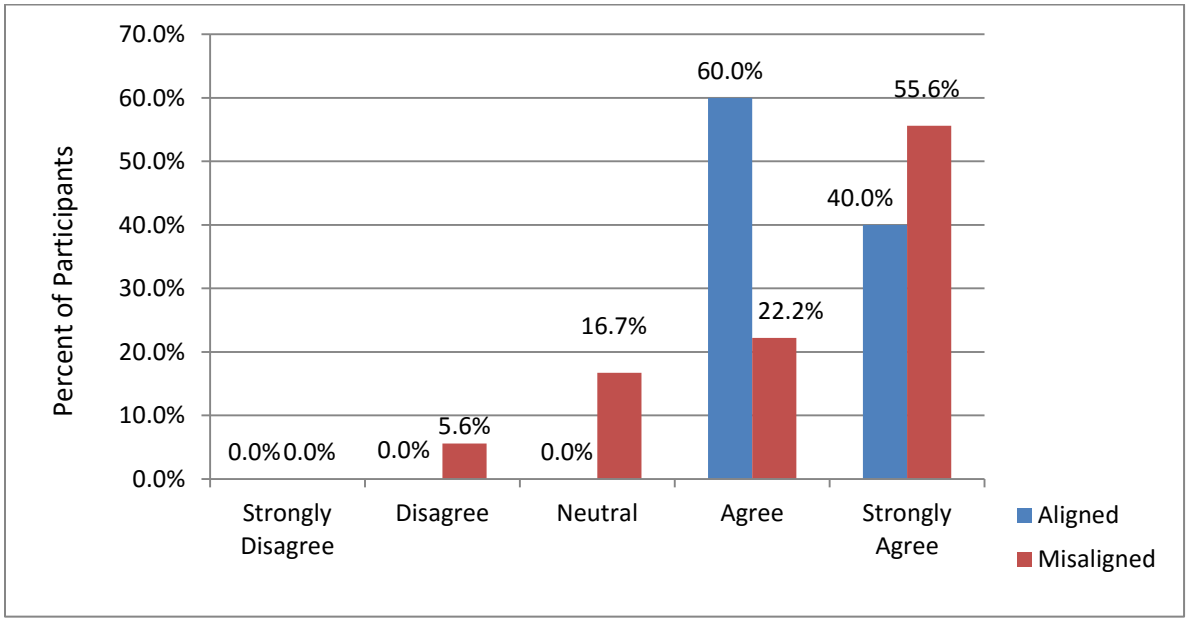


Figure 3.14 Students' perceived quality of care with their own surgical loupes in response to the statement "I feel that I can provide improved quality of care wearing my surgical loupes".
There are no significant differences between participants with co-axially aligned and misaligned surgical loupes (P = 0.499).

With regards to practice patterns using surgical loupes, Figure 3.15 summarizes the students' responses to the question "how often do you wear your surgical loupes while working in a dental situation?" While more students with aligned surgical loupes (80%) answered "almost always" than students with misaligned surgical loupes (61.1%), the results were not significant statistically. Also, while none of the students with aligned surgical loupes identified that they never, rarely or occasionally wear surgical loupes, 11.1% of students with misaligned surgical loupes identified that they only use surgical loupes occasionally.

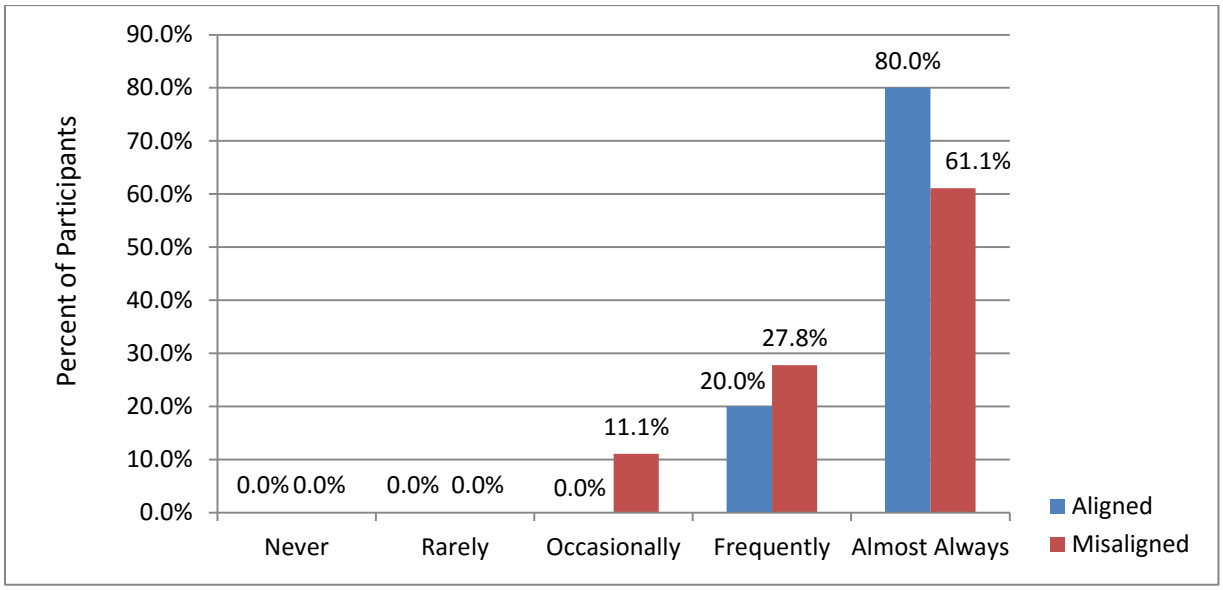


Figure 3.15. Frequency of surgical loupes use in a dental setting in response to the question "how often do you wear your surgical loupes while working in a dental situation?
There are no significant differences between participants with co-axially aligned and misaligned surgical loupes (P = 0.995).

Chapter 4: Discussion

This is the first study that has examined co-axial alignment of surgical loupes in a cohort of dental professionals. A simple quantifiable tool to measure co-axial alignment of surgical loupes was developed for the first time and trialed among dental professionals in British Columbia; it revealed that a high prevalence of co-axial misalignment is present among surgical loupes users in this cohort.

4.1 Prevalence of Co-axial Misalignment

This study revealed that a high prevalence of co-axial misalignment of surgical loupes is present among both practicing dental professionals as well as dental and dental hygiene students surveyed in BC (82.5% and 78.3% respectively). Approximately four out of five dental professionals in this cohort are experiencing the visual and discrepancies illustrated in Figure 1.6, Figure 1.8 and Figure 1.9. For the 80 practicing professionals with misaligned surgical loupes, more than half were experiencing up to 3 units of misalignment (or 19.5mm), one third were experiencing up to 7 units of misalignment (or 45.5mm) and three were experiencing 9 units (or 58.5mm) or more (Figure 3.2). Similar trends were observed among the students as well (Figure 3.10). This is rather unsettling as the maximum opening of the human mouth is approximately 45-50mm, hence a dental clinician with 7 or more units of misalignment would be experiencing a visual discrepancy larger than the human mouth itself. Moreover, two practicing professionals reported seeing “more than one red line” in their magnified views while using the co-axial alignment measurement tool, indicating that they were experiencing double vision with their surgical loupes. This means these two participants may have seen double images of their patients’ teeth and their instruments when looking through their surgical loupes, and they were unaware of such visual disturbances prior to the survey.

4.1.1 Clinical Implications of Co-axial Misalignment

There has been no previous research on the prevalence or implications of co-axial misalignment of surgical loupes among dental professionals. Existing reports were limited to describing the phenomenon only.(81) However, it has been documented that dental professionals experience an “adjustment period” when they first started using surgical loupes, and up to 50% of novice

surgical loupes users identified that the “adjustment period” serves as the most significant disadvantage of using surgical loupes.(26,68,69) While most dental professionals will experience an initial adjustment period while integrating magnification into practice(49), our research suggests that the visual discrepancy and chromatic aberrations caused by co-axial misalignment may be significant contributors to the prolonged adjustment period, eye strain, headaches, and vertigo that many clinicians experience. One study conducted by Hayes *et al*. involving 12 dental hygienists revealed that while all participants were using surgical loupes during the 6-month study, 75% of the participants discontinued using surgical loupes afterwards due to the lengthy adjustment period, limited depth of vision, headache and vertigo.(68) Similarly, another study involving 116 dental students showed that 20% of the students had difficulty adapting to surgical loupes after the first year.(69) The discomfort of using surgical loupes was also reported by Narula et al, where 25% of dental students reported discomfort when performing tooth preparation with surgical loupes.(75) It is important to point out that none of these studies checked for co-axial alignment of the surgical loupes they provided for the participants prior to the studies. Therefore, it is possible that co-axial misalignment was one of the potential causes of their symptoms and lengthy adjustment period. These participants could be experiencing vertigo from working with various degrees of visual discrepancies (some may be larger than the size of the human mouth), or experiencing headaches and eye strain from seeing double vision when they look through their surgical loupes.

Co-axial misalignment of surgical loupes might also contribute to the mixed report on the diagnostic abilities of surgical loupes identified in previous research. Particularly, the chromatic aberrations caused by co-axial misalignment (as illustrated in Figure 1.9) might compromise a clinician’s decision making and diagnostic abilities. Hayashi *et al*. found no differences between clinicians with and without surgical loupes when identifying marginal discrepancies of composite restorations.(72) Similarly, Sisodia and Manjunath found inconclusive results on the identification of occlusal caries with surgical loupes.(73) Neither of these studies mentioned checking for co-axial alignment (or any aspect of fitting) of surgical loupes to the participants. Therefore, it is possible that some dentists involved in these studies were experiencing chromatic

aberrations from misaligned surgical loupes and thus facing challenges discriminating margins of restorations or identifying tooth decay.

While there have not been documented cases of dental professionals causing patient injuries with misaligned surgical loupes, co-axial misalignment of surgical loupes can impose serious risk on patient safety and compromise a clinician's quality of care. As identified by Fehrenbach and Weiner, dental instruments need to be handled with care at all times, and a dental instrument should never be passed directly over a patient's face.(91) A dental clinician with misaligned surgical loupes might be uncertain as to the exact location of the patient's face, or the clinician might be constantly moving his hands "up and down" to align the magnified image through the surgical loupes with the unmagnified instrument and as a result, greatly increase the potential for losing control of the instruments near the patient's face and causing patient injuries. Moreover, a dental clinician with misaligned surgical loupes might be at higher risk of operating on an incorrect tooth or area of the mouth, as the magnified image through the surgical loupes could be centimeters away from the intended tooth. While our study did not specifically include a comment section, one participant did comment that "I hit the patient's chin [with my instrument]" and similar observations were indicated by UBC students with misaligned surgical loupes. Although a limited number of clinicians' experiences and observations may not be fully generalizable to the entire dental community, it is still of great clinical importance to indicate that co-axial misalignment of surgical loupes potentially has significant impact on patient safety and quality of patient care.

Current evidence does not demonstrate that any correlational or causational relationship exists between co-axial misalignment of surgical loupes and musculoskeletal disorders among dental professionals. Unlike the other two criteria (working distance and declination angle), it is still undetermined if co-axial misalignment of surgical loupes leads to direct postural challenges or musculoskeletal pain and loss of function. However, the researcher suspects that a clinician with misaligned surgical loupes might need to constantly move his neck or hands "up and down" in attempt to visually locate or correctly align the instrument with its magnified image prior to starting any procedure. As identified by Hayes *et al*., Leggat *et al*. and Morse *et al*., repetitive

motions are one of the major contributors to MSDs among dental professionals.(32,34,92) Therefore, the repeated movement of the clinician's neck and hands can potentially lead to repetitive strain injuries of the neck, shoulder, upper arm, and wrist. Constantly "craning" the neck (possibly many times a day over an extended period of time) may also aggravate or worsen existing symptoms for dental professionals who already suffer from MSDs in the neck and shoulder area.(33) A study conducted by Hayes *et al*. found mixed results on the effect of surgical loupes on upper body MSDs(52), and since this study did not check for co-axial alignment of surgical loupes to the participants, it is probable that some surgical loupes used in this study were misaligned and contributed to the mixed results on upper-body MSDs this study reported. Some participants of this study might be repeatedly moving their necks and arms due to the misalignment of their surgical loupes, and as a result, diminishing the ergonomic benefits of those surgical loupes or even developing further musculoskeletal disorders.

4.2 The Co-axial Alignment Measurement Tool

Prior to this study, there has been scarce examination of co-axial alignment of surgical loupes in existing dental and medical literature. The previously described method of simply placing a straight instrument into a clinician's magnified view (illustrated in Figure 1.5 and 1.6) presents with severe limitations, as this method was neither reliable nor repeatable (results could be easily adversely affected by the location and thickness of the straight instrument). The previous method also did not show severity of misalignment, neither was there a clear step-by-step protocol for surgical loupes users to follow. The severe limitations of the previous method might explain why UBC dentistry students whose surgical loupes were supposedly in co-axial alignment at time of purchase still demonstrated very high prevalence of misalignment during the survey: perhaps the students were never in "true" alignment in the first place due to the crude, unreliable method they used previously. These observations are echoed by almost all existing studies involving surgical loupes in dentistry: these studies either do not mention co-axial alignment, or in the limited cases that do mention co-axial alignment, checking for co-axial alignment was not at all integrated in the study design. In a study conducted by Hayes *et al* 12 participants had surgical loupes adjustable for working distance, declination angle and co-axial alignment, but the only factor the study checked prior to commencing was the working distance.(68) It is probable that

the researchers of this study were either not aware of how to check for co-axial alignment, or they had only used the unreliable method of using a straight instrument and were therefore unable to reliably obtain co-axial alignment measurements for their participants.

The co-axial alignment measurement tool developed in this study (illustrated in Figure 2.3) is a significant improvement over the previous method of measuring co-axial alignment of surgical loupes. Compared to the previous method, the new co-axial alignment measurement tool is not only to able determine if a pair of surgical loupes is aligned or misaligned, but also the degree/severity of misalignment. The co-axial alignment tool is more reliable because the red dot and red line clearly indicate the centre of the magnified view; whereas the previous method only provided a rough estimate that could easily be affected by the shape or thickness of the straight instrument of choice, or the way in which it was held in the magnified field.

The co-axial alignment measurement tool is also demonstrated to be repeatable within half a unit (or ±3.25 millimeters) over multiple days, thus providing repeatability of co-axial alignment measurements. This tool is simple to use (as outlined in section 2.2) and one can obtain a co-axial alignment measurement of his surgical loupes in less than a minute, requiring only minimal instructions. A dental professional can easily print out and carry a copy of this measurement tool with his surgical loupes to monitor co-axial alignment on a regular basis.

Lastly, due to its simplicity, the co-axial alignment measurement tool has the potential to be implemented in larger dental educational institutions with large numbers of students and faculty. The students can use this tool to guide their selection, adjustment and re-adjustment of surgical loupes, and faculty can help students align their surgical loupes as needed while keeping their own surgical loupes in alignment.

4.3 Demographic Variables

Of 97 practicing professionals, the majority of participants were female. The elevated percentage of female participants is due to the presence of dental hygienists in the sample, as most dental hygienists are female.(93) The participants' median age, number of years in practice and roles in

dental practice were consistent with the demographics reported by CDSBC and CDHBC, suggesting that our sample was reflective of the "true" population of practicing professionals in BC.(88) However, our sample of practicing professionals does have a much higher percentage of faculty members from dental educational institutions compared to the overall population of dental professionals in B.C. Similar demographic trends on gender and professional roles were observed amongst the 23 students as well, except that student participants were predictably younger in age and had no practice experience outside of UBC.

This study demonstrates that male and female participants are equally likely to be using surgical loupes that are co-axially misaligned. Moreover, no differences were found between dentists and hygienists or between dental and dental hygiene students in terms of prevalence of co-axial misalignment, suggesting that both professions in this cohort are equally likely to work with misaligned surgical loupes. Lastly, clinician's age and year of program were not reliable predictors of the co-axial alignment of their surgical loupes in this cohort.

This study revealed that faculty members of dental educational institutions are equally as likely to wear co-axially misaligned surgical loupes as non-educators. In fact, the two participants who purchased surgical loupes from unknown Internet distributors were both dental educators (Table 3.4). This is rather surprising because surgical loupes are mandatory or high recommended in dental educational institutions in BC, and it was anticipated that educators would stay more up-to-date with current research. It is also to our surprise that recent dental and dental hygiene graduates are equally likely to be out of co-axial alignment as are more experienced dental professionals (Table 3.3). Since UBC works closely with students to encourage optimal selection and adjustment of their surgical loupes at the outset of the course of their studies, we had expected the prevalence of misalignment to be lower among recent graduates. This suggests that there might be room for improvement in our current protocol to monitor surgical loupes use, reinforce the importance of wearing properly adjustment surgical loupes among students, and follow up with graduates after they complete the program.

4.4 Front-Lens-Mounted (FLM) vs. Through-the-Lens (TTL) Surgical Loupes

Since FLM with FVA surgical loupes offer full vertical adjustability, it was expected that the prevalence of co-axial misalignment to be lower among dental professionals using FLM with FVA surgical loupes than dental professionals using FLM with LVA surgical loupes or TTL surgical loupes. A difference in prevalence of misalignment among various manufacturers was also expected, as SurgiTel ® and Orascoptic^{TM} surgical loupes contained both FLM with FVA and TTL; whereas Designs for Vision, Inc. surgical loupes were TTL only (Table 3.4).

However, contrary to the expectations of the researcher, the prevalence of misalignment was the same across all manufacturers, and dental professionals wearing FLM with FVA, FLM with LVA and TTL surgical loupes were equally likely to be out of alignment (Table 3.6 and Table 3.12). This suggests that dental professionals are either uninformed about the level of adjustability of their surgical loupes, or they are not fully utilizing the adjustable features of their surgical loupes. In other words, having "fully adjustable" surgical loupes does not mean these surgical loupes are "fully adjusted" to fit the individual clinician. In fact, approximately one third of dental professionals surveyed had never opened or had misplaced the adjustment tools which accompanied the original purchase, indicating that adjustment and alignment of surgical loupes were not part of their clinical routine. These findings and observations again support the need for a simple co-axial alignment measurement tool such as the one developed in this study, made readily available to all clinicians for digital download, combined with online video instructions, to help dental professionals self-assess, adjust and align their surgical loupes on a regular basis.

Despite the high prevalence of misalignment, only one third (26/80) of practicing professionals agreed to have their surgical loupes adjusted by the researcher. This could be due to the clinician's lack of understanding of the adjustability of their surgical loupes, or perhaps the clinicians were concerned that a known but tolerated compromise might be preferable to an unknown outcome of adjustment. Out of the twenty-six consented participants, eighteen were able to achieve full co-axial alignment with their surgical loupes after the adjustment: seventeen pairs of these surgical loupes were FLM with FVA, only one pair were TTL and zero pairs were FLM with LVA (Figure 3.5). Similarly, among the students, all twelve pairs of surgical loupes

capable of achieving full-coaxial alignment were FLM with FVA models (Figure 3.12). These observations were sufficient to demonstrate that FLM with FVA is the system that can be most reliably adjusted to full co-axial alignment. These results were expected because while some of the other two systems offer some level of vertical adjustability, they do not possess the full range of vertical movement that FLM with FVA models can offer, and therefore may not be adjustable to achieve full co-axial alignment to the clinician.

4.5 Perception of Surgical Loupes Use

This study demonstrates that dental professionals' responses to the statements "I feel that I can see well wearing my surgical loupes" and "I feel that I can provide improved quality of care wearing my surgical loupes" are both very positive. These findings are comparable to a number of previous studies, in which surgical loupes users self-reported improved visual acuity and enhanced quality of care.(26,67,69,75,94) Maggio et al. showed that 87% of first-year dental students "agree to strongly agree" that surgical loupes helped them be more accurate in advanced clinical rotations.(69) In a similar study, 91% of dental hygiene students identified that surgical loupes enabled them to provide better quality of treatment during scaling and root planing than without surgical loupes.(67) In a large scale survey study among 868 dental hygienists in the U.S, 65% of the participants identified that surgical loupes were helpful in achieving better quality of care.(26)

However, it was surprising that the responses are the same for participants with aligned and misaligned surgical loupes, as the researcher had expected dental professionals with misaligned surgical loupes to report weakened visual acuity or compromised quality of care. This unexpected result could be due to self-reporting bias, as many dental professionals surveyed may have never been shown how to align their surgical loupes or experience what it is like to work with properly aligned surgical loupes. This limitation of self-reporting was also observed by Eichenberger *et al.*, who found dental professionals tend to self-report improved visual acuity with surgical loupes when there is only a weak correlation between self-reported visual acuity and objective visual acuity, suggesting that dental professionals are not always aware of their own visual performances and challenges.(28) This is also observed in a study conducted by

Hoerler *et al*., where participants self-reported visual enhancements and improved quality of care with surgical loupes but the objective measurements on clinical performances could not strongly support such claims. (67)

Intriguingly, although the dental professionals in this survey did not report any changes in visual acuity with misalignment surgical loupes, all participants were able to identify the discrepancy between the magnified and unmagnified red lines when using the co-axial alignment measurement tool. This combined with the observation that only a small number of practicing professionals wanted adjustment of their surgical loupes after the survey, suggest that dental professionals are not necessarily insensitive to visual changes and discrepancies; they perhaps have lacked the necessary tools to discriminate. Or perhaps human tendencies toward adaptability predominate, and the clinicians have just learned to compensate (and/or have assumed that such compensation is a necessary condition for surgical magnification). It is interesting to note that although post-adjustment responses were no part of the survey questions, dental clinicians who had their surgical loupes adjusted to full co-axial alignment indicated that they were pleasantly surprised by the visual improvements on their adjusted surgical loupes. Many dental professionals have taken it for granted that visual disturbances were "part of the package" when using surgical loupes and the side effects were part of a new routine to adjust to.(68,69) These findings further support the importance of the simple co-axial alignment measurement tool developed in this study, as it helps dental professionals efficiently and proficiently identify visual discrepancies with their equipment and perform adjustments accordingly.

4.6 Practice Patterns with Surgical Loupes

The majority of the participants in this study identified that they used surgical loupes "frequently"" to "almost always." The participants also identified that surgical loupes were used in a variety of dental and dental hygiene procedures. These observations are similar to what is currently documented in extant research, where the use of surgical loupes has been found in endodontics, orthodontics, general restorative dentistry, and dental hygiene treatment procedures.(14,26,52,75,78)

However, it is to the researcher's surprise that dental professionals with aligned and misaligned surgical loupes used surgical loupes at similar frequencies, as the researcher has expected dental professionals with misaligned surgical loupes to use surgical loupes less often due to the visual discrepancies created by co-axial misalignment. The study also revealed that large proportion of the participants used their misaligned surgical loupes for the majority of the procedures they performed. This result did not differ from participants using aligned surgical loupes. This finding was also surprising as the researcher had expected that for the same procedure, more dental professionals with aligned surgical loupes would use surgical loupes for that procedure, and fewer dental professionals with misaligned surgical loupes would use their loupes for that procedure, due to the visual discrepancies created by co-axial misalignment. However, the data from this study has not clearly demonstrated such trends.

This lack of difference in practice patterns between clinicians with aligned and misaligned surgical loupes has led the researcher to speculate whether a "clinically tolerable" range exists for co-axial misalignment. Although there is no previous research specifically on the severity of co-axial misalignment of surgical loupes, the concept of "tolerance" does exist in ophthalmology literature regarding prescription eyewear.(95) For instance, if a person's "true" prescription is -2.0, he might be able to wear eye glasses between -2.125 and -1.875 in prescription and not experience any problems. The specific range of tolerance may depend on the individual person or the visual issue (e.g. nearsightedness, astigmatism) being corrected.(96) Therefore, it is probable that co-axial misalignment of surgical loupes has a "clinically tolerable range", where dental clinicians do not experience any symptoms or find the symptoms tolerable until a certain severity of misalignment is reached. This clinical tolerable range may also depend on the individual dental clinician, as some people might be more sensitive to visual changes than others.(28,96) If such range does exist, it might explain why dental professionals with misaligned surgical loupes use surgical loupes as frequently and in as many procedures as dental professionals with aligned surgical loupes. This "clinically tolerable range" might also explain why in some studies only 25%-50% of dental professionals report symptoms of headaches and vertigo (26,69,75)when the prevalence of co-axial misalignment could be as high as 82.5%.

However, based on current research and understanding of co-axial misalignment of surgical loupes, this clinically tolerable range of co-axial misalignment remains speculation and the specific range remains undetermined.

4.7 Limitations

This study is the first to examine specifically co-axial alignment of dental surgical loupes. It was presented with the challenges and limitations of a large pilot study. The initial sample size of 97 was determined using proportion estimates only, and post-hoc power calculations revealed that the overall statistical power was low for both the practicing professional group and the student group, which may account for some of the statistically non-significant findings in this study. The student group had an unexpectedly low response rate of 23 students (from over 300 students enrolled) despite the recruitment efforts employed. Moreover, some dental professionals might have surgical loupes so misaligned that they have stopped using surgical loupes altogether, and were therefore not captured by this study.

The majority of practicing professionals who responded to this study were limited to metro Vancouver, and 46% of the practicing professionals surveyed were faculty members from dental educational institutions. Although there is no existing evidence on the relationship among geographical location, employment status and the use of surgical loupes, this sample may not be a fair representation of the dental professional population in British Columbia. For instance, clinical instructors may not be practicing for as many hours and therefore may not be as affected by visual discrepancy of their misaligned surgical loupes. Also, the UBC students were exposed to only a limited number of surgical loupes manufacturers; thus, what they purchased may not be as generalizable to all available products in B.C. Moreover, the frequency and procedures that students perform were subject to change as they progress in the program. Therefore, the results on the student group were not pooled with the practicing professionals and were reported separately.

For the survey questions regarding clinicians' perceived visual acuity and quality of care with surgical loupes, the responses might be subject to self-reporting bias. While self-report is an

effective measure of obtaining information about a particular population, the responses will be limited by the experience of the participants as well as the participants' interpretation of the questions.(97) For instance, due to the high prevalence of co-axial misalignment, many dental professionals may have never experienced working with aligned surgical loupes, and therefore may not be able to identify the visual changes associated with misalignment. A clinician's response may also be biased as he has spent time and money invested in the purchasing of the surgical loupes, and is thus may be less likely to report negative experiences. Moreover, the participants' interpretation of the term "quality of care" may differ from one individual to another. Some might interpret "quality of care" as clinical/intra-oral care and agree that surgical loupes have enhanced their quality of care; whereas others might interpret "quality of care" as patient communication and education, and thus respond that surgical loupes have compromised their quality of care because they could not see the patients' facial expressions as clearly or make direct eye contact with patients while wearing surgical loupes. Self-reporting bias can be managed by combining self-report measures with more objective measures. (97) For instance, one can combine a self-reported response of visual acuity with an object measurement of visual acuity to obtain more comprehensive information on the effect of surgical loupes on visual acuity.

Lastly, there has been a lack of blinding in this study design. Blinding is challenging for this study as co-axial alignment in surgical loupes is unique to each individual and to each pair of surgical loupes. Blinding will help reduce or eliminate bias introduced by the investigator or the participant.(98) For instance, a dental professional may answer the questions pertaining to visual acuity, quality of care, and practice patterns with less bias if he were blinded from the status of co-axial misalignment of his surgical loupes.

Chapter 5: Conclusion

Although surgical loupes have been popular in dentistry over the past decade, this study is one of the few investigations to explore the fitting and adjustment of surgical loupes to their users. Particularly, this study focused on the co-axial alignment of surgical loupes, one of the three key non-negotiable criteria when selecting and evaluating dental surgical loupes. (80) This study developed a simple quantifiable tool to measure co-axial alignment of surgical loupes and revealed that a high prevalence (as high as 82.5%) of co-axial misalignment is present among surgical loupes users in this cohort. This study also demonstrated that not all surgical loupes systems can be adjusted to fully meet the co-axial alignment requirements for the clinician, and dental clinicians are not always aware of the discrepancies and challenges of their equipment on their quality of care and clinical practice patterns.

5.1 Implications of This Study

Currently, surgical loupes are either mandatory or highly recommended in all dental educational institutions across the Province of British Columbia. The University of British Columbia, for example, is home to over 300 dental, dental hygiene, and dental specialty students. The results demonstrated that students and recent graduates are as prone to co-axial misalignment of surgical loupes as their more experienced colleagues. This suggests that there is room for improvement in current protocol to monitor surgical loupes use, to reinforce the importance of wearing properly adjustment surgical loupes among students, and to follow up with graduates after they complete the program. Dental and dental hygiene educators might also need to be calibrated on how to recognize signs of misaligned surgical loupes and help students make adjustments accordingly.

The co-axial alignment measurement tool developed in this study not only measures co-axial alignment with reliability and repeatability, but also provides information on the severity of co-axial misalignment. This tool has already been implemented at UBC Dentistry to assist students and faculty in making more informed choices when purchasing, adjusting and re-adjusting surgical loupes. This simple co-axial alignment tool can be made easily available for broader populations of dental professionals. For instance, one can develop a website which includes a printable version of this simple co-axial alignment measurement tool (e.g., in one-page PDF

format), combined with online video instructions, to help large populations of dental professionals self-assess, adjust and align their surgical loupes on a regular basis.

In 2015, the preliminary findings of this study were shared at the National Network for Canadian Oral Health and Research (NCOHR) seminars at the University of Toronto and at the Asia Pacific Dental Conference (APDC) in Singapore. In March 2016, the findings of this study were also shared at the Pacific Dental Conference (PDC), one of the largest dental conferences in North America. The findings of this study will not only enable dental professionals to make more informed decisions about selecting and implementing surgical loupes, but also promote surgical loupes manufacturers to improve on their product design and functionality. For instance, surgical loupes manufacturers might utilize the findings from this study and produce FVA surgical loupes that can be fully "locked-in", such that co-axial aligned surgical loupes won't easily go out of alignment from the flip-up mechanisms. The manufacturers might also choose to distribute the co-axial alignment measurement tool developed from this study to sales representatives and customers, creating a safer and more evidence- based practice environment for our dental communities and beyond.

5.2 Future Research Directions

This study is the first study to examine co-axial alignment of surgical loupes. It included both practicing dental professionals in a real clinical practice setting as well as dental and dental hygiene students. Prior to this study, the majority of research on surgical loupes was limited to comparing a group of dental professionals with surgical loupes to a group without surgical loupes; and often times these studies were conducted in simulated clinical settings with only students. Therefore, this study serves as a solid foundation for a variety of potential research opportunities in the field of dental surgical magnification.

Due to limited statistical power of this study, future studies should increase the sample size to include more dental professionals and students in BC and all of Canada to see if the findings of this study can be generalized to larger populations. An increased sample size would generate a more precise estimate of prevalence of misalignment for the entire population of dental

professionals in BC and in Canada. The prevalence of misalignment found in this study can be used as a basis to calculate more appropriate sample sizes for future studies. For instance, a future study could expand to include all dental hygiene programs in the province. Since a number of popular surgical loupes manufacturers found in this study are from the U.S., it would be valuable to also expand this study to include U.S. dental professionals to examine if the prevalence of misalignment varies by country.

This study also sets the stage for follow-up studies in this area. One possibility is a follow-up study among the dental professionals whose surgical loupes had been adjusted to co-axial alignment by the researcher, to ascertain if their responses to self-perceived visual acuity and quality of care would change with their surgical loupes now being in alignment. Similarly, one can conduct a follow-up study to see if the prevalence of co-axial misalignment changes among the dental professionals surveyed by this study. These dental professionals are now informed about the co-axial misalignment of their surgical loupes and have the measurement tool, so will they continue to practice with their misaligned surgical loupes, or will they replace their surgical loupes to achieve better co-axial alignment?

Moreover, since there has been no research on the effect of co-axial alignment and MSDs, another direction of a future studies would be to explore MSDs with dental educational institutions and practicing professionals in an attempt to identify a correlation between misaligned loupes and discomfort or MSDs. One can first follow-up with participants of this study to inquire if participants with misaligned surgical loupes suffer from more musculoskeletal symptoms than those with aligned surgical loupes and then expand the study to larger populations of dental professionals.

With regard to quality of care using surgical loupes, one could expand on this study by objectively comparing the outcomes of treatment with alignment and misaligned surgical loupes and see if there is correlation between self-reported quality of care and objective measures of outcomes of treatment. For example, one could conduct an experiment similar to what Mohan *et al*. performed: scale/root plan on teeth scheduled for extraction then utilize electron microscopy

to compare the outcomes of debridement on those extracted teeth.(74) Rather than comparing outcomes of debridement with and without surgical loupes, this experiment can compare outcomes with aligned and misaligned surgical loupes. It might also be possible to implement a split-mouth design, where the same dental hygienist can instrument on half of the mouth wearing aligned surgical loupes and then the other half of the mouth wearing misaligned surgical loupes, then compare the outcomes of treatment by measuring the patient's healing responses (such as bleeding and pocket depths).

The co-axial alignment measurement tool can be further refined through future research. It has been observed that although participants were able to report half units of misalignment, participants appear to have a tendency of rounding up to the nearest whole unit. Therefore, instead of asking participants to report in half units (*e.g.* 1.5 units), a future study could explore the possibility of working with units smaller than 6.5 mm and asking participants to report in whole units only. One could design an experiment with increasingly narrower grids/ smaller units and find the point at which a unit becomes too small for dental clinicians to reliably distinguish (this value might also depend on clinicians' age and magnification power of the surgical loupes). Alternatively, a future study could explore a tool which adopts millimetre measurements instead of arbitrary units; however surgical loupes users may find millimetres on the side of a grid even more difficult to read and report.

This study has focused only on the *vertical* alignment between the magnification lenses of the surgical loupes and the eye line of the clinician. There exists another dimension of alignment, which is the *horizontal* alignment between the eyes of the clinician and the position of the magnification lenses.(82) To maintain single binocular vision when viewing an object, a person's eyes will need to simultaneously move inwards towards each other, a phenomenon known as convergence.(99) The magnification lenses of surgical loupes need to be aligned horizontally with the eyes of the clinicians when the eyes are in convergence, or else the clinician might experience blurry or double vision when looking through the surgical loupes.(99) Many surgical loupes manufacturers have managed horizontal alignment by measuring and adjusting inter-pupillary distance at point of purchase.(82) Horizontal misalignment is also very noticeable by

surgical loupes users due to the blurry or double vision it creates. However, there has yet to be a study specifically on horizontal alignment of surgical loupes among dental professionals and thus might be a valuable subject of future investigation.

Lastly, a future study should be conducted to determine if a “clinically tolerable range” exists for co-axial misalignment of surgical loupes. Since the co-axial alignment measurement tool can provide information on the severity of misalignment, one could conduct a future study in which participants were given aligned surgical loupes first, then slowly increase units of misalignment to see at what unit of misalignment the participant experiences discomfort. This study could also determine if clinically tolerable range varies by clinician and assess other participant contributing factors (*e.g*. age, gender, or years in practice).

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Appendices

Appendix A Appendix: 15-minute in-person Survey

Part One: Demographic information

1. Which year were you born?

2. Gender:

A. Male
B. Female
C. Other

3. How many years have you been practicing dentistry? If you are a student, put down which year of the program you are in (ie. 1st year DMD, 2nd year DHDP):

4. Role in dental practice:

A. Dentist
B. Hygienist
C. Certified Dental Assistant
D. Other (Please specify_____)

5. Are you a student or faculty member of an educational institution?

A. Neither
B. Student
C. Faculty

Part Two: About the loupes

1. Type of Loupes:

    A. Through-the -lens
    B. Flip-up Mounted
    C. Other (specify) _____

2. Magnification:_____x

3. Manufacturing Company:

4. How old the loupes are (if known):_____years

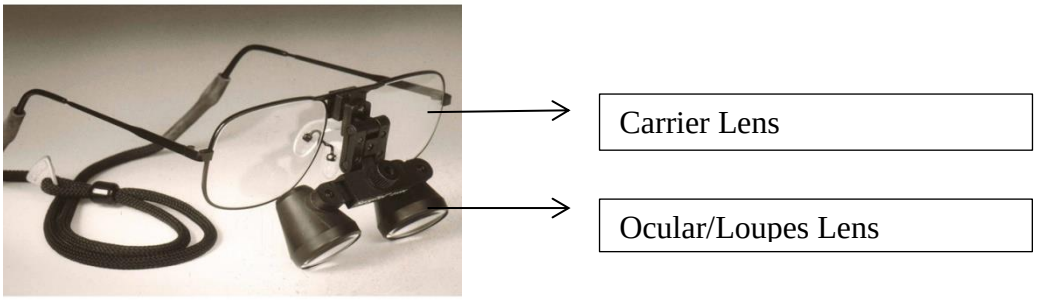
5. Distance between eyes and target (as measured by the researcher): _____cm

6. Are any of the lenses optically corrected?

A. Yes
B. No (skip to question 10)

7. If yes, which side(s) is (are) corrected?

A. Not sure
B. Both left and right eye
C. Left eye only
D. Right eye only



8. Are the carrier lenses optically corrected?

A. Not sure
B. Both left and right eye
C. Left eye only
D. Right eye only

9. Are the ocular (loupe) lenses optically corrected?
A. Not sure
B. Both left and right eye
C. Left eye only
D. Right eye only

10. Approximate time since your last visit to ophthalmologist/optometrist:____ months

Part Three: Usage Patterns

1. How often do you wear your loupes while working in a dental situation?
A. Never
B. Rarely
C. Occasionally
D. Frequently
E. Almost always

2. During what procedures do you look through the lens of your loupes?

□ Examination (dental, occlusal, intraoral, extraoral)
Yes No Not Applicable

□ Radiographic interpretation
Yes No Not Applicable

□ Periodontal assessment (including probing)
Yes No Not Applicable

□ Scaling/Root Planing
Yes No Not Applicable

□ Polishing/prophylaxis
Yes No Not Applicable

□ Direct restoration
Yes No Not Applicable

□ Crown and bridge
Yes No Not Applicable

- Simple extractions
  Yes No Not Applicable

- Complex oral surgery
  Yes No Not Applicable

- Orthodontics
  Yes No Not Applicable

- Other (please specify): _____)

Part Four: Perception

1. Please indicate the extent to which you agree with the following statement: “I feel that I can see well wearing my loupes.”

2. Strongly agree
3. Agree
4. Neutral
5. Disagree
6. Strongly Disagree

3. Please indicate the extent to which you agree with the following statement: “I feel that I can provide improved quality of care wearing my loupes.”

1. Strongly agree
2. Agree
3. Neutral
4. Disagree
5. Strongly Disagree

Appendix B Letter of Introduction

UBC DENTISTRY | THE UNIVERSITY OF BRITISH COLUMBIA

Re: Are your Surgical loupes working for you?

Thank you for expressing interest in our study. I am a Master's student at the Faculty of Dentistry at the University of British Columbia. As part of my MSc. requirements, I will be conducting a survey study. The purpose of this letter is to provide you with further insight of our study.

Surgical telescopes, or "loupes", have been increasingly popular among dental professionals in North America. Today, over 60% of dental professionals in British Columbia are reported to wear loupes at some point of patient care. Current research suggests that the loupes provide better visual acuity and increased ergonomic benefits. However, dental professionals will only receive the full benefits of surgical loupes if the loupes are adjusted to fit the specific and individual needs of each clinician. Incorrectly adjusted surgical loupes are associated with poor clinician posture and visual acuity, which can lead to increased muscle fatigue and pain for the clinician as well as compromised safety for the patients. In this research project, the safe and effective use of surgical loupes among dental professionals in B.C. will be examined by measuring the co-axial alignment of clinicians' surgical loupes, a key indicator for the proper adjustment of these optical systems.

By participating in this study, you will get the opportunity to find out if your loupes are properly adjusted for your own needs. If you choose to participate, I will meet you at a time and location of your preference. I will measure the co-axial alignment of your surgical loupes and collect information on participant demographics and usage patterns. This entire survey will take approximately **15** minutes. Your participation in this study is voluntary and all measures will be in place to protect your confidentiality and anonymity.

Please feel free to contact myself or my Graduate supervisor, Dr. Lance Rucker if you have any further questions or concerns about our study. We look forward to meeting you soon.

Sincerely,

Lance M. Rucker, AB, BScD, DDS Professor, Oral Health Sciences Director, Surgical Telescope Evaluation Program The University of British Columbia 2199 Wesbrook Mall, Vancouver, BC V6T 1Z3	Maggie Wen, BSc, Dip DH, MSc (Cand), RDH The University of British Columbia 2199 Wesbrook Mall, Vancouver, BC V6T 1Z3

Appendix C Letter of Consent

UBC DENTISTRY | THE UNIVERSITY OF BRITISH COLUMBIA

Consent Form
Study Title: Are your loupes working for you? An exploratory study

I. Who is doing the study?

Principal Investigator: Lance M. Rucker, AB, BScD, DDS Professor, Oral Health Sciences Director, Surgical Telescope Evaluation Program The University of British Columbia 2199 Wesbrook Mall, Vancouver, BC V6T 1Z3	Co-investigator: Maggie Wen, BSc, Dip DH, MSc (Cand), RDH The University of British Columbia 2199 Wesbrook Mall, Vancouver, BC V6T 1Z3

Note to participants: Information shared in this study will be used in the graduate student's thesis and, thus, may form part of a public document if published. All information generated in this study will remain anonymous to all outside of the research team. All efforts will be made to ensure that you are not identified by others by changing or removing information that might otherwise identify you.

II. Why are we doing this study?

You are being invited to take part in this research study because you are currently a practising dental professional in BC who work with dental surgical loupes. Over 60% of dental professionals in BC now wear surgical loupes so the purpose of this study is to identify the issue of fitting and adjustment of loupes among BC dental professionals; and whether fitting and adjustment of surgical magnification systems are associated with usage patterns as well as musculoskeletal symtoms.

III. What happens to you in the study?

If you decide to participate in this study, the co-investigator identified above will meet you at a time and location of your convenience. The co-investigator will measure the co-axial alignment of your surgical loupes, a key indicator in fitting and adjustment of these optical systems. You will then be asked to complete a form with questions on your demographic information and loupes usage patterns. This entire survey will take **one** visit of approximately **15 minutes**.

Your participation in this study is voluntary; therefore, you are free to withdraw from the study at any time. You have the right to refuse to answer any questions, to request to stop the survey at any time and to withdraw any information you do not wish to be included in this study. Should you withdraw, the information you have provided up to the point of your withdrawal will not be used in the data analysis, unless you consent to have it included. If you are a current student or Faculty at the Faculty of Dentistry at the University of British Columbia, please be assured that choosing or refusing to participate in this study will not affect your grading or employment status in any way (all current students of Ms. Maggie Wen will be excluded from the study to further avoid any concerns about coercion).

IV. How will the study be reported?

The results of this study will be reported in a graduate thesis and may also be published in journal articles, seminars and conferences. The results of the study will also be made available on UBC Dentistry's Clinical Ergonomics website (http://www.dentistry.ubc.ca/ergo/) and can be e-mailed to you if you wish. Check the box on page 4 if you want to hear directly about findings from this study.

V. What are the benefits of participating?

By participating in this study, you will get the opportunity to find out if your loupes are misaligned optically for your own needs. You will also gain access to UBC dentistry's online ergonomics learning modules, where the findings of this study will be integrated and disseminated.

VI. What are the risks of participating?

We do not think there is anything in this study that could harm you or be bad for you. However, you do not have to answer any question if you do not want to.

VII. Who can you contact if you have questions about the study?

If you have any questions or concerns about what we are asking of you, please contact the principal investigator, Dr. Lance Rucker or the co-investigator, Ms. Maggie Wen . Their names and telephone numbers are listed at the top of the first page of this form.

VIII. Contacts for complaints

If you have any concerns or complaints about your rights as a research participant and/or your experiences while participating in this study, contact the Research Participant Complaint Line in the UBC Office of Research Ethics at 604-822-8598 or if long distance e-mail RSIL@ors.ubc.ca or call toll free 1-877-822-8598.

IX. Participant consent and signature page

Taking part in this study is entirely up to you. You have the right to refuse to participate in this study. If you decide to take part, you may choose to pull out of the study at any time without giving a reason and without any negative impact on your employment, class standing or licensure.

- Your signature below indicates that you have received a copy of this consent form for your own records.
- Your signature indicates that you consent to participate in this study.

_____

Participant Signature Date
(or Parent or Guardian Signature)