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# Uptake and experience of visual magnification and illumination aids by Otago University Bachelor of Dental Surgery students'

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## Abstract

**Background and objectives:** Visual demands on dental practitioners may cause them to adopt detrimental postures leading to musculoskeletal dysfunction. Dental loupes and LED lights significantly improve visual acuity, work quality and ergonomics. Scholarly work in these areas is lacking. This study aimed to gain insights from Bachelor of Dental Surgery (BDS) students at the University of Otago who do or do not own dental loupes and lights, in respect to their levels of knowledge of these devices, how they might choose them and what benefits they feel it may confer.

**Methods:** University of Otago undergraduate students enrolled during 2019 in BDS 2, 3, 4 and 5 were asked to complete an analogue questionnaire.

**Results:** 209 of possible 356 students responded to the questionnaire (58.7%). Some 21.1% of respondents owned loupes. Students purchased loupes to see more details (36.0%), improve work quality (35.0%) and to improve posture (34.0%). Eighty percent of students self-reported that wearing loupes made them a better dentist; the reasons include wearing loupes enabled better work quality (25.0%), ability to see in more detail (65.1%) and improved posture (29.6%). Without loupes, 56.9% of students experienced neck/back pain; wearing loupes reduced pain for 63.6% of students. Almost two thirds of students believed that a light conferred significant benefit. Almost 90.0% desire expert teaching on dental loupes and lights.

**Conclusions:** Students who use loupes and lights report significantly improved clinical experiences, particularly with visual acuity, clinical performance, and reduced neck/back pain.

**Keywords:** dental loupes, LED lights, visual magnification, illumination aids, questionnaire, survey, dental students.

## Introduction

The profession of dentistry can be cognitively, emotionally and physically demanding. The areas of vision and biomechanics are particularly challenging and are where practitioners may experience dysfunction and negative impacts on their practice and career-longevity. The use of visual magnification aids such as dental loupes and illumination improves visual acuity and posture, leading to better clinical performance and musculoskeletal wellbeing (James and Gilmore, 2010).

Low et al. (2018) suggested that higher magnification reduces ambiguity in a range of areas of clinical diagnosis including endodontics, cracks, incipient caries and microleakage. They also suggested that magnification reduces iatrogenic damage and treatment time. Wajngarten and Garcia (2019) showed that any form of magnification device (Galilean, Keplerian, Microscope) improved dental students' visual acuity, regardless of their year of enrollment and therefore suggested loupe integration into pre-clinical training to help develop professional motor skills. This suggestion is further supported by other studies examining the effect of loupes on pre-clinical dental students' performance (Maggio, 2011). There is relatively little literature reporting the investigation of magnification and illumination aids used in dental schools by students or staff (Leknuis and Geissberger, 1995; Farook et al., 2012; Narula et al., 2015; Murray et al., 2016; Chandler et al., 2017; Hayes et al., 2019). Chandler et al. (2017) noted that 'very little' scientific investigations had been carried out into the visual acuity of dentists and the influence of magnification devices on their clinical performance, while Carpentier et al. (2019) stated that scientific evidence is 'very scarce' on the beneficial effects of loupes on posture. Scientific investigation into visual acuity and posture is well-documented but under-researched (James and Gilmore 2010), particularly where it relates to dental students' awareness, uptake and experience of these devices.

While the term loupe technically refers to a magnifying glass, this study defines the colloquial dental loupe as the whole functional unit that comprises binocular telescopes mounted onto spectacles or a headband. The telescopes can be mounted onto the front of the spectacle frame using a hinge (front-lens-mounted), can be bonded into the carrier lenses of the spectacle frame (through-the-lens), and/or frames can be mounted to a headband (essentially also front-lens-mounted). The magnifying telescopes can be Galilean or Keplerian in design and their power is typically measured via angular magnification with at least two manufacturers using spatial magnification (Designs for Vision, Merident Optergo). A dental light is defined here as a small light-emitting diode (LED) in a housing that is mounted to the spectacle frame or headband and illuminates the field of view by emitting light coaxial to the telescopes.

The University of Otago's Bachelor of Dental Surgery (BDS) is a 5-year undergraduate degree programme.



The first year comprises comprehensive health science courses generic to many health professions. Pre-clinical dental training begins in the second year. Patient clinics are introduced during the third year and patient contact increases over the remaining 2-years of the programme in years 4 and 5.

### *Visual acuity; clinical performance*

Dentists require exceptional visual acuity throughout their practising career. An increasing number of dental schools recognise that the use of visual magnification confers benefits to dental students (Hedge and Hedge 2016, Perrin et al. 2016). The schools of dentistry at the University of Southern California, University of Mississippi, Tufts University and Loma Linda University in the USA (Farran 2018, Tufts 2019, UMMC 2018, LLU 2019) require their students to purchase and use loupes as part of their dental programme; similarly King's College (2019) London requires loupes to be purchased for their endodontic postgraduate programme. As of 2012, at least 23.0% of US dental schools mandate the use of loupes (Congdon et al. 2012). Currently, the BDS degree at the University of Otago has no requirement for students to own loupes or a light.

Magnification confers clinical benefits to practitioners. Perrin et al. (2016) reported dramatic individual visual differences between dentists irrespective of their age and demonstrated that loupes can compensate for visual deficiencies. Hegde and Hegde (2016) argued that better visual acuity, via magnification and coaxial illumination, greatly enhance contemporary dentistry. This post-amalgam age (Schmidlin 2019) is driven by the technological advancements of adhesive dentistry (Magne 2006), which is advancing the areas of aesthetic and minimally invasive dentistry and biomimetics. It is an increasingly technique-sensitive, visually demanding field.

### *Posture; musculoskeletal health*

There is a high prevalence of musculoskeletal dysfunction and pain experience among dental practitioners. Managing pain in dentistry requires addressing multiple risk factors (Congdon et al. 2012, Valachi 2017). Wearing dental loupes allows the dental student to sit in an upright, near-neutral and balanced posture. Branson et al. (2004) and Maillet et al. (2008) demonstrated that, in student hygienists, magnifying loupes effectively reduce poor posture and reduce musculoskeletal disorders. Maillet et al. also showed that significant postural benefits are realised with very early adoption of magnification aids. During dental education, the earlier a student's uptake and attainment of proficiency, the better. Pîrvu et al. (2014) argued that the subject of posture and musculoskeletal health is poorly understood by dental professionals and suggested that misuse of loupes could increase the risk of injury. During the University of Otago's BDS programme the only formal training on ergonomics is provided during the fourth year in a once-off, half-hour presentation by the University's School of Physiotherapy, although the importance of ergonomics is reinforced in the clinical environment.

The aim of this study was to gain insights from students enrolled in the Bachelor of Dental Surgery at the University of Otago who (1) own dental loupes and/or a light, and (2) do not own dental loupes and/or a light, in respect of their levels of knowledge of dental loupes, how they choose dental loupes and what benefits wearing these may confer.

### *Methods*

Category B Ethics approval for this enquiry was granted in March 2019 by the University of Otago Human Ethics Committee (reference number D19/088). The study was not sponsored and financial grants were not applied for. The participants' data were given under anonymity, and they were offered no reward (financial or otherwise).

### *Information sources and analysis*

University of Otago undergraduate students enrolled during 2019 in the Bachelor of Dental Surgery (BDS) in years 2, 3, 4 and 5 were asked to read a participant information sheet and complete an analogue questionnaire. Students were given a paper questionnaire and the data collected, manually collated and entered into a multi-page Google Sheets spreadsheet (Google LLC, Mountain View, CA, USA), which facilitated calculations and analysis.

### *Questionnaire*

A questionnaire with 44-questions incorporating multiple choice, yes/no and open-ended questions was used in this study. The overall structure and flow of the questionnaire facilitated ease of participation by quickly establishing whether participants were loupe owners or non-owners. Early in the questionnaire, the two groups were directed to answer only questions relevant to their ownership status. The survey took on average three minutes to complete. Both groups were asked to complete a small number of generic questions while the bulk of the enquiry comprised group-exclusive questions covering several areas.

Loupe owners were asked: which year of study they acquired loupes; the reason they acquired loupes; the magnification; how they decided on that magnification; whether they were happy with the magnification; when they might purchase again if unhappy; the loupe working distance (focus length) and whether they were happy with the working distance; whether they experienced neck or back pain while working prior to ownership and whether using loupes had reduced that pain; which brand and why; whether Keplerian or Galilean telescopes and if they knew the advantages/ disadvantages/ differences of each; whether through-the-lens (TTL) or front-lens-mounted (FLM) frame mounting and the advantages/ disadvantages/ differences of each; whether wearing loupes assisted their clinical practice and how they have benefited; whether they found their loupes too heavy; and if there was anything they did not like about wearing loupes.

Non-owners were asked: whether they intended purchasing loupes, and if they did, then when

they intended to; why they would get loupes; what magnification and why; whether they had experienced neck and back pain while working; which brands they were interested in and why; whether they were intending acquiring Keplerian or Galilean telescopes and whether TTL or FLM-style mounting.

All participants were asked a total of six generic demographic questions. Loupe owners were asked an additional 21 questions exclusive to their group and non-owners were asked an additional 11 exclusive questions. In addition to the demographic questions and group-specific investigations, all participants were asked a final seven questions on whether they own a dental light emitting diode (LED) light; in which year of study they purchased it; subjectively, how much the light improved their clinical practice; whether they were considering purchasing a light if they did not already own one; whether they felt a light and/or loupes should be mandatory equipment for all BDS students; and whether the faculty should provide comprehensive expert teaching on loupes and lights and how to go about selecting them.

## Results

A total of 209 out of 356 students chose to participate in the survey (58.7%), with the lowest number of responses received from BDS 2 (46%) students and the highest response rates received from BDS 3 (62%).

### Demographic make-up

Details of response rates, and characteristics of the participants are shown in Table 1. The mean age of respondents was 21.9 years. The participants comprised 76 males (36.4%) and 133 females (63.6%) and represented a range of ethnicities with the majority being Asian (51.2%) and New Zealand European (25.4%). A fifth of respondents already held a university degree prior to entering the programme (20.6%), the majority of which were various Health Science degrees (15.8%).

### Loupe owners

Overall, just over a fifth (21.1%) of respondents owned a pair of loupes (Table 1). The majority of loupe owners were in BDS 5 (52.3%), followed by BDS 4, 3 and 2. Further details on loupes owners are summarized in Table 2. The majority of students who owned loupes had purchased them during their BDS 3 and 4 years (43.2% and 40.9% respectively). The vast majority (88.6%) of students were satisfied with their loupes' magnification with 3.0x magnification being the most common choice (34.1%). Despite this, 81.8% intended to purchase a different magnification after graduation. Several working length ranges were reported by loupe owners. Most students owned loupes with working lengths over 41 cm (52.3%), while 38.6% of students did not know what the working length of their loupes was. Overall, 81.8% were happy with their current working length of their loupes.

Orascoptic (31.8%) and Zeiss (20.5%) were the most commonly owned brands while over one fifth bought generic/own-brand, internet-bought loupes, (20.5%)

**Table 1.** Participants' demographic make-up (N = 209)

Question	n (%)
Year of study	
BDS 2	46 (22.0)
BDS 3	62 (29.7)
BDS 4	47 (22.5)
BDS 5	54 (25.8)
Sex	
Male	76 (36.4)
Female	133 (63.6)
Ethnicity	
NZ European	53 (25.4)
Māori	17 (8.1)
Pacific Peoples	10 (4.8)
Asian	107 (51.2)
Indian	7 (3.4)
Middle East	8 (3.8)
Other (various)	7 (3.4)
Citizenship	
NZ	140 (67.0)
Malaysia	35 (16.8)
Canada	5 (2.4)
Singapore	8 (3.8)
China	6 (2.9)
Other (various)	15 (7.2)
Hold a prior university degree	
Yes	43 (20.6)
No	166 (79.4)
Field of study (prior degree)	
Science	7 (3.8)
Health Sciences (various)	33 (15.8)
Sports Science	1 (0.5)
Chemistry	2 (1.0)
	Mean/Min/Max
Age (years)	21.9/18/42

Abbreviations: BDS, Bachelor of Dental Surgery; NZ, New Zealand; Min/Max, Minimum/Maximum.



Table 2. Loupe owners: Loupes (N = 44)

Question	n (%)
Year of study	
BDS 2	0 (0.0)
BDS 3	3 (6.8)
BDS 4	18 (40.9)
BDS 5	23 (52.3)
Purchased in which study year	
BDS 2	4 (9.1)
BDS 3	19 (43.2)
BDS 4	18 (40.9)
BDS 5	3 (6.8)
Magnification	
~2.5x	11 (25.0)
~3.0x	15 (34.1)
~3.5x	11 (25.0)
~4.0x	7 (15.9)
Magnification satisfaction	
Just right	39 (88.6)
Too low	5 (11.4)
Too high	0 (0.0)
Intend to change magnification	
Before graduation	6 (13.6)
After graduation	36 (81.8)
N/A	2 (4.5)
Working length	
20–30 cm	1 (2.3)
31–40 cm	3 (6.8)
41–50 cm	18 (40.9)
>51 cm	5 (11.4)
Do not know	17 (38.6)
Working length satisfaction	
Just right	36 (81.8)
Too short	8 (18.2)
Too long	0 (0.0)
Loupe brand	
Generic	9 (20.5)
ErgonoptiX	4 (9.1)
Heine	4 (9.1)
Hogies	1 (2.3)
Orasoptic	14 (31.8)
Student Loupe Company	3 (6.8)
Zeiss	9 (20.5)

Abbreviations: Demo, demonstration; Rep, representative; Generic, (generic/own-brand loupes from online retailers AliExpress, Shopee or Homie).

Table 3. Loupe owners: Loupe telescope and frame types (N = 44)

Question	n (%)
Own which telescope design	
Galilean	5 (11.4)
Keplerian (prismatic)	10 (22.7)
Do not know	29 (65.9)
Telescope design advantages/ disadvantages/ differences	
Do not know	36 (81.9)
Keplerian (prismatic)	
Better lighting	1 (2.3)
See more detail	2 (4.6)
High magnification	2 (4.6)
Heavy	6 (13.7)
Better image quality	3 (6.8)
Same convex lens	1 (2.3)
Multi-mag. available	1 (2.3)
Have distortion issues	1 (2.3)
Galilean	
Low magnification	1 (2.3)
Lightweight	1 (2.3)
Concave-convex lens	1 (2.3)
Less precise	1 (2.3)
Own which frame mount	
TTL	19 (43.2)
FLM	25 (56.8)
Frame mount advantages/ disadvantages/ differences	
Do not know	16 (36.4)
TTL	
Lighter weight	11 (25.0)
Does not look professional	1 (2.3)
Better field of view	1 (2.3)
Can not adjust PD	3 (6.8)
Customised	2 (4.6)
More difficult to see	1 (2.3)
More difficult to repair	1 (2.3)
Less maintenance	5 (11.4)
Looks better	1 (2.3)
Field transition difficult	1 (2.3)
Lens close to eyes	1 (2.3)
FLM	
Less field of view	1 (2.3)
Heavier weight	10 (22.7)
Can adjust PD	4 (9.1)
Can share	2 (4.6)
Can adjust angle	1 (2.3)
More maintenance	2 (4.6)
More fragile	2 (4.6)
Field transition easier	12 (27.3)
Cheaper	1 (2.3)
Better quality	2 (4.6)

Abbreviations: TTL, Through-the-lens; FLM, Front-lens-mount; PD, pupillary distance.



(e.g., AliExpress, Shopee, Homie). As shown in Figure 1, reasons for acquiring loupes included improving visual acuity and seeing more details (28.8%); the second most common reason was to improve their work quality (28.0%) followed by improve posture (27.2%).

Respondents cited several reasons influencing their particular choice of telescope magnification (Figure 2); the most common being advice given by other students (40.7%) and the students' own research (39.0%), while advice from tutors had little impact on students' decision-making (3.4%). The main reasons for brand choice were price and advice from other students and/or staff (both 19.0%) (Figure 3).

Loupe owners were asked to share information about the type of telescopes and mounting options they possessed (Table 3). Keplerian (prismatic) telescopes were twice as popular as Galilean telescopes; 22.7% and 11.4% respectively. Two thirds of the respondents (65.9%) did not know which telescope design they owned.

Loupe owners were asked to respond subjectively about their experience of wearing loupes (Table 4). The majority of respondents (79.5%) reported that wearing loupes helped make them a better student dentist. When asked how loupes had benefited them, 48.3% felt that it has improved their ability to see in more detail while 21.7% felt it has improved their posture. The most common negative aspect of wearing loupes that was reported was weight of the loupes (27.3%).

#### Loupe non-owners

Of the 209 respondents, 165 (79.0%) did not own loupes, however, 160 (97.0%) indicated that they intend to purchase loupes in the future. Most students intending to purchase loupes in the future (Table 5) thought they would do so during their BDS 4 year of study (43.1%). While a third of students did not know what magnification they would choose (31.8%), 2.5x (26.0%) and 3.0x (23.4%) magnification were the common choices based on advice from other student's (32.8%). Over a third of respondents (33.6%) did not know what brand they would purchase, but 12.2% of students reported that they were influenced by sales representatives, and 14.2% were influenced by staff or student recommendations. The most common reasons for purchasing loupes were to see more details (26.5%), to improve their work quality (26.5%), and to improve their posture (23.5%).

Some indecision or lack of knowledge was also evident when students were asked about

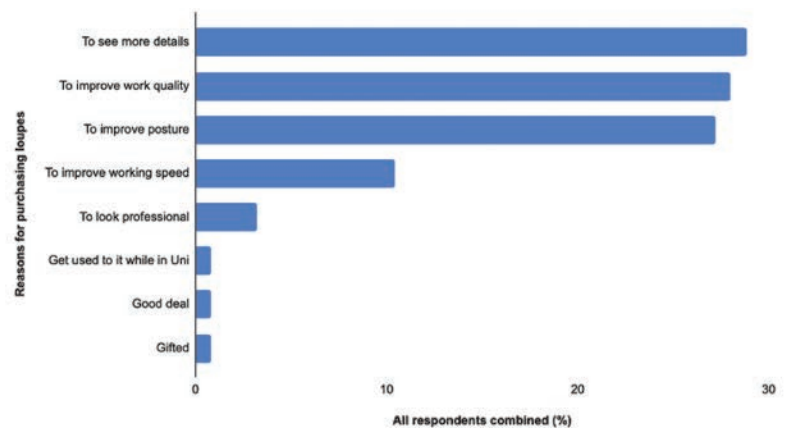


Figure 1. Reasons for loupe ownership.

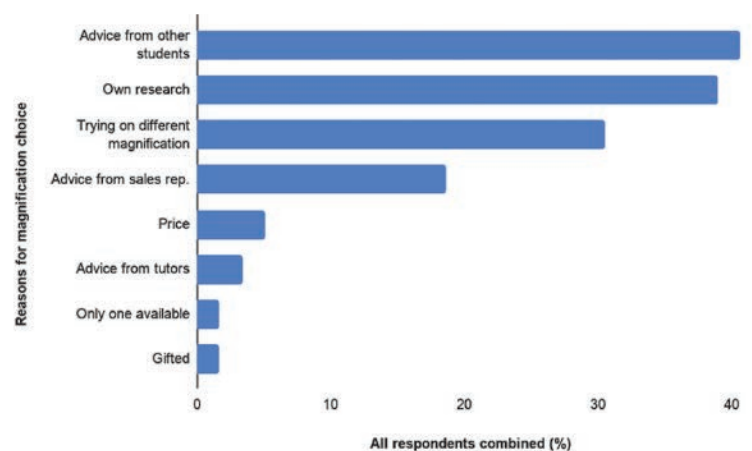


Figure 2. Loupe owners' reasons for choice of telescope magnification.

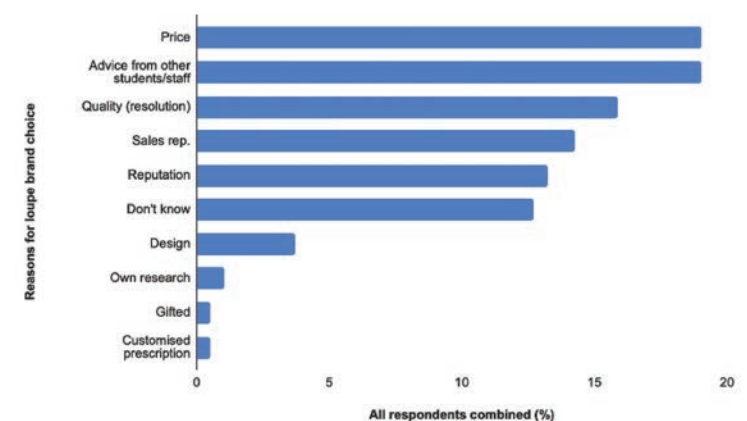


Figure 3. Loupe owners' reasons for choosing a brand of loupes.

choices of telescope designs and frame-mounts. Table 6 shows that 80.0% of those who intended to purchase loupes in the future did not know whether they would choose a Galilean or Keplerian design, and for frame-mount style, 50.0% of students did not know whether they would purchase TTL or FLM mounts.

#### Dental LED lights, loupes and the BDS curriculum

Less than half (42.6%) of participants owned a dental LED light (Table 7). Ownership prevalence increased with higher year of study, with no BDS 2 participants owning a light, while 88.9% of

Table 4. Loupe owners: Subjective aspects (N = 44).

Question	n (%)
Wearing loupes make you a better student dentist	
Yes	35 (79.5)
No	7 (15.9)
Did not wear them	2 (4.6)
How have loupes benefited you	
Improve posture	13 (21.7)
See more detail	29 (48.3)
Work faster	2 (3.3)
Look professional	1 (1.7)
Better work quality	11 (18.3)
Did not know	4 (6.7)
Are your loupes too heavy	
Yes	15 (34.1)
No	28 (63.6)
Did not wear them	1 (2.3)
What do you not like about wearing loupes	
Weight	12 (27.3)
Limited working length	4 (9.1)
Not used to them yet	3 (6.8)
A small field of view	3 (6.8)
Nose dent	2 (4.6)
Setup time	2 (4.6)
Look funny (headband)	1 (2.3)
Can't sterilise	2 (4.6)
Flimsy	1 (2.3)
Makes me dizzy	1 (2.3)
Hurts ears	1 (2.3)
Fiddly light cord	1 (2.3)
Neck strain	1 (2.3)
Price	1 (2.3)

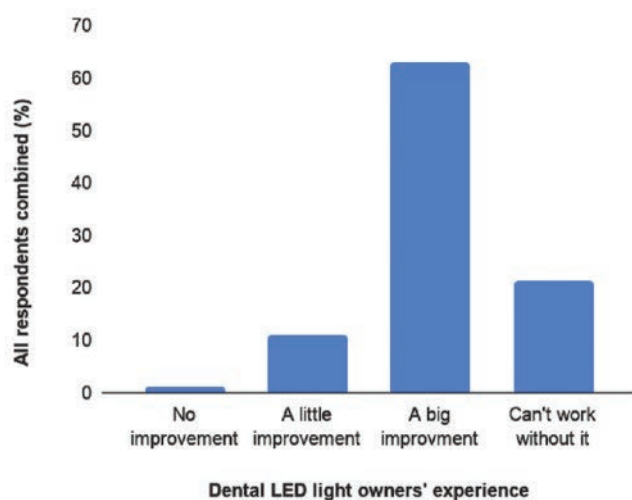


Figure 4. How much a dental LED light improves students' clinical practice.

Table 5. Loupe non-owners' responses in regards to future loupe purchase (N = 160).

Question	n (%)
Do you intend to purchase loupes in the future	
Yes	160 (97%)
No	5 (3%)
When will you purchase	
BDS 3	44 (27.5)
BDS 4	69 (43.1)
BDS 5	26 (16.3)
After graduation	21 (13.1)
Interest in which magnification	
~2.5x	50 (26.0)
~3.0x	45 (23.4)
~3.5x	31 (16.1)
~4.0x	5 (2.6)
Do not know	61 (31.8)
Why interest in that magnification	
Own research	33 (12.7)
Demo/try-on	43 (16.6)
Advice from a sales representative	36 (13.9)
Advice from other students	85 (32.8)
Advice from tutors	12 (4.6)
Price	2 (0.8)
Do not know	48 (18.5)
Interested in loupe brand	
Generic	5 (2.0)
LumaDent	16 (6.6)
ErgonoptiX	4 (1.7)
Heine	58 (24.1)
Orascoptic	56 (23.2)
Student Loupe Company	2 (0.8)
Zeiss	13 (5.4)
SurgiTel	1 (0.4)
Designs for Vision	3 (1.2)
Perioptix	1 (0.4)
Pentax	1 (0.4)
Do not know	81 (33.6)
Why interested in that brand	
Sales representative	24 (12.2)
Recommended by staff/student	28 (14.2)
Price	22 (11.2)
Reputation	13 (6.6)
Quality	26 (13.2)
Good fitting	2 (1.0)
Look good	5 (2.5)
Customised prescription	1 (0.5)
Customer service	1 (0.5)
Do not know	75 (38.1)

Abbreviations: BDS, Bachelor of Dental Surgery.

BDS 5 participants did so. The majority of light owners (64.0%) had purchased their lights during the BDS 3 year of study, however, of the respondents who did not currently own a light, it was notable that a large proportion (76.7%) intended to purchase a light in the future (Table 8).

Students who owned a light reported that the light conferred positive effects on their clinical practice, with 62.9% of respondents stating a light improved their clinical practice and 21.3% felt they could not work without their light (Figure 4).

When students were asked whether light and loupe ownership should be made more prescriptive within the BDS curriculum, the majority of respondents (87.1%) felt that the BDS curriculum should include teaching on loupes and lights and how to go about selecting them. Only 28.7% of students thought that lights should be mandatory and 14.4% of students thought that loupes should be mandatory (Table 9).

## Discussion

This study reported on the ownership, use and opinions of dental loupes, of BDS students studying at the University of Otago Faculty of Dentistry. The results showed that undergraduate dental students enrolled in 2019 had a moderate uptake of visual magnification aids (dental loupes) and a high uptake of illumination aids (dental LED lights). The results confirmed that these aids confer positive benefits to students, however, the findings also highlighted students' lack of knowledge across several areas and the need for targeted education on dental loupes and lights.

**Table 6.** Loupe non-owners: Future purchase intentions for loupe telescope design (N = 160)

Question	n (%)
Type of telescope design	
Galilean	20 (12.5)
Keplerian (prismatic)	12 (7.5)
Do not know	128 (80.0)
Frame mounting	
TTL	43 (26.9)
FLM	37 (23.1)
Do not know	80 (50.0)

**Table 7.** Dental LED light ownership (N = 89).

Question	n (%)
Own a light	
BDS 2	0 (0.0)
BDS 3	9 (14.5)
BDS 4	32 (68.1)
BDS 5	48 (88.9)
Purchased in which study year	
BDS 2	4 (4.5)
BDS 3	57 (64.0)
BDS 4	26 (29.2)
BDS 5	2 (2.2)

One strength of this study is the University of Otago Faculty of Dentistry is the only educational facility for the Bachelor of Dental Surgery in New Zealand, making it a good reflection of the majority of new clinicians working in the field of dentistry in New Zealand. Another is the depth of detail in the responses provided by the participants. We acknowledge there are limitations with this study, including the response rate, which is lower than a previous study conducted at the Faculty of Dentistry by Murray et al. (2016) (58.7% vs 89.3%), that partially investigated loupe ownership of dental students at the University of Otago. The lower response rate is possibly an issue when generalizing the findings to the entire dental student population studying at Otago, as is the subjective nature of many of the questions and self-reporting of potential benefits or issues. The depth of detail sought in the study also made it difficult to find a similar study in published literature with the relevant pre-tested questions, hence there may be issues with validity of the survey questionnaire. Finally, the number of variables being investigated made it difficult to provide a statistical analysis of the results.

Three main reasons emerged as to why students purchase loupes or intended to purchase loupes: (1) they believed they will see more detail, (2) their clinical work quality will improve, and (3) their posture will improve. These three beliefs are the same for students who already owned loupes and for students who were intending to purchase loupes.

Students' experience of wearing loupes is generally a positive one, with participants reporting improvement in ergonomics and ability to carry out dental tasks.

**Table 8.** Dental LED light non-owners' intention to purchase a light (N = 120).

Question	n (%)
Thinking of acquiring a light	
Yes	92 (76.7)
No	1 (0.8)
Do not know	27 (22.5)

**Table 9.** Lights and loupes in the BDS curriculum (N = 209).

Question	n (%)
Lights should be mandatory	
Yes	60 (28.7)
No	75 (35.9)
Do not know	74 (35.4)
Loupes should be mandatory	
Yes	30 (14.4)
No	115 (55.0)
Do not know	64 (30.6)
Expert teaching desired	
Yes	182 (87.1)
No	12 (5.7)
Do not know	15 (7.2)



Overall, almost eight out of ten loupe owners believed that wearing loupes made them a better student dentist. However only 21.1% of respondents own loupes, with 5<sup>th</sup> year students being the largest group. Murray et al (2016), reported similar levels of loupe ownership, 22.6% of undergraduate dental students at the University of Otago, again with almost half being 5<sup>th</sup> year dental students. As there has been little change in the proportion of undergraduate students owning loupes, there may be an ongoing barrier, such as cost and a lack knowledge on the topic of loupes. Internationally, Farook et al. (2012) also reported that approximately one fifth of students in their UK study owned loupes. Hayes et al (2019), found that almost half (45.7%) of undergraduate dental and oral health students owned loupes, which is well over twice the proportion of their New Zealand counterparts.

Studies have confirmed that wearing loupes allowed a clinician to see more details and increased the users' visual acuity by improving resolution. The unaided human eye can resolve two distinct lines that are a distance of 200  $\mu\text{m}$  apart; 2.5x loupes improve eye resolution to detect lines at 80  $\mu\text{m}$  apart; with 4.0x loupes the eye can detect lines at 50  $\mu\text{m}$  apart; 6.4x loupes allowed the eye to resolve two distinct lines at 31  $\mu\text{m}$  apart (van As, 2003). It follows that better visual acuity facilitates improved clinical performance. This is supported by Leknui and Geissberger (1995) who reported a 50% reduction in clinical errors by dental students when performing fixed prosthodontic procedures while wearing loupes, and Narula et al. (2015) who showed that wearing loupes enhanced the quality of class II cavity preparations by students in a simulation clinic. This seems to be recognized by respondents in this study with the most common benefit reported by almost half of the loupe owners being the ability to see more clearly. Similarly, Hayes et al (2019), found an improved ability to detect caries and evaluate restorations to be one of the most common reasons why students wore loupes (55% and 73% respectively).

Two studies, however, demonstrated the need for knowledge while using magnification when applying visual caries detection systems for diagnosis: Neuhaus et al. (2015a) showed that ICDAS criteria was suited for natural vision and magnification up to 2.0x and not for higher magnifications; while Mitropoulos et al. (2012) found that 2.5x magnification had no impact on occlusal caries diagnosis using ICDAS II criteria. Higher magnification may involve the risk of overdiagnosis and premature invasive treatment.

Neck and back pain is a common complaint among dental practitioners and a cause of early retirement (Lietz et al. 2018). Of the students in this study who did not own loupes, two thirds reported neck and back pain. This prevalence correlates with the two thirds of loupe-owning students who before acquiring loupes also experienced neck and back pain. An American Dental Association survey of 7,500 dentists showed that poor ergonomics was a major issue; two thirds suffered from neck pain and of those, nearly half suffered moderate to severe pain (ADA 2015). Pain resulted from poor clinical

posture and long periods of isometric, static working positions leading to tension and dysfunction. Farook et al. (2012) showed that loupes improved visual acuity without increasing forward neck bend (an aetiology of poor posture leading to pain). Lindegård et al. (2016) reported that pain is induced when working with the neck bent forward greater than 20 degrees and that prismatic glasses significantly reduced this problem. A third of the respondents reported improved posture once they started wearing loupes. Lietz et al. (2018) suggested that loupes could significantly contribute to a reduction in musculoskeletal disease and pain among dentists. This is corroborated by loupe owners in this study where just over a fifth said that their experience of neck and back pain had reduced since wearing loupes. This perceived benefit to posture was also reported by Chandler et al (2017), where almost half of loupe wearers (49%) attributed improved posture as a reason for wearing loupes, while Hayes et al (2019) reported improved posture was the main reason Australian undergraduate dental students chose to wear loupes (87.9%).

The telescopes in a pair of loupes are designed to focus at a specific distance, which determines the user's working length and, consequently, their posture (for better or worse). A claimed focus distance will have a range of in-focus area longer and shorter than the viewed object. Manufacturers either allow clients to order a custom working length suitable for their height and posture or to use predetermined focal lengths. Over a third of students in our study did not know the working length of their loupes, potentially causing unnecessary strain from posture and negating some of the perceived ergonomics benefits. This may also explain why one out of ten students still reported pain after starting to wear loupes.

The ADA (2015) suggested that magnification choice, working length, field of view and the telescope declination angle must all be correctly chosen to maintain good head and neck posture. Poorly measured loupes can cause practitioners to drop their head forward to correctly focus on the oral cavity, 'leading to poor posture along with neck, shoulder and neck pain'. There are drawbacks to wearing loupes. A University of Newcastle study (Hayes et al, 2015) found that students' complaints about loupes included the need for an adjustment period, limited depth of vision, headache, dizziness and trouble in infection control. In this current study, participants cited several of these issues, however, the biggest drawback was the weight of the loupes.

Overall, less than half of respondents to this survey owned a dental LED light; however, by the final study year almost nine out of ten of them own a light. The greater uptake of lights over loupes may be due to their lower cost or easy off-the-shelf access. The findings showed that for the majority of students who use a light, their clinical experience is greatly improved and one out of five believed they could no longer work without a light.

Neuhaus et al. (2015b) suggested the popularity of a personal LED light over a dental chair overhead lamp is the reduction of shadows due to the coaxial beam of the



headlamp light. There is a caveat, however, their study showing that an overhead lamp's high colour rendering index (>90 CRI) is superior for visual caries detection compared to the (usually) low CRI of personal LED headlamps. It was also noted that there is a need for greater illumination for practitioners over 40 years of age. However older practitioners can suffer from reflection glare, which increases with greater light intensity (>20,000 lux) and coaxial beams that reflect directly into the eye. Therefore, buying a dental LED light without understanding their shortcomings may induce visual problems for some dental practitioners.

The most common brand of loupes among owners in this study were Orascoptic and Zeiss as well as generic no-name brands. Choosing these brands may derive from the sales representatives who regularly attend the campus. Interestingly, as many students (one fifth) chose to purchase no-name brands off the internet from websites such as Ali Express as chose to purchase Zeiss. Brands are chosen primarily on price and advice from other students or staff, while many students did not know why they purchased a particular brand. Magnification choice is also mostly influenced by advice from other students as well as their own research. Students intending to purchase loupes were most interested in Orascoptic and Heine. Heine recently began marketing to Otago students, and on the basis of this survey, presentations to students appear to be an effective marketing strategy.

The results of this study revealed students' lack of knowledge around important aspects of loupe design. Half of the students intending to buy loupes did not know whether they would purchase FLM or TTL frame mount designs. Lack of awareness is consistent between loupe owners and those intending to purchase loupes. Eight out of ten loupe owners did not know the differences, advantages or disadvantages of the two common telescope designs, viz. Galilean and Keplerian, or which of the two designs they would purchase.

Choosing the appropriate telescope design is an important decision as visual acuity among individuals is highly variable, and vision deteriorates with age. Telescope design conferred different benefits to practitioners depending on their age and needs. Eichenberger et al. (2015) showed that many dentists are not aware of their visual deficiencies. They suggested that early adoption of magnification devices to compensate for individual handicaps or age-related vision impairment, namely presbyopia. Their study included participants over 40 years of age, the age of presbyopic onset.

Studies have demonstrated that Galilean telescopes allowed practitioners over 40 years to almost match the visual acuity of the unaided, natural vision of young practitioners by compensating for presbyopic deficiencies (Eichenberger et al. 2015, Perrin et al. 2016). Simple Galilean telescopes do not significantly improve the visual performance of young practitioners; they do improve working posture. Young practitioners can improve acuity (magnification) by moving their head closer to the oral cavity, although this results in

poor ergonomics and musculoskeletal dysfunction. Older practitioners cannot reduce the distance between eye and oral cavity due to a lack of eye accommodation (presbyopia). The comparatively complex Keplerian telescopes, however, significantly improve visual performance of practitioners in both age groups.

Almost nine out of ten students that took part in this study expressed a desire for expert teaching on loupes and lights. While 28.7% believe lights should be required equipment, only 14.4% felt the same about loupes. Many students reported a positive experience and an awareness of the benefits of these visual aids, e.g. improved posture, pain avoidance, quicker learning, finer visual acuity and improved clinical performance. Prevalence of neck and back pain among these students mirrors the prevalence levels in the profession.

Meraner and Nase (2008) suggested that to garner students' 'buy-in' to acquire loupes, the faculty staff members needed to be 'on board' as well. A recent study of dental students in Jeddah (Alhazzazi et al. 2017) showed that their students were aware of the significance of magnification in improving the accuracy and quality of their work, and that using loupes should be reinforced by faculty early during dental school. As noted, several Australian dental schools have already mandated their use by their students (Hayes et al 2019).

The clinical relevance of this study is that loupes and lights significantly improved dental student experiences, particularly in the areas of posture, visual acuity, and clinical performance, and revealed a lack of awareness of various important aspects of loupes and lights. The study also contributed to the small yet growing pool of work investigating the use of magnification and illumination aids by dental students and dentists.

Future research will investigate several areas identified in this study including faculty staff education and attitudes towards loupes and lights, and staff uptake of these devices. Additionally, appropriate clinically focused study designs could investigate ergonomics, visual acuity and clinical performance of loupe wearers and non-wearers to verify the self-reported benefits. Focused study questions might include: (1) Differences of attitudes towards loupes and lights between undergraduate and postgraduate students, (2) Would practicing dentists recommend early uptake of loupes and lights at dental school, (3) Measuring the neck bend of undergraduate students who do and do not wear loupes, (4) Does the early uptake of loupes during dental training years translate to career longevity, (5) Should the use of dental loupes and lights be mandated in undergraduate-level dental training, and (6) Does colour temperature and CRI of a dental headlight impact on caries diagnosis.

## Conclusion

This study investigated dental students' uptake and experience of visual magnification and illumination aids. The research concluded that undergraduate students who use dental loupes and an LED light report significantly improved visual acuity, clinical performance and posture. We did find though, that there is a lack of of



knowledge among students of important considerations when choosing to purchase loupes, causing unnecessary issues. Students also desire expert teaching on visual magnification and illumination aids and this could be included for students while in their undergraduate programme. Students, however, did not want the faculty to mandate the use of loupes and lights.

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