ORIGINAL ARTICLE

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Surgical magnification in dental hygiene practice

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Abstract: The potential for improving the occupational health of dental clinicians has expanded as increasingly sophisticated equipment enters the marketplace, yet there has been little improvement to the ergonomics with which dental hygienists operate. The use of surgical magnification has great potential to increase the quality of dental hygiene clinical care and to support the musculoskeletal health of dental hygienists. Although the research evidence to support a relationship between the use of surgical magnification and increased quality of dental hygiene care is extrapolated from parallel studies in dentistry, specific dental hygiene studies suggest that the integration of surgical magnification would be helpful in reducing the incidence of musculoskeletal symptoms experienced by dental hygienists. This is not to suggest that the integration of surgical magnification is a panacea for the musculoskeletal problems experienced by dental hygienists. In fact, improperly selected or adjusted surgical magnification systems can promote positions that place clinicians at increased risk for such problems. Clinicians must first determine the optimal working position that supports their musculoskeletal health and then select magnification systems that will support that position. The working distance, depth of field and optical declination angle of the chosen system must correspond to the musculoskeletal needs of the clinician.

Key words: ergonomics, dental hygienist, dental equipment, lenses

Introduction

The potential for improving the occupational health of dental clinicians has expanded as increasingly sophisticated equipment enters the marketplace, yet there has been little improvement to the ergonomics with which dental hygienists operate. By and large, dental hygienists still bend, twist and otherwise contort to provide clinical dental hygiene services. The literature continues to indicate that both dental hygienists and dentists are experiencing back, neck and shoulder pain, and are in many cases attributing these problems to the provision of clinical care (1–10). In dentistry, we have tended to adapt to our equipment as best as we could, given our limited knowledge of the relationship between our work environment and physical health.

Surgical magnification has been a routine part of microsurgical procedures in medicine since the 1920s (11), but the knowledge gained by surgeons in medicine has largely not been transferred to dentistry. The use of surgical magnification presents dental hygienists with an opportunity for increased visual acuity and has a potential for reducing the risks for musculoskeletal discomfort and pain that is often associated with dental hygiene clinical practice. In this article, we will explore the evidence that exists to support the use of surgical magnification in dentistry. We will also analyse the critical factors clinicians must consider when selecting surgical magnification systems for dental hygiene practice. An exploration of these areas is integral to making an informed decision about the potential contribution of surgical magnification to dental hygiene clinical practice.

Evidence for the use of surgical magnification

The literature regarding the use of surgical magnification in dentistry is largely descriptive. Authors often discuss the different types of systems and provide a comparative analysis based on product characteristics (12–15). A variety of surgical magnification systems are available including surgical microscopes, spectacles-mounted fixed (through-the-lens) telescope systems, flip-up systems and headband-mounted systems. However, this article will be directed to the magnification systems that are spectacle- or head- mounted (Figs 1–3). Product information articles can be helpful in understanding the options that exist, but they contain little evidence to support the integration of surgical magnification systems.

There are few studies related to surgical magnification in dentistry and dental hygiene in particular. The evidence that does exist to support the integration of surgical magnification into dental hygiene practice is directed to two key areas, the quality of care that can be provided and better support for balanced positioning for clinicians providing the care.

Fig 1. Spectacle mounted through the lens system.

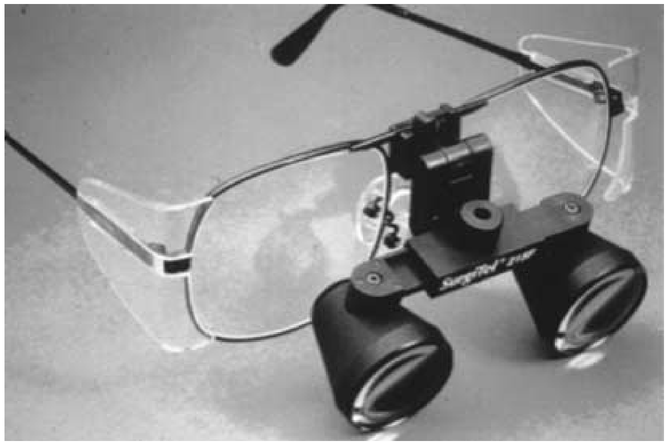

Fig 2. Spectacle mounted flip-up system.

Fig 3. Head band mounted system.

Quality of care

Surgical magnification is described as having many benefits including better visual acuity, greater motor control, improved diagnostic abilities and better treatment outcomes (13–19). An American study of endodontists ($n = 2061$) provided a 68% response rate and revealed that 52% of the respondents used surgical magnification (20). Many reported that it was a valuable tool essential to their practice. Whitehead and Wilson (21) found that there was a statistically significant increase in the decisions to restore teeth and to replace restorations when surgical magnification of 3.0× was compared to normal vision. This, however, may be a controversial area as it raises questions about appropriate treatment versus over-treatment.

The above authors suggest that clinical decision making in dentistry is enhanced by the use of magnification. Extrapolation of this evidence to dental hygiene care would support the benefit for greater visual acuity during assessments. Increased visual acuity is particularly important to discern the subtle tissue changes that are often evidence of pathological changes (13). As Clovis (22) argues, dental hygienists have an important opportunity and responsibility to assist in the early detection of oral cancers. Other benefits could also arise from the assessment of hard-tissue lesions, radiographs and restorations, as well as the measurement of attachment loss and periodontal pockets. From this evidence and a deductive reasoning perspective, the assessment and evaluation phases of dental hygiene care would support the value of increased visual acuity in providing quality dental hygiene services.

Several dental researchers have conducted studies to assess the impact of surgical magnification on the implementation of dental care (11, 23, 24). The Leknius and Geisseberger study (11) involved dental students ($n = 85$) trimming two sets of dies in a laboratory setting as well as a clinical simulation setting involving dentoforms. The study included a cross-over design, so each student served as her/his own control. Using paired *t*-tests, statistically significant differences were found between the two groups ($P > 0.001$) using a 5-point rating scale for the evaluation of the work. When working with surgical magnification, the students committed less errors than they did when working without magnification. Statistical tests were also conducted to explore the influence of the 'practice effect' (second preparation being better than the first one) or the influence of previous experience with magnification; neither factor was found to have a statistically significant effect.

However, Donaldson *et al.* (23) found no statistically significant differences in their study of dental students' paediatric amalgam preparations. The 52 dental students in this study were randomly assigned to the experimental (with magnification) or control (without magnification) group. The authors postulate a number of variables that may have affected their results. For example, the Class 2 preparations may not have been challenging enough to discriminate between skill level of participants, and the 3-point rating scale may not have been sensitive enough to differentiate between subtle differences in the product.

Forgie *et al.* (24) investigated differences in cavity size using normal vision and surgical magnification (2.6×). Four experienced clinicians performed multiple restorations ($n = 76$) on extracted teeth that had been placed within phantom heads. Although the preparations performed with unaided vision were larger compared to those performed with magnification, the differences were not statistically significant. The authors argue that clinical significance is more substantive than statistical significance and that the cumulative removal of tooth structure over years of practice supports the value of surgical magnification. It may have been difficult to find a statistically significant difference given the small number of clinicians used in this study. The authors also noted that all four clinicians indicated that surgical magnification eased task performance and favoured its integration into clinical practice.

In the area of oral surgery and periodontics, the benefits of surgical magnification involve the exploration of minimally invasive approaches and effective wound closure (14). In their study of the outcomes of periodontal surgery involving 26 clients with a deep interdental infrabony defect, Cortellini and Tonetti (25) found that improved visual acuity supported increased soft tissue management with resultant gains in clinical attachment levels. Similarly, Khayat (26) also argued that magnification has enhanced endodontic assessments and provided treatment options that were not possible in the past. It is however important to note that this type of microsurgery involved the use of a microscope whose magnification is higher than that provided by head-mounted magnification systems.

Visual acuity is obviously important for oral care; however, it is also important to acknowledge the use of tactile sensitivity and proprioception in the provision of dental care (20, 23, 27). It could be argued that the impact of surgical magnification may not be as significant for dental hygienists given the periodontal focus so common in their clinical practices. Once the instrument tip or blade has been placed subgingivally, tactile sensitivity and proprioception may be more critical to the outcome of dental hygiene therapy than visual acuity.

The evidence to suggest that surgical magnification will have a positive effect on the assessment and diagnostic aspects of dental hygiene care appears to be more substantive and intuitively logical when compared to the evidence to support its effect on the quality of periodontal debridement therapy. We have little evidence-based information about the outcomes of dental hygiene services, let alone any evidence regarding differences that might exist in the outcomes of clinical therapy with and without surgical magnification. Furthermore, it is unlikely that research will be directed to this issue given the many other competing priorities for research funding. Dental hygienists will individually need to determine if they value increased visual acuity for their oral care.

Ergonomic positioning and musculoskeletal health

Perhaps the most convincing argument for the use of surgical magnification is its impact on the musculoskeletal health of clinicians. The results of a qualitative study at Vancouver Community College (VCC) in British Columbia (28) involving dental hygiene students and clinical educators ($n = 25$) suggested physical health benefits of surgical magnification. The study participants reported decreased neck, back and shoulder problems, decreased time leaning forward, decreased eye fatigue, and enhanced vision.

This was followed by a larger study conducted in 1999 to assess the musculoskeletal health and practice patterns of British Columbia dental hygienists (10) and dentists (9). A total of 170 responses were received from dental hygienists (39% response rate) and a total of 421 responses from dentists (43% response rate). The surveys consisted of a combination of open-ended and closed-ended questions asking respondents for information about their practice ergonomics, practice management issues, lifestyle, perceived control of their work environment and questions about musculoskeletal symptoms (MSSs). Their use of surgical magnification was one of many questions posed.

Fifteen per cent of the dental hygiene respondents in the study used surgical magnification systems of some sort (10). Their experience with these systems was however limited. Few of the dental hygienists (6%) had used surgical magnification systems for more than 3 years. Among the dentists, 59% used surgical magnification systems. Of those using such systems, most (60%) have been using them for several years (>3 years) (9). This difference can be attributed to the integration of surgical magnification in the University of British Columbia (UBC) dentistry programme in 1990; after the initial pilot year, it became mandatory. At VCC, our faculty experimented with surgical magnification in 1993 and then introduced them to students in 1994. While many Canadian dental hygiene programmes introduce surgical magnification systems to their students via manufacturer's representatives, to the best of our knowledge VCC is the only Canadian dental hygiene programme to integrate surgical magnification into its preclinical and clinical education in any substantive manner, although the purchase of scopes was not mandatory until 2002. It was therefore not surprising to find the difference in use by dental hygienists and dentists.

The results of the study indicated that there was a strong negative correlation between an increased use of surgical magnification and lower back problems for both dental hygienists ($P < 0.001$) and dentists ($P = 0.034$) (10). This is not to suggest that surgical magnification by itself is a panacea for the musculoskeletal problems reported by dental hygienists. Several other equipment and positioning variables were also correlated with problems in this and other areas including the hands, arms, neck, shoulders, upper and mid-back and legs.

The correlation of increased use of surgical magnification with decreased risks for experiencing lower back pain should be considered in the context that most of the users of surgical magnification in the study were VCC and UBC graduates with surgical telescopes that allowed for appropriate declination angles to match their optimal working postures. Some systems in use by clinicians today have limited ability to produce optimal declination angles (29, 30), and the reductions of MSSs for such users may not be the same as those generated in the British Columbia study. Surgical magnification without balanced positioning may not have the same effect.

There is an important caveat associated with the use of surgical magnification. While it appears that appropriately selected and adjusted magnification can help to support balanced posture (29), poorly selected or adjusted systems can actually promote positions that place clinicians at increased risk for problems. In our 1999 study (9, 10), the following patterns were associated with statistically significant increased risk of MSSs.

- torso twist (Fig. 4),
- tipped shoulders (Fig. 5),
- elbow raised during operation (Fig. 6),
- operatory light positioned away from clinicians' sightline (Fig. 7C)
- operating with hands close to face (Fig. 8),
- increased time practising in the 7 : 00 to 8 : 30 and the 3 : 30 to 5 : 00 positions (Fig. 9), and
- increased use of ultrasonic instrumentation.

Many of these variables have been previously described in the literature related to rehabilitation (31–35) and clinical ergonomics in dentistry (13, 36–40). Reduction of high-risk variables has been a fundamental aspect of Performance Logic, a problem-solving model based on individualised positioning (41–43). This model is based on clinicians' musculoskeletal requirements using self-derivational approaches that attempt to neutralise the limitations that might have been imposed by specific equipment and by habituation from prior psychomotor experience.

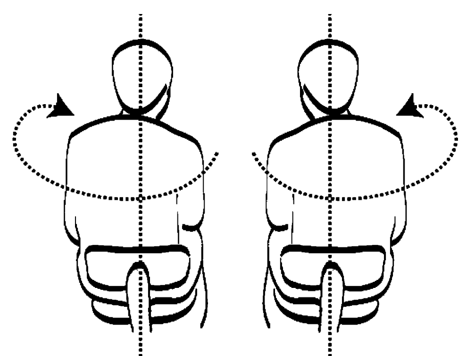

Fig 4. Torso twisting.

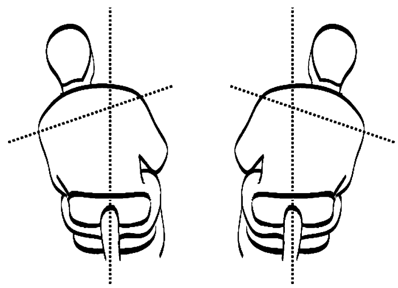

Fig 5. Tipped shoulders.

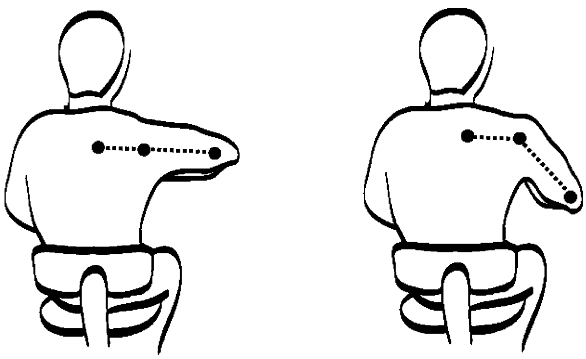

Fig 6. Elbow raised during operation.

In the Performance Logic approach, clinicians are encouraged to determine their most balanced and comfortable working position, and then to integrate that position into their clinical practice (Fig. 10). Once the operator is in a comfortable position, the clients' oral cavity is positioned to support the operators' derived balanced position, and fine adjustments are made during the appointment to allow the operator to maintain balanced positioning. The Performance Logic approach essentially involves a system of reasoning that guides clinicians to determine their most comfortable working position and then provides a number of strategies for them to maintain their optimal control position (28). It increases the clinicians' awareness of their work environment and preferred working position.

The Performance Logic model helps operators discover new ways to position themselves comfortably and effectively but is not able to resolve the differences between clinicians' musculoskeletal and individual preferences for eye-to-object distances (28, 44). There is often a difference between clinicians' preferred musculoskeletal preference and their preference for visual acuity.

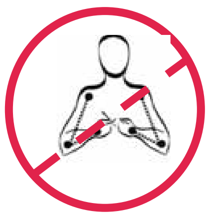

Fig 8. Hands close to face.

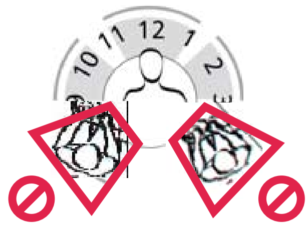

Fig 9. Increased time in the 7 : 00 to 8 : 30 and the 3 : 30 to 5 : 00 positions.

Fig 10. Self-derived balanced position.

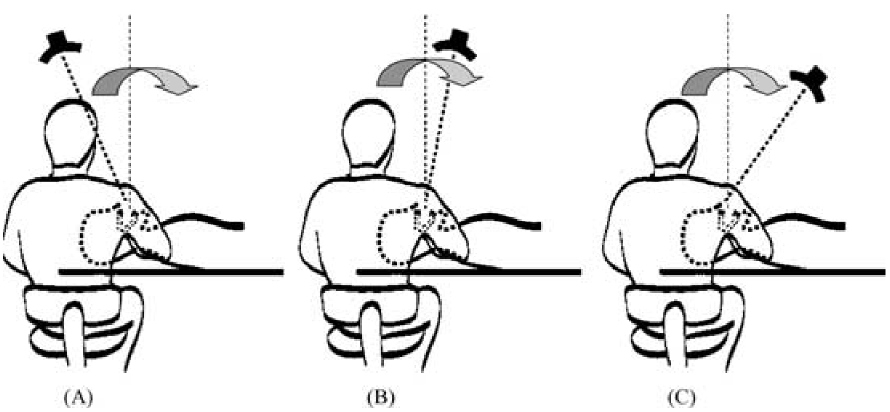

Fig 7. Operatory light positions.

Clinicians start in a balanced position, but then lean forward to achieve a higher magnification; they create their own magnified field by leaning forward to see better (13, 15, 23, 44). The use of surgical magnification has been found to be effective in supporting clinicians' preferred angle of vision while maintaining their optimal musculoskeletal operating posture (28–30). The integration of surgical magnification into Performance Logic has enhanced the value of the model in supporting clinicians' balanced positions during clinical care.

The positioning of the operator light is another important variable to support balanced positioning. For optimal illumination, the lightline must be as close to clinicians' sightline as possible (Fig. 7A); the greater the deviation of lightline from the clinicians' sightline, the greater the shadowing (Fig. 7C). As long as the lightline and sightline are within 15° of each other, the view will be essentially unshadowed and highly visible using standard mouth mirrors (45). Rather than adjusting the lightline towards their sightline, most clinicians will tend to tip or twist to get their sightline closer to the lightline. Light positioning is one of the most critical factors affecting the posture of clinicians, but many texts have ignored these principles of physics and suggest light positions that are located towards the clients' feet. To effectively integrate surgical magnification, clinicians must orient the lightline within 15° of their sightline; otherwise, they will continue to lean forward to adapt to the lightline.

Specific light systems have been designed to provide coaxial illumination, both halogen and fibre optic; they can be clipped onto surgical magnification system frames or headband mounted. Current designs add weight (about 20–25 g) and require attachment by cables or cord, to power or light sources. Their integration is another opportunity to support the musculoskeletal health of dental hygienists, but a more comprehensive discussion of light systems is beyond the scope of this article.

While there appears to be increasing evidence that surgical magnification systems have the potential to support the musculoskeletal health of clinicians, their integration is not a panacea for imbalanced position. The magnification system must not force clinicians to compromise regarding their chosen working position. As with all equipment in the operatory, the magnification equipment must be adapted to the needs of clinicians, not vice versa (46, 47). Clinicians must first determine their optimal balanced position for providing care before making decisions about surgical magnification systems.

Selection of magnification system

When a clinician chooses a surgical magnification system to support optimal intraoral vision, it is important to consider the magnification desired, and to also determine that the working distance, depth of field, and optical declination angle of the chosen system correspond to the musculoskeletal needs of the clinician. In the following section we will explore these critical factors to assess when selecting a surgical magnification system.

There are a variety of magnifications that can support operators' balanced positions while providing dental hygiene care. However, more magnification is not necessarily better – the higher the magnification, the smaller the actual field of view. Given that dental hygienists commonly work with sextants, quadrants or the entire arch in a particular appointment it is helpful to have a larger field of view. Higher magnification also reduces the depth of field, the distance through which the particular area remains in focus without the operator having to move closer or further from the object viewed. In addition, the use of magnification also reduces the light available for vision, and the light will be increasingly reduced with higher magnifications. We encourage our students to try different magnifications to assess their preferences, but have found that most dental hygiene students select 2.0× or 2.5× magnification for their work. Dental students often also select such magnification, but specialists such as endodontists and periodontists often prefer higher magnifications for their microsurgical procedures. The determination is often based on clinicians' work characteristics and their individual preference for magnification.

Working distance and depth of field

The working distance is the distance between the clinician's eye and the working site. This measurement is related to the depth of field, which pertains to the range over which the clinician is able to achieve visual discrimination. Depth of field is recorded in terms of the nearest and furthest extremes of distance from the surface of the eye to the object observed (e.g. from 13 to 17 cm). It may also be recorded in terms of the difference between these extremes (e.g. in the above example, a 4-cm depth of field). Manufacturers may identify the characteristics of their magnification systems in terms of these characteristics, but it is best to assess these characteristics individually given that the depth of field provided by a particular system will vary greatly between clinicians based on their vision. There is a relationship between these characteristics and the clinicians' ability to work comfortably and efficiently (29, 48), so it is important to assess them carefully to determine that the working distance meets the clinicians' optimal control position and that the depth of field provides visual resolution of the entire oral cavity.

Optical declination angle

Once the clinician has determined the optimal working position in musculoskeletal terms (49), the degree to which the eyes will be declined (i.e. inclined downward) must be determined. This optical declination angle must be assessed as carefully as the clinicians' working distance and depth of field (15, 44).

The optical declination angle is defined as the angle between the support line of a clinician's spectacles-mounted system and the actual line of sight chosen by the clinician while in her/his optimal balanced position (29). The line from where the temple piece of the spectacles rests on the ear, the superior auricular crevice (SAC) to the bridge of the nose, is used as the reference point for measuring the declination angle. The bridge of the nose for purposes of this reference is the weight-bearing part of the nose, which supports the nose pads of the spectacles [Fig. 11). This line is identified as the SAC–bridge-of-nose line. This same parameter can be used for headband-mounted telescope systems or loupes, even though they do not bear upon the nose.

A study at UBC looked at this issue of optical declination angle by assessing 165 dentists and dental students to determine the range of head inclination identified by participants associated with their optimal control postures (50). The angles were measured using a specifically designed optical measurement frame that measured parameters for precise sitting and angling of surgical telescopes. Rucker *et al.* found that declination angles ranged from 15 to 44° (mean = 34°; SD = 5.5°). The results of this study suggested that clinicians and novice students were quite specific in their choice of declination angle and their choices were reliably repeated.

To determine their optimal declination angle, clinicians must first derive their most balanced comfortable working position as if vision were not an issue. This is often best accomplished with eyes closed. Clinicians can then open their eyes and cast them downward to look at their hand position. Keeping the eyes on this point, clinicians should tip the head forward and downward until musculoskeletal strain is felt in the neck. Then, clinicians' head should be raised until strain is felt in the ocular musculature (i.e. as the clinician peers down at the optimal control point over the lower eyelids). These two postures are the extreme head positions that will allow clinicians to achieve visual contact with the operating site. Keeping the eyes on the optimal control point, clinicians can then tip the head forward and backward a few times through this range of movement until an optimal balanced head position is determined. This position will simultaneously derive the clinicians' optical declination angle.

Fig 11. Optical declination angle.

Having first established this optimal balanced position, declination angles can be measured with protractor devices, but often clinicians use this position to evaluate the appropriateness of various magnification systems. Carefully maintaining this balanced position, clinicians can place and secure the magnification system to be evaluated. They should notice whether the entire magnified portion of the mouth is visible, without requiring any turning or tipping of the head. The field of view should be centred on the clinicians' optimal control position. If clinicians must tip their head down or raise it up in order to see the working field, the optical device is not adequate in its current configuration, and must either be modified or rejected.

The assessment of the declination angle is critical to selection of a system to support operator comfort and balance. Several types of problems can result from declination angles that are not appropriate for clinicians. These include muscular strain, obscured vision and the diffraction effect (29). Clinicians are likely to experience eye strain and/or muscle strain of the head, neck and back if the declination angle of the system does not meet the clinicians' optimal working position. The border of the frame or the border of the lenses may obscure part of the operating field, necessitating a compromise by clinicians from their optimal balanced position. When the telescopes are not in perfect alignment (coaxial) with the clinicians' sightline, clinicians will experience a diffraction effect. To evaluate the diffraction effect, clinicians can pass a straight instrument from outside the unmagnified field (moving either from the right or the left side) toward the centre of the magnified field and then notice whether the point of the instrument goes directly to the centre of the field or whether it passes above or below the centre. If it passes above or below, diffraction has occurred. Diffraction effect can also manifest as colour aberrations (for example, purple or yellow halos around lines, points or margins in the magnified field). Both of these manifestations can be troublesome for clinicians and need to be corrected if possible or avoided.

The technology of surgical magnification systems has become increasingly sophisticated. There are many systems that will meet the needs of dental hygienists, but they must be assessed to ensure that they support the anatomical and physiological requirements of the individual clinician for balanced posture. Compromises can often result in frustrations, discomfort and pain (15, 29).

Adaptation to surgical magnification

As with any new technology, there are adaptations that need to be made, and change can be challenging given the often tight time constraints involved in dental hygiene practices. The limitations identified by participants in the 1994 VCC study included the following: cost of scopes, uncomfortable weight, time needed to adjust and difficulty monitoring client cues (28). These issues are still dominant themes in the discussions we have with dental hygienists and dental hygiene students. Since 1993 when the VCC faculty first explored surgical magnification, they have made many observations about the integration of surgical magnification and had numerous discussions with students about their value and limitations. Although data has been collected, it could not be described as research given that it was not collected and analysed in a systematic manner. However, the issues arising from this data collection can make a contribution to a better understanding of surgical magnification in dental hygiene practice.

While the weight of spectacles-mounted magnification systems has been substantially reduced, new clinicians who are not used to wearing glasses often still find them heavy. However, most find that they adapt to the weight over time especially with the various straps that are available to support them. Shifting to head-mounted devices has also assisted some in overcoming the weight issue.

For experienced clinicians, a challenging aspect is the adjustment time required for the integration of surgical magnification. The time most frequently reported by VCC faculty members was about 2–3 weeks, although some found that they had adjusted within a few days. In spite of the fact that VCC faculty did not mandate the use of surgical magnification, all the clinical faculty members have chosen to use them.

Both novices and experienced clinicians often encounter some signs of vertigo and/or nausea when first working with scopes, which is usually a result of frequently moving back and forth between the magnified and the unmagnified fields. Being conscious of this habit and focusing on the magnified field is often found to relieve this situation; it is essentially a matter of relaxing.

When moving instruments from the non-magnified to the magnified field, clinicians will cross through a blind zone known as a magnification scotoma. The instrument is temporarily out of view, and this can be disconcerting for both new and experienced clinicians. Placing the middle finger over the tip of any instrument during transport onto the magnified field is helpful for the novice. Knowing that the tip or blade is thus guarded makes clinicians more confident as they adjust to the magnification system. During the integration period, there may be times when clinicians bump their fingers into different structures such as lips and noses as they access the operating site, but open communication with clients is usually effective in managing such situations.

The issue that appears to be most challenging for experienced clinicians is the difficulty in monitoring client cues. Dental hygienists talk about feeling 'disconnected' from clients (28). This may be an issue unique to dental hygiene practice given that we do not commonly have an assistant to support us in our work. This issue can often be managed by requesting clients to become more involved in providing ongoing feedback through vocal or hand signals. Some dental hygienists have indicated that their peripheral vision has adapted and they can still view the clients' eyes, but many do not appear to develop this ability. The size of the frame borders may be an influencing factor related to this ability. Experienced clinicians are aware of the need for ongoing communication with clients; however, novices need to be encouraged to develop strategies for gaining client feedback on an ongoing basis during care. Adaptation to surgical magnification does take time and patience, although these adaptation issues appear to be transient in nature.

Perhaps one of our most convincing pieces of evidence to support surgical magnification for dental hygiene care came from the VCC graduates. They asked the VCC faculty to make surgical magnification mandatory given that they felt it would be easier to integrate surgical telescopes during their educational experiences, rather than waiting until they had graduated. Although they were in a better financial position to purchase such systems upon graduation, they felt that the cost of purchasing them during their education could have been managed. The combination of graduate feedback, clinical observations, discussions with current students and the result of the 1999 British Columbia study (10) led the VCC faculty to make surgical magnification mandatory for students in 2002. Given the high incidence of MSSs and problems among clinical dental hygiene practitioners (1–10), the VCC faculty felt an ethical responsibility to support students in establishing and maintaining balanced positions during their clinical care. They felt that this was not possible without the use of surgical magnification.

Conclusion

The prevention and management of MSSs among dental hygienists is an important professional issue. The recent developments in ergonomic work environments are a positive step towards operator comfort, but new ergonomic equipment has limited value without the critical analysis of current practice patterns. Balanced positioning is the first step in supporting the health of clinicians; this step is essential for the successful integration of other strategies and equipment. Once this has been established, the integration of surgical magnification has the potential to support the musculoskeletal health of dental hygienists and it may also increase the quality of dental hygiene care. Surgical magnification needs to be supported by balanced positioning; by itself, surgical magnification is not a panacea for the musculoskeletal problems reported by dental hygienists. Dental hygienists have prided themselves as prevention and health promotion practitioners. In striving to meet the needs of clients, it appears that they have neglected to attend to the preventive and health promotion aspects of their own practices. Dental hygienists need to give their own practices the same attention and consideration that they provide their clients.

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