Original Contributions

Out of the loupe

The prevalence of coaxial misalignment of surgical loupes among dental professionals

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ABSTRACT

Background. Surgical loupes have been increasingly popular among dental professionals for their visual and postural benefits. However, dental professionals will receive the full benefit of surgical loupes only if the loupes are adjusted fully to fit the individual needs of each clinician. In this study, the authors examine coaxial alignment of surgical loupes, a critical criterion for the proper adjustment of these optical systems.

Methods. The authors conducted an in-person survey by using a simple, quantitative visual tool to assess the coaxial alignment of surgical loupes among 97 dental professionals in British Columbia, Canada.

Results. Findings indicated that 82% of dental professionals surveyed experienced coaxial misalignment with their surgical loupes. Dental professionals wearing front—lens-mounted (flip-up) surgical loupes with full vertical adjustability, front—lens-mounted surgical loupes with limited vertical adjustability, and through-the-lens surgical loupes were equally likely to be practicing with coaxial misalignment of their surgical loupes. Front—lens-mounted surgical loupes with full vertical adjustability were the only type of surgical loupe that can be adjusted to achieve full coaxial alignment reliably ($P < .05$).

Conclusions. There was a high prevalence of coaxial misalignment among dental professionals in this cohort. Not all surgical loupes on the market satisfy the criteria for optimal postural and visual support of clinicians.

Practical Implications. The visual tool developed in this study enabled dental professionals to identify coaxial misalignment effectively and efficiently. Findings from this study will assist dental professionals in making informed decisions when choosing their magnification equipment and prompt surgical loupe manufacturers to develop more evidence-based products.

Key Words. Magnification; ergonomics; dentists; dental hygienists.

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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] These devices usually consist of frames and carrier lenses similar to those of regular glasses or protective goggles, with binocular magnifying lenses either mounted on the frames or fixed in the carrier lenses (Figure 1). Depending on how the magnifying lenses are integrated, the devices can be divided into 3 categories: front—lens-mounted (FLM) with full vertical adjustability (FVA) surgical loupes, FLM with limited vertical adjustability (LVA) surgical loupes, and through-the-lens (TTL) surgical loupes. As Figure 1 illustrates, FLM plus FVA surgical loupes have a center slide that allows full vertical movement of the mounted magnifying lenses. FLM plus 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 available with FLM plus FVA surgical loupes. 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.[3,4]

Over the past 2 decades, surgical loupes have been increasingly popular among dental professionals for their visual and postural benefits.[5-10] In British Columbia, Canada, more than 60% of dental clinicians practice with surgical loupes, and many dental educational institutions have made

surgical loupes mandatory for students in all preclinical and clinical environments.[5] However, dental professionals will receive the full benefit of surgical loupes only if the loupes are fitted to the individual needs of each clinician.[11] Clinicians practicing with misaligned surgical loupes may experience serious effects on their posture and the quality of care they deliver.[12]

Previous researchers have identified 3 critical criteria for selecting and adjusting surgical loupes: working distance, declination angle of the oculars, and coaxial alignment.[3,11,12] Although investigators have researched the first 2 criteria more thoroughly, there remains limited understanding of coaxial alignment. Coaxial alignment refers to the vertical alignment between the magnified image seen through the surgical loupes and the observed object. A visual discrepancy can occur when misalignment takes place (Figure 2). Moreover, clinicians wearing misaligned surgical loupes might experience chromatic aberrations of the magnified image. Chromatic aberrations occur either when the magnifying lenses are unable to bring all color to the same focal plane or when different colors are focused at different positions in the focal plane.[13] As a result, the clinician might experience bright sparks of different colors in the magnified view.

To our knowledge, unlike with the 2 other critical criteria (working distance and declination angle) there has been no established reliable method to measure coaxial alignment quantitatively. Despite the ongoing popularity of wearing surgical loupes for dental procedures, among dental professionals, there is little understanding of the prevalence or severity of coaxial misalignment, as well as the clinical and ergonomic implications of practicing with coaxially misaligned surgical loupes. Moreover, to our knowledge, there has been no research to determine whether clinicians with different types of surgical loupes (that is, FLM plus FVA, FLM plus LVA, or TTL) are equally likely to experience coaxial misalignment. In this study, we aimed to address some of these research gaps.

METHODS

The coaxial alignment measurement tool

We developed a simple, quantitative tool to detect and measure coaxial misalignment (Figure 3A). We tested the tool for reliability and repeatability through 2 pilot studies with students (n = 11) and faculty (n = 6) at the University of British Columbia (UBC) Faculty of Dentistry. Results from the pilot studies indicated that this tool repeatedly can produce consistent measurements. We will publish the tool development process and results of the pilot studies separately.

How to use the coaxial alignment measurement tool

To measure the coaxial alignment of a given pair of surgical loupes, participating dental clinicians performed the following steps:

- donned the surgical loupes;
- looked at the coaxial alignment measurement tool through the surgical loupes and aligned the view so that the red dot was positioned or located in the center of the magnified field of view;
- used the color bands to ensure the red dot truly was centered vertically—specifically, the clinician needed to see the same color band on the top and bottom borders of the magnified view;
- checked whether the long red line extending from the red dot was aligned continuously or was broken between the magnified view and the unmagnified view;
- identified that if the red line was continuous (Figure 3A), then the surgical loupes were aligned coaxially for the clinician; otherwise, as Figure 3B shows, the surgical loupes are misaligned coaxially.

The tool contains 2 columns of arbitrary units on the right-hand side, indicating severity of misalignment (each unit = 6.5 millimeters). The 2 columns are mirrored vertically to address the issue of left and right dominance of the eyes. Clinicians who are left-eye dominant will need to rotate the paper 180° and have the columns on their left-hand side instead of the right. Each clinician using the tool identifies the number of units (to the nearest 0.5 unit) between the red line in the magnified view and the red line in the unmagnified view. For instance, Figure 3B shows an example of a misalignment of 2.5 units.

Participant sampling and recruitment

In this study, we used an in-person survey. The researchers used the measurement tool to assess coaxial alignment of participants' surgical loupes and then asked each participant to complete a 2-page questionnaire about demographic information. This survey took approximately 10 through 15 minutes for each participant to complete.

ABBREVIATION KEY

FLM:	Front lens mounted.
FVA:	Full vertical adjustability.
LVA:	Limited vertical adjustability.
MSD:	Musculoskeletal disorder.
NA:	Not applicable.
TTL:	Through-the-lens.
UBC:	University of British Columbia.

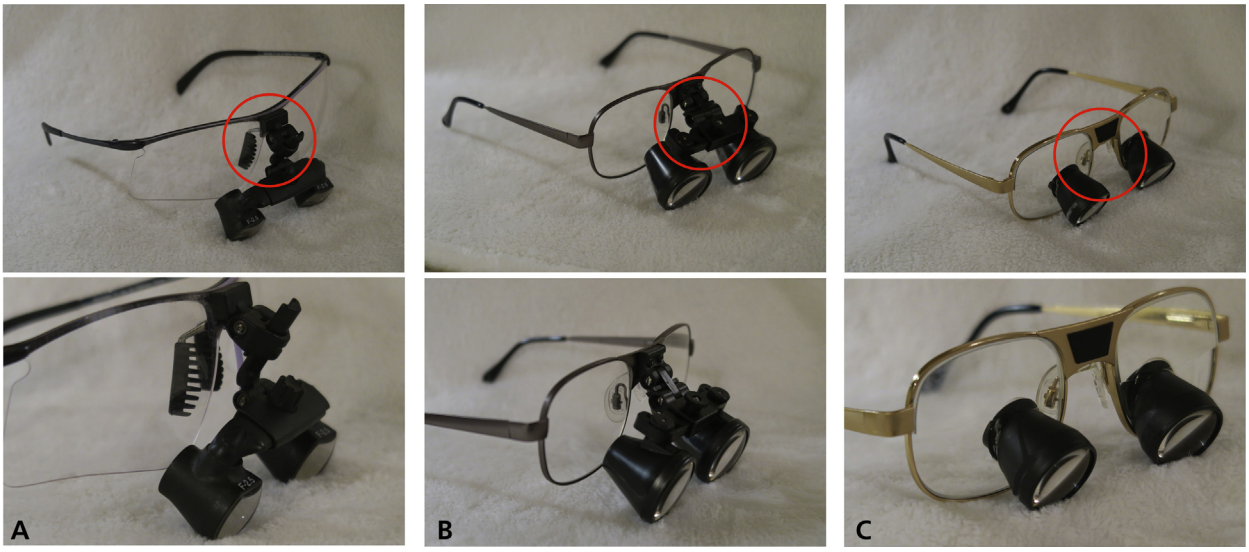


Figure 1. The 3 types of surgical loupes. **A.** Front—lens-mounted surgical loupes with full vertical adjustability. **B.** Front—lens-mounted surgical loupes with limited vertical adjustability. **C.** Through-the-lens surgical loupes. The red circles highlight the vertical adjustment mechanism of each type of surgical loupes. The researcher photographed all images.

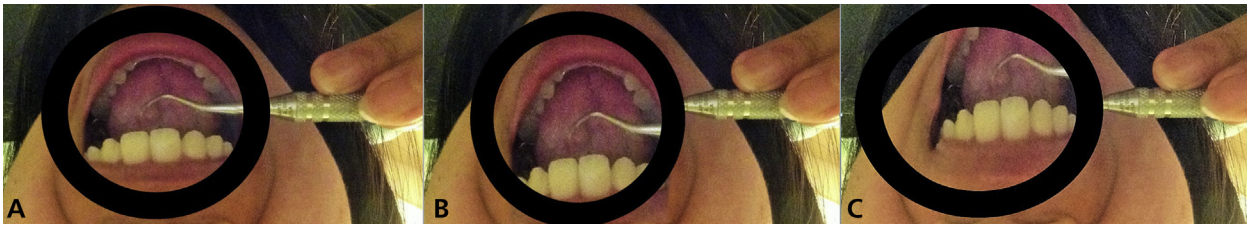


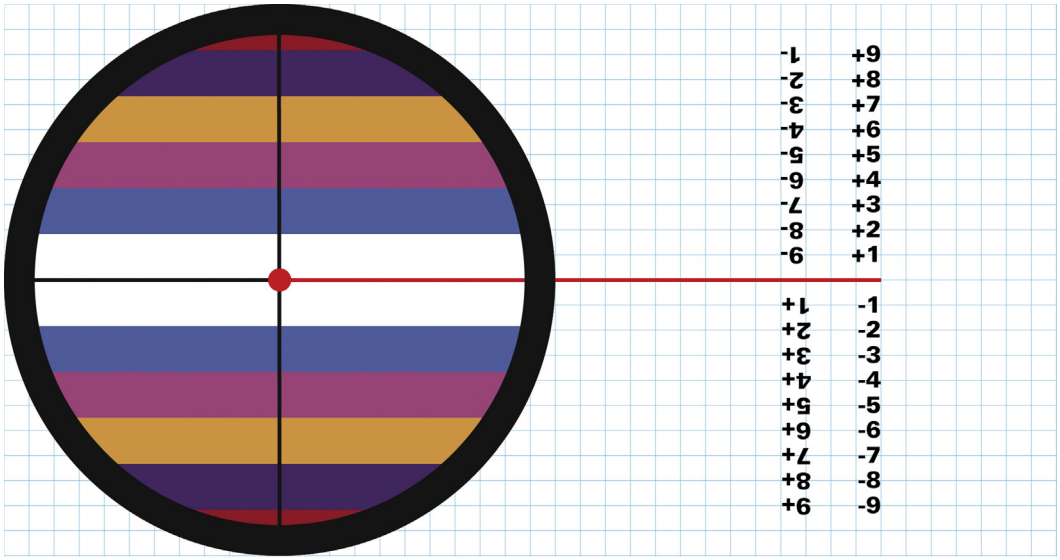
Figure 2. Coaxial alignment versus misalignment. **A**. The magnified image of a dental instrument and the actual instrument in coaxial alignment. **B**. The clinician's view when the magnified image of a dental instrument is lower than the actual instrument because of surgical loupe coaxial misalignment. **C**. The clinician's view when the magnified image of a dental instrument is higher than the actual instrument because of surgical loupe coaxial misalignment.

For this study, we recruited participants through posters and e-mails at the UBC Faculty of Dentistry and e-mails to all members of British Columbia Dental Association and British Columbia Dental Hygienists' Association. The e-mail recruitment messages were sent by third-party administrative staff at the UBC Faculty of Dentistry, British Columbia Dental Association, and British Columbia Dental Hygienists' Association in November and December 2014. The researchers also used snowball sampling; we encouraged participants to circulate the recruitment e-mail among their own professional circles. Interested people contacted the researchers directly to arrange 15-minute appointments. One researcher then traveled to a location of the participant's choice (either at the UBC clinic or at the participant's private practice) to meet the participant and conduct the study. The same researcher (W.W.) conducted all the surveys to avoid any variations between researchers.

Clinicians had to satisfy the following inclusion criteria:

- be a dental professional (that is, general dentist, dental specialist, or dental hygienist);
- practice in the British Columbia Lower Mainland;
- work clinically with surgical loupes.

For participants with misaligned surgical loupes, the researchers offered to adjust the surgical loupes and determine whether they could be aligned coaxially for the clinician after the adjustment. We offered this service to all participants with misaligned surgical loupes, including those with TTL types (by manipulating the frames and nosepieces). Only participants who consented to the adjustment had their surgical loupes adjusted, and the adjustment took place after the survey was completed and all data were recorded. We fully informed all participants, and they consented to participate on a signed form in accordance with the guidelines of the UBC Behavioural Research Ethics Board (certificate H14-01945).



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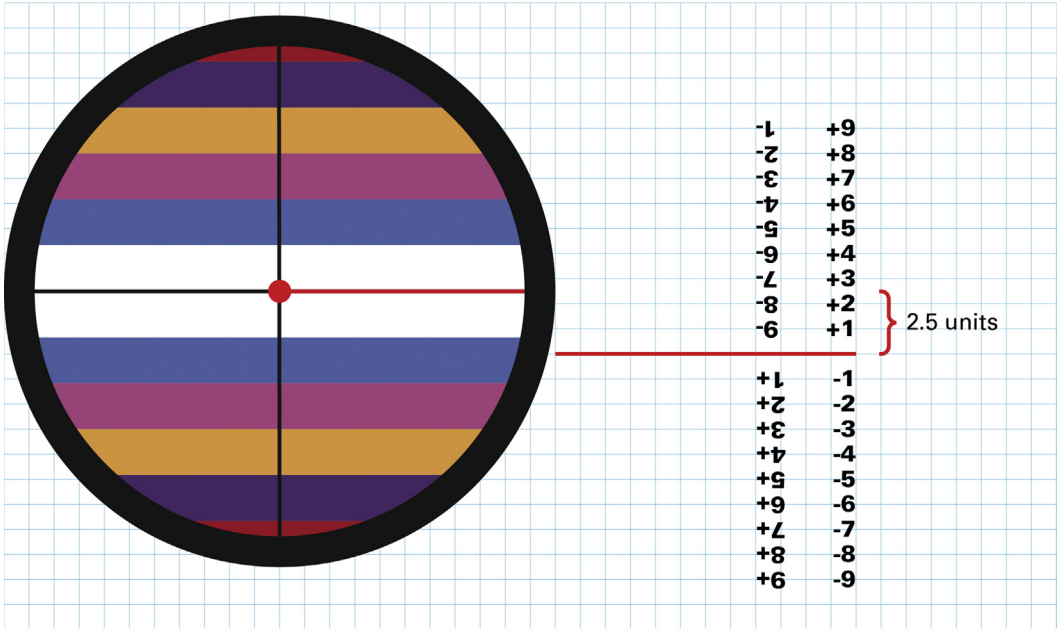

B

Figure 3. The coaxial alignment measurement tool and a misaligned view on the measurement tool. **A**. The coaxial alignment measurement tool. **B**. A coaxially misaligned view of 2.5 units according to the measurement tool. Reproduced with permission from Wen (Maggie) Wen and Dr. Lance Rucker.

Statistical analysis

We analyzed categorical data such as sex, profession, and surgical loupe manufacturer and type by using the Fisher exact test. For continuous data such as a clinician's age and number of years in practice, we used the Wilcoxon-Mann-Whitney test. All the tests were 2-sided, and we considered the results statistically significant at P less than .05 (95% confidence interval). In addition, we calculated post hoc statistical power by using software (OpenEpi, www.openepi.com). The assumption we used for post hoc power calculation was with the α set to .05, and we considered power sufficient if it were to reach 80% or greater.

RESULTS

From the 97 dental professionals surveyed, only 17 (18%) were practicing with coaxially aligned surgical loupes. The remaining 80 (82%) participants were practicing with coaxially misaligned surgical loupes and were, thus, experiencing a visual discrepancy as illustrated in Figures 2 and 3.

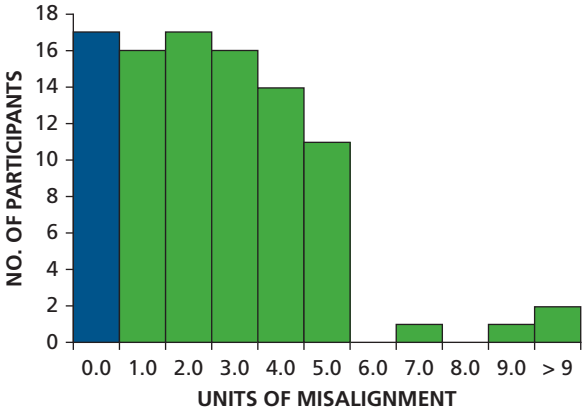

Figure 4. Distribution of coaxial misalignment among the 97 practicing dental professionals in British Columbia. Blue indicates alignment, and green indicates misalignment (1 unit = 6.5 millimeters).

Table 1. Demographic variables of 97 participants in relation to the coaxial alignment of their surgical loupes.

VARIABLE	ALL	ALIGNED	MISALIGNED	*P* VALUE
Total, No. (%)	97 (100)	17 (18)	80 (82)	NA*
Sex, No. (%)				
Male	34 (35)	5 (15)	29 (85)	.781
Female	63 (65)	12 (19)	51 (81)	
Age, y, Mean (SD†)	43 (13)	46 (11)	43 (14)	.227
Years in Practice, Mean (SD)	17 (13)	19 (12)	16 (13)	.500
Role in Dental Practice, No. (%)				
Dentist	53 (55)	10 (19)	43 (81)	.792
Hygienist	44 (45)	7 (16)	37 (84)	
Faculty, No. (%)				
Yes	45 (46)	7 (16)	38 (84)	.937
No	52 (54)	10 (19)	42 (81)	

* NA: Not applicable. † SD: Standard deviation.

Figure 4 shows the severity of misalignment and its distribution among the 97 participants. Given that each unit measures 6.5 mm on the coaxial alignment measurement tool, the severity of misalignment that many of the participants were experiencing would correspond to the entire working length of a dental instrument, and, in some cases, this visual discrepancy would be equivalent to a patient's maximum oral opening.

Demographic variables

Table 1 presents participants' demographic variables. Overall, clinician's sex, role in dental practice, age, number of years in practice, or faculty status was not a reliable predictor of the coaxial alignment of their surgical loupes.

Manufacturing companies

The 3 most popular manufacturing companies we found in this study were SurgiTel, Orascoptics, and Designs for Vision. Together, these 3 companies accounted for 77 pairs of surgical loupes (79.4%) surveyed. Two participants reported that their surgical loupes were of unknown manufacturers because these participants simply purchased their surgical loupes from online stores that did not disclose the name of the manufacturer. There were no identifying markings on these 2 pairs of surgical loupes.

Table 2 displays the breakdown of surgical loupes for each manufacturer, sorted according to the percentage of aligned surgical loupes in descending order. We calculated the percentages only for

Table 2. The number of coaxially aligned and misaligned surgical loupes for each manufacturer.

MANUFACTURER	FLM*		TTL†	TOTAL	ALIGNED‡	MISALIGNED‡	*P* VALUE§
	FVA¶	LVA#					
SurgiTel	26	0	1	27	7 (26%)	20 (74%)	
Orascoptic	2	2	23	27	7 (26%)	20 (74%)	.214
Designs for Vision	0	0	23	23	2 (9%)	21 (91%)	
Zeiss	0	2	0	2	1	1	NA**
Heine	2	3	0	5	0	5	NA
Q-Optics	2	0	1	3	0	3	NA
ExamVision	0	0	2	2	0	2	NA
Univet	0	0	1	1	0	1	NA
Other††	0	2	3	5	0	5	NA
Unknown‡‡	0	2	0	2	0	2	NA

* FLM: Front lens mounted. † TTL: Through-the-lens. ‡ The authors calculated the percentage aligned and the percentage misaligned only for the top 3 manufacturers because the total count was too small for all other manufacturers. § The authors calculated the *P* value only for the top 3 manufacturers because the total count was too small for all other manufacturers. ¶ FVA: Full vertical adjustability. # LVA: Limited vertical adjustability. ** NA: Not applicable. †† Other includes Rose Micro Solutions (2 pairs), Snap On Optics (1 pair), SheerVision (1 pair), and Brasseler USA (1 pair). ‡‡ The participants purchased these surgical loupes from online stores and did not know the name of the manufacturer.

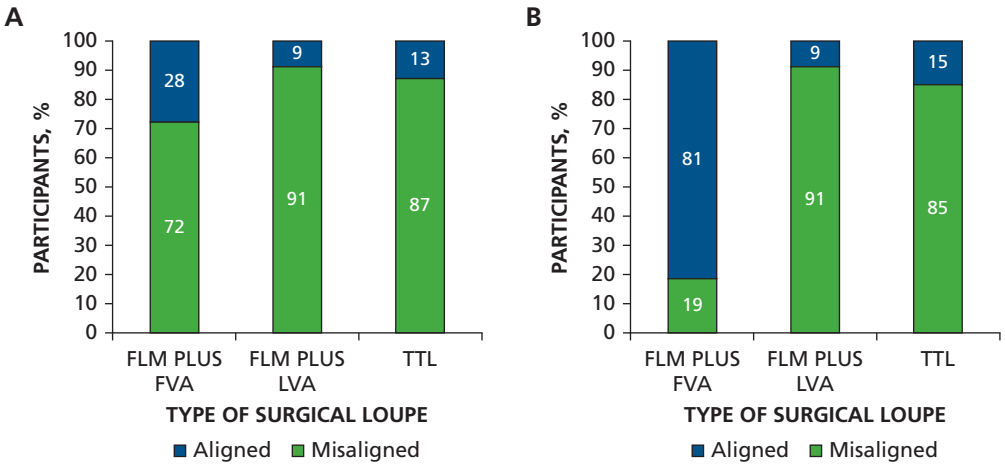

Figure 5. **A**. The prevalence of coaxial misalignment for each type of surgical loupe before adjustment ($P = .167$). **B**. The prevalence of coaxial misalignment for each type of surgical loupe after adjustment ($P = .000$). FLM: Front–lens-mounted. FVA: Full vertical adjustability. LVA: Limited vertical adjustability. TTL: Through-the-lens.

the top 3 manufacturers because the total counts were too small for all other manufacturers for the data to make a fair statistical representation of their products. Although Designs for Vision had a greater proportion of misaligned surgical loupes than did the other 2 top manufacturers, the results were not statistically significant among the top 3 companies regarding the number of coaxially misaligned surgical loupes ($P = .214$).

FLM versus TTL types

Among the 97 participants, 54 used TTL surgical loupes, and 43 used FLM surgical loupes. Among the 43 participants with FLM surgical loupes, 32 participants used FLM plus FVA surgical loupes, and 11 participants used FLM plus LVA surgical loupes. Before the researcher made any adjustments, the prevalence of misalignment was high across all 3 types of surgical loupes ($P = .167$) (Figure 5A).

Among the 80 participants who used coaxially misaligned surgical loupes, 26 participants consented to have their surgical loupes adjusted by the researcher. Eighteen pairs of surgical loupes were

able to achieve full coaxial alignment after the adjustment: 17 of these were FLM plus FVA, 1 was TTL, and 0 were FLM plus LVA. The remaining 8 participants experienced 0.5 through 3.0 units of reduction in misalignment, but their surgical loupes could not achieve full coaxial alignment after adjustment.

Figure 5B shows the prevalence of misalignment after adjustment. FLM plus FVA loupes were significantly more likely to be adjustable to full coaxial alignment than were FLM plus LVA or TTL loupes ($P < .05$).

DISCUSSION

Prevalence and implications of coaxial misalignment

To our knowledge, there has been no previous research on the prevalence or implications of coaxial misalignment of surgical loupes among dental professionals. The existing report was limited to describing the phenomenon.[12] However, dental professionals experience an adjustment period when they first start using surgical loupes, and up to 50% of novice surgical loupe users identified that the adjustment period serves as the most significant disadvantage of using surgical loupes.[14-16] Although most dental professionals will experience an initial adjustment period when integrating magnification into practice,[4] the results of this research suggest that the visual discrepancy and chromatic aberrations caused by coaxial misalignment may be significant contributors to the prolonged adjustment period, eyestrain, headaches, and vertigo that many clinicians experience.

Results of a study conducted by Hayes and colleagues[14] involving 12 dental hygienists revealed that although all participants were using surgical loupes during a 6-month study, 75% of the participants discontinued using surgical loupes afterward because of the lengthy adjustment period, limited depth of vision, headache, and vertigo. Similarly, results of another study involving 116 dental students indicated that 20% of the students had difficulty adapting to surgical loupes after the first year.[16] Narula and colleagues[17] also reported the discomfort of using surgical loupes; 25% of dental students reported discomfort when performing tooth preparation with surgical loupes. None of these studies' investigators checked for coaxial alignment of the surgical loupes they provided to the participants for the studies. Therefore, it is possible that coaxial misalignment contributes to the clinician's symptoms and lengthy adjustment period. These participants could be experiencing vertigo from working with visual discrepancies (some of the discrepancies measured in the current study were of greater dimension than the size of the opened human mouth) or experiencing headaches and eyestrain from seeing double vision when they look through their 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 clinical significance to warn that coaxial misalignment of surgical loupes has a potentially significant effect on patient safety and quality of patient care. As identified by Fehrenbach and Weiner,[18] 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. A dental clinician with misaligned surgical loupes is often uncertain as to the precise spatial location of each facial anatomic feature, and clinicians frequently and intermittently may move their hands up and down to align the magnified image seen through the surgical loupes with the proprioceptively sensed center of attention. All such compensatory strategies by the clinician to try to compensate for misaligned surgical magnification greatly increase the potential for loss of control of the instruments near the patient's face and potential for patient injury. Moreover, a dental clinician with misaligned surgical loupes might be at higher risk of contacting an incorrect tooth or area of the mouth because the magnified image seen through the surgical loupes could be multiple centimeters away from the intended tooth. Although this study's survey did not specifically include an open comment section, a few participants observed that they periodically hit the patient's chin with their instruments.

Lastly, wearing misaligned surgical loupes might affect dental professionals' musculoskeletal health. Results of existing research indicate that repetitive motions are 1 of the major contributors to musculoskeletal disorders (MSDs) among dental professionals.[19-21] Therefore, the repeated movement of the clinician's neck and hands to line up the instruments potentially can 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) also may aggravate or worsen existing symptoms for dental professionals who already have MSDs in the neck and shoulder area.[22] Hayes

and colleagues[23,24] and Ludwig and colleagues[25] found mixed results on the effect of surgical loupes on upper body MSDs and body orientation. Because these investigators did not check for coaxial alignment of surgical loupes to the participants, some of the surgical loupes used in these studies may have been misaligned and may have contributed to the mixed results.

It is also possible that coaxial misalignment coincides with poor declination angles, especially in situations in which adjustability is limited. Declination angle is the angle to which the dental clinicians can lower their eyes comfortably when working with a patient.[11] Wearing surgical loupes with improper declination angles may cause the clinician to bend his or her neck unnecessarily to look through the magnifying lenses of the surgical loupes.[26] Working in such unbalanced postures over an extended period can impose tension on the neck muscles much higher than that of daily activities.[27] Such muscle overload prevents blood circulation and causes increased pressure on the surrounding body structures, resulting in pain, discomfort, and limited functionality in those who are affected.[23] Existing research results indicate that forward neck bending in excess of 30° significantly increases the static load on the spine, thereby elevating one's risk of developing headaches, neck pain, and upper and lower back pain.[28] Therefore, surgical loupes with FVA do not just enable a significant decrease in coaxial misalignment but also provide an opportunity to set more precise declination angles, hence further improving clinicians' musculoskeletal health.

FLM versus TTL types

Because FLM plus FVA surgical loupes offer FVA, the researchers expected that the prevalence of coaxial misalignment to be lower among dental professionals using FLM plus FVA surgical loupes than that of dental professionals using FLM plus LVA or TTL surgical loupes. We also expected a difference in the prevalence of misalignment among various manufacturers because some companies made both FLM plus FVA and TTL loupes, whereas others made only TTL loupes (Table 2).

However, the results indicated that the prevalence of misalignment was high across all 3 types (Figure 5A), which suggests either that dental professionals are uninformed about the level of adjustability of their surgical loupes or that they are not using the adjustable features of their surgical loupes fully. In other words, having fully adjustable surgical loupes does not mean these surgical loupes are necessarily fully adjusted to fit the individual needs of each clinician. Approximately one-third of dental professionals surveyed had never opened or had misplaced the adjustment tools that accompanied their original purchase, indicating that adjustment and alignment of surgical loupes were not part of their clinical routine. These findings strongly support the need for a simple coaxial alignment measurement tool such as the 1 we developed for our study.[29] This tool survey can be used to help dental professionals self-assess, adjust, and align their surgical loupes on a regular basis.

Despite the high prevalence of misalignment, only 26 of the 80 dental professionals agreed to have their surgical loupes adjusted by the researcher to see whether improvements could be made. This reluctance could be owing to the clinicians' 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. The results also indicated that FLM plus FVA loupes can be adjusted most reliably to full coaxial alignment (Figure 5B). We expected this result because, although the other 2 types offer some level of vertical adjustability, they do not have the full range of vertical movement that FLM plus FVA types can offer and, therefore, may not be adjustable to achieve full coaxial alignment to the clinician.

Some limitations of this study are small sample size and low statistical power, as indicated by the post hoc power calculation. Most practicing dental professionals who responded to this study were limited to the metropolitan Vancouver geographic area, and 46% of the practicing dental professionals surveyed were faculty members from dental educational institutions. Although there is no existing evidence, to our knowledge, of the relationship among geographic location, employment status, and the use of surgical loupes, this sample may not be a fair representation of all dental professionals.

CONCLUSIONS

This study is 1 of the few investigations in which investigators explore the fitting and adjustment of surgical loupes to their users. In this study, we contribute to the existing literature by using a simple quantitative tool to measure coaxial alignment of surgical loupes, revealing a high prevalence of coaxial misalignment (82%) among surgical loupe users. Working with coaxial misalignment may lead to musculoskeletal issues for the clinician and affect the quality of care

delivered to patients. This study's results also indicated that many surgical loupes cannot meet the coaxial alignment requirements fully for the clinician. The findings of this study not only will enable dental professionals to make more informed decisions about selecting and implementing surgical loupes but also will promote improvement of surgical loupe product design and functionality among manufacturers. ■

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Disclosure. Dr. Rucker stated that he has been called on over the past 3 decades to advise and review surgical loupe designs and evaluations for more than 10 of the several dozen manufacturers of surgical loupes. In no way has any of this influenced the position presented in this article, despite a collective wisdom that has emerged to suggest that all manufacturers (and all of their customers, including dentists) are well advised to understand the principles and information gathered and reported in this study to ensure that dentists' and hygienists' choices of products and verification of the correct adjustment of whichever loupes they have chosen are maintained in daily practice. None of the other authors reported any disclosures.

1. Stanbury SJ, Elfar J. The use of surgical loupes in microsurgery. *J Hand Surg Am*. 2011;36(1):154-156.
2. Strassler HE, Syme SE, Serio F, Kaim JM. Enhanced visualization during dental practice using magnification systems. *Compend Contin Educ Dent*. 1998;19(6):595-598, 600, 602 passim.
3. Chang BJ. Ergonomic benefits of surgical telescope systems: selection guidelines. *J Calif Dent Assoc*. 2002; 30(2):161-169.
4. Rucker L, Sunell S. Ergonomic risk factors associated with clinical dentistry. *J Calif Dent Assoc*. 2002;30(2): 139-148.
5. Sunell S, Rucker L. Surgical magnification in dental hygiene practice. *Int J Dent Hyg*. 2004;2(1):26-35.
6. Dable RA, Wasnik PB, Yeshwante BJ, Musani SI, Patil AK, Nagmode SN. Postural assessment of students evaluating the need of ergonomic seat and magnification in dentistry. *J Indian Prosthodont Soc*. 2014;14(suppl 1):51-58.
7. Eichenberger M, Perrin P, Neuhaus KW, Bringolf U, Lussi A. Visual acuity of dentists under simulated clinical conditions. *Clin Oral Investig*. 2013;17(3):725-729.
8. Perrin P, Ramseyer ST, Eichenberger M, Lussi A. Visual acuity of dentists in their respective clinical conditions. *Clin Oral Investig*. 2014;18(9):2055-2058.
9. Branson BG, Bray KK, Gadbury-Amyot C, et al. Effect of magnification lenses on student operator posture. *J Dent Educ*. 2004;68(3):384-389.
10. Hoerler SB, Branson BG, High AM, Mitchell TV. Effects of dental magnification lenses on indirect vision: a pilot study. *J Dent Hyg*. 2012;86(4):323-330.
11. Rucker L, Beattie C, McGregor C, Sunell S, Ito Y. Declination angle and its role in selecting surgical telescopes. *JADA*. 1999;130(7):1096-1100.
12. Rucker L, Sunell S. Selecting surgical telescopes for dental hygiene practice. *Can J Dent Hyg*. 2005;39(2):54-66.
13. Sebastian S, Burge J, Geisler WS. Defocus blur discrimination in natural images with natural optics. *J Vis*. 2015;15(5):16.
14. Hayes M, Taylor J, Smith D. Introducing loupes to clinical practice: dental hygienists experiences and opinions. *Int J Dent Hyg*. 2016;14(3):226-230.
15. Thomas J, Thomas FD. Dental hygienists' opinions about loupes in education. *J Dent Hyg*. 2007;81(4):82-89.
16. Maggio MP, Villegas H, Blatz MB. The effect of magnification loupes on the performance of preclinical dental students. *Quintessence Int (Berl)*. 2011;42(1): 45-55.
17. Narula K, Kundabala M, Shetty N, Shenoy R. Evaluation of tooth preparations for Class II cavities using magnification loupes among dental interns and final year BDS students in preclinical laboratory. *J Conserv Dent*. 18(4):284-287.
18. Fehrenbach MJ, Weiner J. *Saunders Review of Dental Hygiene*. 2nd ed., St. Louis, MO: Saunders; 2008:398-420.
19. Hayes MJ, Smith DR, Cockrell D. An international review of musculoskeletal disorders in the dental hygiene profession. *Int Dent J*. 2010;60(5):343-352.
20. Leggat PA, Kedjarune U, Smith DR. Occupational health problems in modern dentistry: a review. *Ind Health*. 2007;45(5):611-621.
21. Morse T, Bruneau H, Dussetschleger J. Musculoskeletal disorders of the neck and shoulder in the dental professions. *Work*. 2010;35(4):419-429.
22. Hayes M, Cockrell D, Smith DR. A systematic review of musculoskeletal disorders among dental professionals. *Int J Dent Hyg*. 2009;7(3):159-165.
23. Hayes MJ, Osmotherly PG, Taylor JA, Smith DR, Ho A. The effect of wearing loupes on upper extremity musculoskeletal disorders among dental hygienists. *Int J Dent Hyg*. 2014;12(3):174-179.
24. Hayes MJ, Osmotherly PG, Taylor JA, Smith DR, Ho A. The effect of loupes on neck pain and disability among dental hygienists. *Work*. 2016;53(4):755-762.
25. Ludwig EA, McCombs GB, Tolle SL, Russell DM. The effect of magnification loupes on dental hygienists' posture while exploring. *J Dent Hyg*. 2017;91(4): 46-52.
26. Valachi B. Ergonomic positioning: a few degrees add years to your career. *Dent Today*. 2010;29(9): 124-126.
27. Pîrvu C, Pătraşcu I, Pîrvu D, Ionescu C. The dentist's operating posture: ergonomic aspects. *J Med Life*. 2014;7(2):177-182.
28. Marklin RW, Cherney K. Working postures of dentists and dental hygienists. *J Calif Dent Assoc*. 2005; 33(2):133-136.
29. Wen W, Rucker L. Visual tool to assess co-axial alignment of surgical telescopes. Available at: https://secure.dentistry.ubc.ca/survey/app/fb_01/PDF/Co-axial_Alignment_Tool_and_Instructions.pdf. Accessed October 28, 2018.