Effect of Loupe and Microscope on Dentists' Neck Muscles Activity during Crown Preparation – A Pilot Study

Soohyun Hong

The Graduate School

Yonsei University

Department of Dentistry

Effect of Loupe and Microscope on Dentists' Neck Muscles Activity during Crown Preparation – A Pilot Study

Directed by Professor Jeong-Won Park

A Master Thesis

Submitted to the Department of Dentistry

and the Graduate School of Yonsei University

in a partial fulfillment of the

requirements for the degree of

Master of Dental Science

Soohyun Hong

December 2022

This certifies that the Master's Thesis
of Soohyun Hong is approved.

_____
Thesis Supervisor: Jeong-Won Park

_____
Su-Jung Shin

_____
Jung Hyun Park

The Graduate School
Yonsei University
December 2022

감사의 글

석사과정 2년과 본 학위논문을 마치기까지 저에게 도움을 주신 많은 분들께 짧은 지면을 빌려 감사의 말씀을 전하고자 합니다.

본 논문을 작성하며 처음부터 끝까지 부족한 저를 지도해주신 박정원 교수님께 진심으로 감사드립니다. 교수님께서 보여주신 학자로서의 모습을 항상 깊이 존경하며 아낌없는 가르침을 주셔서 다시 한 번 감사드립니다. 또한 바쁘신 와중에도 논문 심사를 맡아 좋은 지적과 미처 생각하지 못한 부분까지 조언을 아끼지 않아 주신 신수정 교수님, 박중현 교수님께도 감사의 말씀을 올립니다. 더불어 보존과 수련의로서 임상 경험을 넓히고, 대학원생으로서 지식의 깊이를 더할 수 있도록 많은 가르침을 주신 노병덕 교수님, 박성호 교수님, 김의성 교수님, 신유석 교수님, 김선일 교수님, 김도현 교수님, 강수미 교수님, 전미정 교수님께도 감사의 말씀드립니다.

또한 본 논문을 위해 장비 대여를 허락한 재활의학과 교실, 특히 본 논문을 작성하는 데에 있어 열정적으로 의견을 내주신 박진영 교수님 그리고 장비 사용법에 대해 자세히 알려주신 윤순웅 선생님께 감사드립니다. 그리고 함께 수련을 받으며 서로 힘이 되어주고, 즐거운 수련 생활을 할 수 있게 해주고, 바쁜 수련과정 중에도 본 연구에 있어 많은 도움을 준 동기 이종인 선생과 의국 선, 후배님 들에게도 모두 감사의 말을 전합니다. 특히 늦은 시간까지 연구에 많은 도움을 준 양소연 선생에게 한번 더 감사의 말을 전합니다.

마지막으로 터키에서 항상 저를 믿어 주시고, 든든하게 버팀목이 되어 주신 부모님과 오빠, 그리고 언제나 저를 응원해주고 도와주는 예비신랑 고영승에게 말로는 전하지 못했던 감사와 사랑한다는 말을 전합니다.

Table of Contents

List of Figures

List of Tables

Abstract

Effect of Loupe and Microscope on Dentists' Neck Muscles Activity during Crown Preparation – A Pilot Study

Soohyun Hong, D.D.S

Department of Dentistry

The Graduate School, Yonsei University

(Directed by Professor Jeong-Won Park, D.D.S., M.S., Ph.D.)

The purpose of this study was to evaluate the effect of different types of visual aid (naked eye, loupe, and dental microscope) on the muscle activity of dentists during crown preparation according to dentists' muscle (bilateral upper trapezius, sternocleidomastoid (SCM), cervical erector spinae, and anterior deltoid), patients' tooth position (#16, #26, #36, and #46), and tooth surface (occlusal, buccal, lingual/palatal, proximal).

Six right-handed dentists from Gangnam Severance Hospital, Department of Conservative Dentistry participated in this pilot study. The muscle activity of the eight muscles studied were evaluated by surface electromyographic signals. The participants performed crown preparations on artificial first molars of every quadrant (#16, 26, 36, and 46) in a phantom head with the naked eye, using a loupe, and a microscope. One-way analysis of variance and Bonferroni's post-hoc test were used to evaluate the effect of visual aid according to muscle, tooth position, and tooth surface ($p < 0.05$).

There were significant differences according to visual aid ($p < 0.05$). Overall, compared to working with the naked eye, the muscle activity reduced when using a loupe but the differences were significant during crown preparation of mandibular first molars. Significant differences in muscle activity were shown with the use of a microscope. The muscle with the highest workload for all types of visual aid was the cervical erector spinae followed by upper trapezius. Except for left upper trapezius, no significant difference according to tooth position was found. As for tooth surface, statistical difference in muscle activity according to visual aid was observed for proximal surface of every tooth ($p < 0.05$).

Therefore, during crown preparation, the workload of the studied muscles can successfully be reduced with the use of a loupe and microscope.

Keywords: Dentist, Surface electrographic signals, Loupe, Microscope, Visual aid, Muscle activity, Crown preparation

Effect of Loupe and Microscope on Dentists' Neck Muscles Activity during Crown Preparation – A Pilot Study

Soohyun Hong, D.D.S

Department of Dentistry

The Graduate School, Yonsei University

(Directed by Professor Jeong-Won Park, D.D.S., M.S., Ph.D.)

I. INTRODUCTION

In order to gain precise vision inside small and dark working field, the patient's mouth, it is unavoidable for dentists to work in a forward head posture, neck tilted forward, and shoulders drooping forward in a rounded position (Mansoor et al., 2022). This unbalanced

posture leads to a high prevalence of musculoskeletal disorders among dentists (Cherniack et al., 2010). According to Pejcić et al. (2016), over 60% of dentists suffer from various musculoskeletal disorders throughout their work life, mostly in the neck, shoulder, and back. Many studies show that this disorder is prevalent since dental pre-clinical training periods. According to Ng et al. (2016), approximately 85% of dental students reported musculoskeletal disorder in at least one body region with the neck being the most common. Therefore, many authors point out the need to prevent musculoskeletal disorders of dentists.

Numerous strategies include alternating between standing and sitting (Valachi and Valachi, 2003), increasing physical activity (Thakar et al., 2015), stretching (Kumar et al., 2014), taking rest breaks (Pope-Ford and Jiang, 2015), and utilizing visual aid (Lietz et al., 2020). As for the use of visual aid, more focus in on the success rate of dental treatments due to enhanced vision (Floratos and Kim, 2017) than its benefits regarding enhanced posture. Although visual aid has also been highly recommended during dental treatment in order to enhance working posture and thus reduce muscle workload, evidence regarding this subject is relatively scarce.

In order to evaluate dentists' working posture, multiple outcome measures can be used including postural assessment (Dable et al., 2014), pain scales (Hayes et al., 2016), and muscle activity (De Bruyne et al., 2016) (Haddad et al., 2012). Surface electromyography (sEMG) is a non-invasive method that directly assesses muscle contraction and can be used to measure muscle activity, muscle fatigue, and timing of muscular contraction (Strimpakos

et al., 2005). It is currently being used in various fields such as research, rehabilitation, sports, and ergonomics (Tapanya et al., 2021). Up to date, the various studies related to the effect of visual aid on ergonomics in dentistry using sEMG have focused on loupes. Pazos et al. (2022) reported the effect of different levels of magnification (2.5x, 3.0x, 3.5x) of Galilean loupes on working posture and López-Nicolás et al. (2019) evaluated the effect of ergonomic stool and/or loupes. So far, no previous study has investigated the effect of dental microscope on working posture during dental treatment.

The purpose of this pilot study was to evaluate the effect of different types of visual aid (naked eye, loupe, dental microscope) on the muscle activity during crown preparation, according to muscle (bilateral upper trapezius, sternocleidomastoid, cervical erector spinae, and anterior deltoid), tooth position (#16, #26, #36, and #46), and tooth surface (occlusal, buccal, lingual/palatal, proximal).

II. MATERIALS AND METHODS

1. Participants

Six dentists from Gangnam Severance Hospital, Department of Conservative Dentistry participated in this pilot study. The inclusion criteria were right-handed dentists, without any self-reported musculoskeletal pain. After a thorough explanation of the purpose and the procedures of this study, written informed consent was obtained. This study was approved by Gangnam Severance Hospital (IRB No.: 3-2022-0272).

2. Variables

The independent variables were (a) visual aid (naked eye, loupe, and dental microscope), (b) muscle (bilateral upper trapezius, SCM, cervical erector spinae, and anterior deltoid), (c) tooth position (#16, #26, #36, and #46), and (d) tooth surface (occlusal, buccal, lingual/ palatal, proximal).

3. Muscle Activity

Surface electromyographic signals were recorded with FreeEMG 1000 8ch (BTS Bioengineering, Milano, Italy) and the electrodes were placed with an inter-electrode distance fixed at 2cm, parallel to the muscle fibers, at the locations described in Table 1. The skin was prepared by cleaning the located area with alcohol swab before electrode placement.

Before crown preparation, in order to normalize the data obtained, each participant performed three trials of resisted maximum voluntary isometric contractions (MVICs) for 3 seconds with 20 seconds of recovery break between each trial for each measured muscle. The average MVIC of the three trials was used for normalization. The participants were allowed to rest for 10 minutes before commencing the experimental procedure.

Table 1. Electrode position of selected muscles

Muscle	Electrode position	Reference
Upper Trapezius	20% medial to half the length between lateral part of acromion and C7	Holterman, 2009
Sternocleidomastoid	Half the length between origin and insertion of SCM	Hasan et al., 2022
Cervical Erector Spinae	1cm away from the 4th cervical spinous process	Caneiro et al., 2011
Anterior Deltoid	Midpoint between electrodes at 2cm anterior to midpoint between acromion and deltoid tuberosity	Szeto et al., 2005

4. Experimental Procedures

Gold crown preparations were performed on artificial first molars of every quadrant; maxillary right first molar, maxillary left first molar, mandibular right first molar, and mandibular left first molar. After completion of one crown preparation, a 3-minute break was given.

For each tooth, the sEMG data was collected separately, according to tooth surface; occlusal, buccal, lingual/palatal, and proximal. The EMG signal was recorded for 90 seconds for each tooth surface, followed by a rest time of 90 seconds in order to prevent fatigue. The section with 20 seconds of stable EMG signal was chosen for analysis.

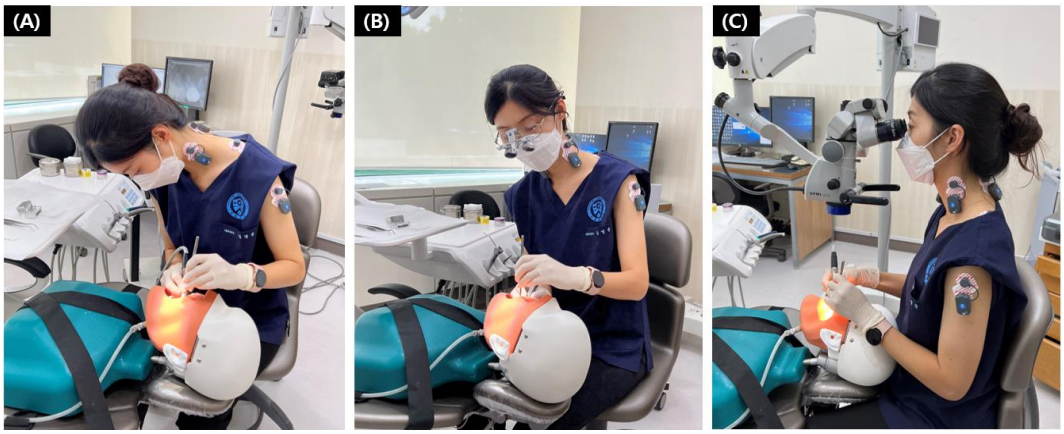

Figure 1. Crown preparation of #26 mesial

(A) Naked Eye **(B)** Loupe (*EyeMag® Smart,* Carl Zeiss, Germany) **(C)** Microscope (OPMI® pico, Carl Zeiss, Germany)

All participants performed these tasks without any visual aid (naked eye), using a loupe of their own with 2.5**x** magnification (*EyeMag® Smart,* Carl Zeiss, Germany or *SurgeLoup®*, Crystal Optic, South Korea), and using a dental microscope under 4.0**x** magnification (OPMI® pico, Carl Zeiss, Germany), as shown in Figure 1.

The procedures were performed on a phantom (Mannequin trunk type type 2, Nissin, Kyoto, Japan) that was placed on a dental chair (Intego, Dentsply Sirona, Bensheim, Germany) in order to stimulate treatment in a clinical setting. A new 102R diamond bur (Shofu inc., Kyoto, Japan) was given to each participant. All treatment was performed with direct view and the participants were allowed to adopt their usual treatment posture. The dental mirror was used for retraction when needed.

Muscle activity data for each muscle obtained from the wireless electrodes were analyzed using EMG Analyzer (BTS Bioengineering, Milano, Italy). The sampling rate was 1,000 Hz and the raw EMG data were processed using the root mean square (RMS) with 50ms and 20-500 Hz filter. The EMG measurements converted to the percentage of MVIC (% MVIC) was used for comparison in this study, as described below.

$$\%\boldsymbol{MVIC} = \frac{\boldsymbol{mean\ task{-}oriented\ RMS}}{\boldsymbol{mean\ MVIC\ RMS}} \times \mathbf{10}$$

5. Statistical Analysis

SAS version 9.4 (SAS Institute, Cary, NC, USA) was used for the statistical analysis. Shapiro- Wilk test and Kolmogorov-Smirnov test was used to test for the normality of data distribution. ANOVA was used to determine the differences of %MVIC among different types of visual aid (naked eye, loupe, microscope), tooth position (#16, #26, #36, and #46), and muscle. The data was further divided into subgroups according to tooth number (#16, #26, #36, #46) and the difference among muscle and surface (occlusal, buccal, lingual/ palatal, proximal) in each subgroup was also examined. Bonferroni correction was applied for the p-value of post-hoc analysis ($p < 0.05$).

III. RESULTS

All 6 participants (4 males and 2 females) performed 12 crown preparations each. The normality tests revealed that most of the values satisfied normality overall.

Table 2. The mean %MVIC of the eight muscles studied (and SD) during crown preparation of all four first molars according to different visual aids

Muscle	Visual Aid				Overall	post-hoc		
	Total	Naked Eye (N)	Loupe (L)	Microscope (M)	p-value	N vs. L	N vs. M	L vs. M
Rt. Trapezius	17.47±14.31	22.47±14.43^{a}	19.91±15.98^{I}	10.03±8.27$^{\alpha}$	<.0001	0.5476	<.0001	<.0001
Lt. Trapezius	12.74±11.32	17.48±14.02^{a,b}	12.26±9.94^{II}	8.47±7.07$^{\alpha,\beta}$	<.0001	0.0025	<.0001	0.045
Rt. SCM	8.67±7.20	11.75±9.45^{c}	8.37±6.37^{II}	5.91±3.07$^{\beta}$	<.0001	0.002	<.0001	0.0386
Lt. SCM	10.02±7.70	13.60±10.19^{b,c}	9.33±6.52^{II}	7.15±3.34$^{\alpha,\beta}$	<.0001	0.0002	<.0001	0.1136
Rt. Erector Spinae	21.75±11.79	25.74±11.81^{a}	23.90±11.83^{I}	15.61±9.04$^{\gamma}$	<.0001	0.7363	<.0001	<.0001
Lt. Erector Spinae	21.53±13.23	24.82±13.41^{a}	23.07±9.67^{I}	16.71±14.79$^{\gamma}$	<.0001	>.9999	<.0001	0.002
Rt. Ant Deltoid	8.34±8.12	9.65±8.54^{c}	8.68±8.53^{II}	6.68±7.00$^{\alpha,\beta}$	0.0349	>.9999	0.0333	0.2605
Lt. Ant Deltoid	3.16±2.74	3.57±3.50^{d}	3.55±2.81^{III}	2.36±1.24$^{\delta}$	0.002	>.9999	0.006	0.0072

Values are mean ± SD. N= 96 surfaces for each muscle (6 participants, 4 teeth/ participant, 4 surfaces/tooth)
Lower case alphabets, Roman numbers, and lowercase Greek alphabets indicate significant differences of muscle activity during crown preparation without visual aid, using loupe, and using microscope respectively.
SCM: Sternocleidomastoid, MVIC: Maximum Voluntary Isometric Contractions

As shown in Table 2, the muscle activity of all muscles differed significantly among the three types of visual aid ($p < 0.05$). During crown preparation without the help of any visual aid, the order of muscle activity in descending order was cervical erector spinae > upper trapezius > SCM > anterior deltoid. The differences between muscle workload of Lt. vs Rt. for erector spinae, upper trapezius, and sternocleidomastoid was not significant. Overall, compared to working with the naked eye, the workload of every muscle reduced when using a loupe but the difference was significant only for Lt. trapezius and bilateral SCM ($p < 0.05$). Meanwhile, the use of a microscope resulted in statistical differences for each of the other method for virtually every muscle ($p < 0.05$).

Table 3. The mean %MVIC of each muscle (and SD) of #16 according to visual aids

Muscle	Visual Aid				Overall	post-hoc		
	Total	Naked Eye (N)	Loupe (L)	Microscope (M)	p-value	N vs. L	N vs. M	L vs. M
Rt. Trapezius	16.70±15.84	19.93±13.61 [b]	21.89±20.86[I]	8.28±6.37 [α]	0.0043	>.9999	0.0247	0.0067
Lt. Trapezius	8.56±6.62	10.67±7.21 [c, d]	7.78±6.19[II]	7.25±6.16 [α]	0.1579	0.3925	0.2244	>.9999
Rt. SCM	7.99±5.47	10.08±6.10 [c, d]	8.10±5.90[II]	5.78±3.26 [α]	0.0217	0.5804	0.0176	0.3915
Lt. SCM	11.33±8.92	16.36±11.95 [b, d]	11.13±6.55[II]	6.50±3.00 [α]	0.0003	0.0825	0.0002	0.1507
Rt. Erector Spinae	19.46±9.94	20.99±7.44 [b]	22.51±12.19[I]	14.88±8.18 [β]	0.0169	>.9999	0.0875	0.021
Lt. Erector Spinae	24.13±13.86	30.27±17.10 [a]	25.75±7.92[I]	16.37±11.55 [β]	0.0012	0.6726	0.001	0.0396
Rt. Ant Deltoid	6.04±6.07	6.19±6.09 [c]	5.82±7.12[II]	6.10±5.11 [α]	0.9769	>.9999	>.9999	>.9999
Lt. Ant Deltoid	4.02±3.36	4.83±4.38 [c]	4.58±3.30[II]	2.64±1.33 [α]	0.0445	>.9999	0.0684	0.1267

Values are mean ± SD. N= 24 surfaces for each muscle (6 participants, 1 tooth/participant, 4 surfaces/tooth). Lower case alphabets, Roman numbers, and lowercase Greek alphabets indicate significant differences of muscle activity during crown preparation without visual aid, using loupe, and using microscope respectively.
SCM: Sternocleidomastoid, MVIC: Maximum Voluntary Isometric Contractions

Table 4. The mean %MVIC of each muscle (and SD) of #26 according to visual aids

Muscle	Visual Aid				Over all	post-hoc		
	Total	Naked Eye (N)	Loupe (L)	Microscope (M)	p-value	N vs. L	N vs. M	L vs. M
Rt. Trapezius	17.38±14.00	24.81±16.98 [a, b]	18.22±9.80 [I,II]	9.10±9.54 [α, γ]	0.0002	0.2216	0.0002	0.0434
Lt. Trapezius	11.66±10.44	16.66±12.61 [b, c]	12.39±9.64 [II,III]	5.92±4.85 [α, β]	0.001	0.3824	0.0007	0.0663
Rt. SCM	8.12±6.04	11.11±7.49 [c, d]	8.08±5.34 [III,IV]	5.16±3.10 [α, β]	0.0021	0.1963	0.0014	0.226
Lt. SCM	11.87±9.53	16.72±11.99 [b, c]	11.86±8.59 [II,III]	7.04±3.73 [α, β]	0.0013	0.1771	0.0009	0.1846
Rt. Erector Spinae	20.61±10.54	23.84±9.26 [a b]	23.75±11.83 [I]	14.23±7.34 [γ, δ]	0.0008	>.9999	0.0029	0.0032
Lt. Erector Spinae	23.22±12.15	28.38±12.08 [a]	25.00±7.82 [I]	16.29±12.93 [δ]	0.0011	0.893	0.0011	0.026
Rt. Ant Deltoid	6.26±6.78	7.22±8.46 [c, d]	6.31±6.94 [III,IV]	5.26±4.46 [α, β]	0.6107	>.9999	0.9683	>.9999
Lt. Ant Deltoid	3.90±3.43	4.89±4.72 [d]	4.39±3.15 [IV]	2.42±0.77 [β]	0.0284	>.9999	0.0349	0.1291

Values are mean ± SD. N= 24 surfaces for each muscle (6 participants, 1 tooth/participant, 4 surfaces/tooth). Lower case alphabets, Roman numbers, and lowercase Greek alphabets indicate significant differences of muscle activity during crown preparation without visual aid, using loupe, and using microscope respectively.
SCM: Sternocleidomastoid, MVIC: Maximum Voluntary Isometric Contractions

Table 5. The mean %MVIC of each muscle (and SD) of #36 according to visual aids

Muscle	Visual Aid				Overall	post-hoc		
	Total	Naked Eye (N)	Loupe (L)	Microscope (M)	p-value	N vs. L	N vs. M	L vs. M
Rt. Trapezius	18.52±14.37	20.87±12.07 [a, b, c]	21.99±19.71 [I,II]	12.69±7.04 [α, β, γ]	0.048	>.9999	0.1385	0.072
Lt. Trapezius	16.73±15.06	25.34±20.24 [a, b]	14.15±9.95 [II,III]	10.69±8.31 [α, β, γ]	0.0013	0.0202	0.0015	>.9999
Rt. SCM	9.93±9.52	15.28±13.82 [b, c]	7.76±5.83 [III,IV]	6.74±3.07 [γ, δ]	0.0022	0.013	0.004	>.9999
Lt. SCM	8.51±5.98	10.82±7.69 [c, d]	7.42±5.41 [III,IV]	7.29±3.70 [γ, δ]	0.0658	0.1421	0.1183	>.9999
Rt. Erector Spinae	23.05±12.48	28.31±13.51 [a]	23.75±11.43 [I]	17.10±10.05 [α]	0.006	0.5513	0.0046	0.1621
Lt. Erector Spinae	18.27±10.84	20.55±10.75 [a, b, c]	19.79±9.03 [I,II]	14.48±11.94 [α, β]	0.1058	>.9999	0.1563	0.264
Rt. Ant Deltoid	9.33±8.62	10.62±8.46 [c, d]	9.41±8.23 [III,IV]	7.94±9.28 [β, γ, δ]	0.5655	>.9999	0.8644	>.9999
Lt. Ant Deltoid	2.36±1.52	2.41±1.14 [d]	2.67±2.25 [IV]	2.00±0.72 [δ]	0.3101	>.9999	>.9999	0.3909

Values are mean ± SD. N= 24 surfaces for each muscle (6 participants, 1 tooth/participant, 4 surfaces/tooth). Lower case alphabets, Roman numbers, and lowercase Greek alphabets indicate significant differences of muscle activity during crown preparation without visual aid, using loupe, and using microscope respectively.
SCM: Sternocleidomastoid, MVIC: Maximum Voluntary Isometric Contractions

Table 6. The mean %MVIC of each muscle (and SD) of #46 according to visual aids

Muscle	Visual Aid				Overall	post-hoc		
	Total	Naked Eye (N)	Loupe (L)	Microscope (M)	p-value	N vs. L	N vs. M	L vs. M
Rt. Trapezius	17.28±13.15	24.28±14.90 [a, b]	17.52±10.81 [I,II,III]	10.05±9.47 [α,β]	0.0005	0.163	0.0003	0.1007
Lt. Trapezius	13.99±10.07	17.27±8.82 [b, c, d]	14.70±12.13 [II,III,IV]	10.00±7.74 [α, β]	0.0379	>.9999	0.0357	0.2976
Rt. SCM	8.67±7.10	10.53±8.19 [d, e]	9.54±8.27 [III, IV,V]	5.94±2.81 [β]	0.0605	>.9999	0.0741	0.2272
Lt. SCM	8.39±4.85	10.49±6.86 [d, e]	6.90±3.14 [IV,V]	7.76±2.91 [α, β]	0.0258	0.0291	0.141	>.9999
Rt. Erector Spinae	23.87±13.53	29.82±14.16 [a]	25.58±12.38 [I]	16.22±10.51 [α,γ]	0.0011	0.7261	0.001	0.0337
Lt. Erector Spinae	20.50±15.13	20.10±10.11 [b, c]	21.72±12.50 [I,II]	19.68±21.10 [γ]	0.8883	>.9999	>.9999	>.9999
Rt. Ant Deltoid	11.72±9.35	14.58±8.73 [c, d]	13.17±9.88 [II,III,IV]	7.42±8.12 [α, β]	0.0171	>.9999	0.0214	0.0872
Lt. Ant Deltoid	2.37±1.54	2.15±0.96 [e]	2.56±1.74 [V]	2.38±1.81 [β]	0.6629	>.9999	>.9999	>.9999

Values are mean ± SD. N= 24 surfaces for each muscle (6 participants, 1 tooth/participant, 4 surfaces/tooth). Lower case alphabets, Roman numbers, and lowercase Greek alphabets indicate significant differences of muscle activity during crown preparation without visual aid, using loupe, and using microscope respectively.
SCM: Sternocleidomastoid, MVIC: Maximum Voluntary Isometric Contractions

Tables 3-6 show the mean %MVIC of each muscle (and SD) for each tooth position according to different visual aids. Regarding #16, most of the muscles showed significant differences according to visual aid ($p < 0.05$, Table 3). The order of muscle workload was Lt. erector spinae > Rt. erector spinae > Rt. trapezius > Lt. SCM with unaided vision, where Lt. erector spinae was the significantly highest. These muscles were all reduced with the help of a microscope although the reduction was not statistically significant for Rt. erector spinae. With the use of a microscope, the highest muscle activity was seen for Lt. and Rt. cervical erector spinae, but the difference was not significant.

On the other hand, working with a loupe did not have a significant impact on muscle activity in all muscles ($p > 0.05$). The order of the highest 4 muscle activities remained the same for loupe and microscope. As for bilateral anterior deltoids, no significant differences were observed according to visual aid.

The mean %MVIC of each muscle (and SD) of #26 according to different visual aids is compared in Table 4. Except for Rt. anterior deltoid, there were significant differences according to visual aid ($p < 0.05$), particularly between naked eye and microscope ($p < 0.05$). Considering the average %MVIC of all the muscles, statistical differences was noted between unaided vision and loupe ($p = 0.0273$), although post hoc analysis revealed no significant difference according to a specific muscle. Similar to #16, although in slightly different order, the muscle with the highest activity during crown preparation with unaided vision was Lt. erector spinae followed by Rt. upper trapezius and Rt. erector spinae. However, the differences among these three muscles were not significant. Crown preparation with the help of a microscope showed statistical difference in the workload of these muscles compared to the other two ($p < 0.0001$), and the order of muscle activity changed to Lt. erector spinae > Rt. erector spinae > Rt. upper trapezius, without significant difference. This order remained unchanged with the use of a microscope. Significant difference was observed between naked eye and microscope for every muscle except Rt. anterior deltoid ($p < 0.05$).

Significant differences were observed between working with naked eye and microscope for Lt. Trapezius, Rt SCM. and Rt Erector Spinae for #36 ($p < 0.005$, Table 5). Moreover, significant difference was noted between the use of a loupe and naked eye for Lt. Trapezius and Rt. SCM ($p < 0.02$). Without the use of magnification, the %MVIC according to muscle in descending order was Rt. erector spinae > Lt. trapezius > Rt. upper trapezius ≈ Lt. erector spinae. The differences between the workload of Rt. erector spinae and Lt. trapezius were not significant. With the use of loupe, this order changed to Rt. erector spinae > Rt. upper trapezius > Lt. erector spinae > Lt. upper trapezius, but the differences of the first three muscles was not significant. Rt. erector spinae remained to be the muscle with the highest activity during crown preparation with a microscope, followed by Lt. erector spinae, Rt. upper trapezius and Lt. upper trapezius ($p>0.05$).

The muscle activity of Rt. erector spinae, which was the highest, showed significant difference only with the use of a microscope ($p < 0.005$). The workload of Lt. trapezius during crown preparation without visual aid was statistically different compared to that of loupe and microscope, presenting higher muscle activity ($p < 0.02$). No significant differences according to muscle was observed between loupe and microscope ($p > 0.05$).

Considering crown preparation of #46 with the naked eye, muscle activity was highest for Rt. erector spinae, followed by Rt. trapezius and Lt. erector spinae (Table 6). Significant differences were found between Rt. erector spinae and Lt. erector spinae. Using a loupe, the order changed to Rt. erector spinae > Lt. erector spinae > Rt. upper trapezius, but

without significant difference. Workload of bilateral upper trapezius, Rt. erector spinae, and Rt. anterior deltoid showed significant difference only with the use of a microscope ($p < 0.03$). There was a statistical difference in %MVIC for Lt. SCM, from 10.49±6.86 with naked eye to 6.90±3.14 when using a loupe ($p < 0.03$).

When evaluated according to tooth type (#16, #26, #36, and #46), no significant differences in muscle activity were detected except for Lt. upper trapezius. Post-hoc analysis revealed that the difference in muscle workload for Lt. upper trapezius was between #16 and #36, with higher muscle activity during crown preparation of tooth #36 (Appendix 1).

Table 7. The significant differences of visual aid summarized according to tooth type

	#16	#26	#36	#46
Rt. Trapezius	N vs M L vs M	N vs M L vs M		N vs M
Lt. Trapezius		N vs M	N vs L N vs M	N vs M
Rt. SCM	N vs M	N vs M	N vs L N vs M	
Lt. SCM	N vs M	N vs M		N vs L
Rt. Erector Spinae	L vs M	N vs M L vs M	N vs M	N vs M L vs M
Lt. Erector Spinae	N vs M L vs M	N vs M L vs M		
Rt. Anterior Deltoid				N vs M
Lt. Anterior Deltoid		N vs M		

The significant differences according to visual aids from Tables 3-6 are summarized. The gray boxes depict significant differences of muscle workload and the detailed type of visual aid with significant difference of %MVIC for post-hoc analysis were written inside.
(N: naked eye, L: loupe, M: microscope)

The majority of significant differences was observed between the naked eye and microscope, regardless of tooth type and was dominant during crown preparation of #26. Meanwhile statistical difference between naked eye and loupe was observed in the mandibular first molars (#36 and #46) while statistical difference between loupe and microscope was observed in the maxillary first molars (#16 and #26). As for muscle, the muscles that were the least affected according to visual aid was bilateral anterior deltoids, and the most frequently affected was Rt. erector spinae.

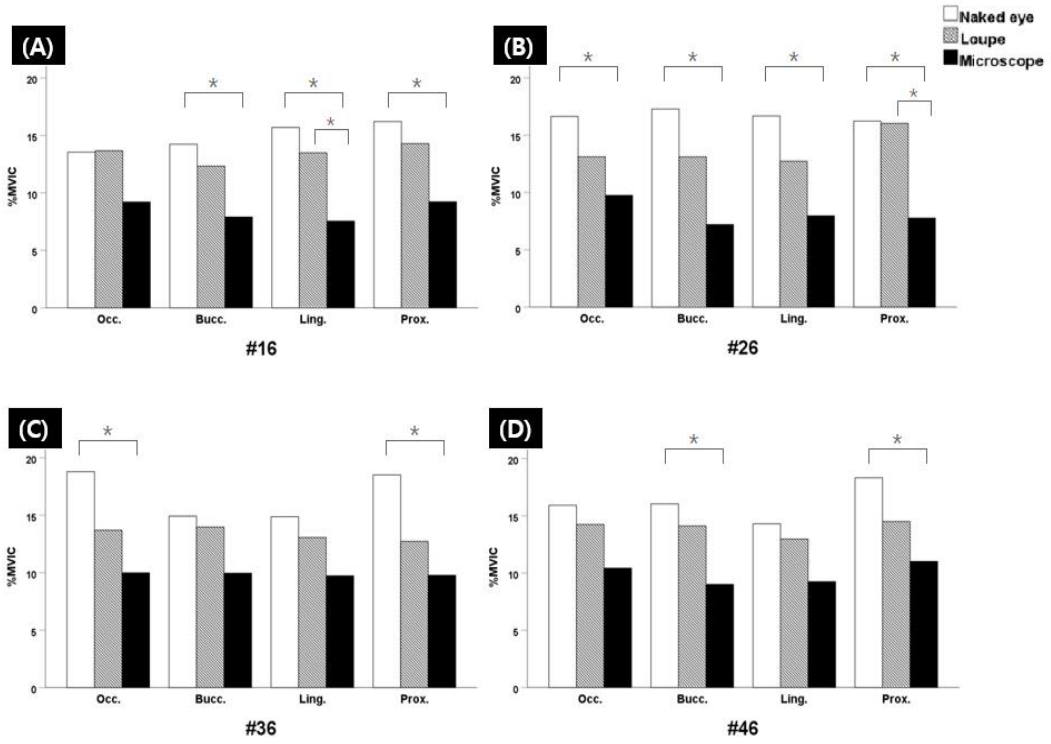

Figure 2. Mean %MVIC of the eight muscles using different visual aid according to tooth surface in each tooth. **(A)** #16, **(B)** #26, **(C)** #36, **(D)** #46

*: Significant differences between visual aids ($p<0.05$)

Figure 2 illustrates the mean muscle activity of the studied muscles according tooth surface of each tooth. When evaluated according to tooth surface, significant differences are observed mostly between the naked eye and microscope, especially for maxillary first molars (#16, #26). There was a significant difference of muscle workload during crown preparation of the proximal surface of every tooth.

IV. DISCUSSION

Up to date, studies that evaluate the effect of magnification have focused on loupes in particular, during class I cavity preparations (Pazos et al., 2020), periodontal probing (Branson et al., 2018) and tooth drilling, filling, and polishing for composite resin restorations (López-Nicolás et al., 2019) (García-Vidal et al., 2019). No studies that assessed the use of microscope during crown preparation was noted.

The muscle activity of cervical erector spinae, upper trapezius, and sternocleidomastoid differed significantly among the three types of visual aid. During crown preparation with the naked eye, the muscles with the highest workload was erector spinae and trapezius regardless of tooth type. This is an anticipated result as dental treatments require the right-handed operator to be in a forward-head posture, forward flexion and rotation of the cervical spine, as well as slight elevation of the scapula in order to gain vision and access to the patient's teeth which is located lower, in front of the operator.

As demonstrated Table 7, the muscle that was the least influenced by visual aid was anterior deltoid. However, the fact that the anterior deltoid muscle did not show significant difference according to visual aid may be attributed to its relatively low muscle activity. Since the function of anterior deltoid is flexion as well as internal rotation of the arm, this muscle may not routinely used during crown preparation. Moreover, the position of the arm remains relatively unchanged regardless of visual aid. This finding is consistent with results

from a previous study that found significant improvements in the positions of the head and neck but not in the arms, when using loupes as compared to those working with unaided eyes (Carpentier et al., 2019).

Although statistical differences for the erector spinae muscle was observed according to visual aid, it remained to be the muscle with the highest workload irrespective of visual aid and tooth type. A major function of the cervical erector spinae is to support the head. Although the use of visual aid can reduce the amount of neck flexion, absolute neutral position is virtually impossible, even with the help of a microscope. From Figure 1., the approximate degree of neck can be estimated to be 60˚ during crown preparation without any visual aid, 45˚ using a loupe, and 15 ˚ using a microscope. According to Hansraj (2014), these positions account for 27.2kg, 22.2kg, and 12.2kg of force to the cervical spine. Therefore, additional preventions for the neck pain such as stretching and taking breaks may be necessary.

When treating the maxillary first molars (#16, #26) the muscle activity of the left erector spinae was higher than the right side (Tables 3, 4), and vice versa when treating the mandibular first molars (#36, #46) (Tables 5, 6). This may be due to the fact that because right-handed dentists always work on the right side of the patient, gaining vision to the maxillary teeth requires more rotation of the head to the left side which requires more workload for the left erector spinae, than the right. Since the mandibular teeth are located relatively further and right to the operator, the more muscle activity from the Rt. erector

spinae is necessary to support the weight of the head. However, this explanation cannot be generalized as the preferred position during dental treatment varies greatly from operator to operator and whether direct view or mirror view is used.

In this pilot study, significant differences in muscle activity were dominantly observed between unaided vision and microscope according to muscle (Tables 2-7) as well as tooth surface (Figure 2), in which the use of a microscope was associated with almost half the workload of muscles compared to unaided vision.

The assumed ergonomic benefits of loupes can be attributed to the fixed working distance due to magnification and the declination angles (Carpentier et al., 2019) (Branson et al., 2018). These two characteristics render the operator free to move yet forced to stay relatively in a less forward-flexion neck position and thereby reduce the workload for neck and back muscles. The positive impact of declination angle on posture is stressed in previous articles. According to Voruganti (2009), loupes that allow a steeper declination angle allow the operator to work in a more neutral position.

Meanwhile, microscopes allow higher magnification levels and further constrains flexion and rotation of the operator's neck. One major difference from loupes is that it is not worn and almost every component of the microscope is adjustable in order to allow the operator to work at the most erect posture with minimal range of movement. For example, most have extendable binoculars and left/right swivel of the main body enables the operator the tilt the microscope in a vertical angulation without altering the horizontal level of the

eyepieces. These characteristics allow the operator to work in a more erect position, especially of the neck (Figure 1 (C)).

In the current study, the muscle activity of the eight muscles studied decreased with the use of the loupe for almost all cases although most differences were not always significant (Tables 2-7). However, there were some exceptions where the use of a loupe resulted in slightly higher muscle activity than that with the naked eye; muscle activity of Rt. trapezius, Rt. erector spinae during crown preparation of #16 (Table 3), Rt. trapezius and Lt. anterior deltoid for #36 (Table 5), and Lt. erector spinae for #46 increased when using a loupe (Table 6). This may be because two participants of this study do not routinely use loupe in clinic, and thus was unfamiliar with its use. Since only 6 participants were involved in this study, it can be assumed that their outranging values had a considerable effect on the results.

Significant differences in muscle activity between the naked eye and loupe was only observed for mandibular first molars (Lt. trapezius and Rt. SCM for #36 (Table 5), Lt. SCM for #46 (Table 6)), whereas significant differences between loupe and microscope was only seen for maxillary molars (Rt. Trapezius and bilateral erector spinae both for #16 and #26 (Tables 3, 4)). A possible explanation for this could be that since mandibular molars are further from the eyes, it is likely that the operator will lean more forwards for better vision during treatment without visual aid resulting in the greater enhancement of posture with the use of a loupe.

No significant difference in muscle activity was found according to tooth position

(Appendix 1). However, this finding needs to be interpreted with caution because the average %MVIC of all types of visual aid was used for analysis. Therefore, the low muscle activities during crown preparation using a microscope might have masked the differences according to tooth type.

Evaluating from tooth surface factor (Figure 2), the proximal surface of every tooth showed significant differences for the overall muscle activity between the naked eye and microscope. This implies that muscle workload can be reduced substantially regardless of tooth type when performing crown preparation of the proximal surface, which is usually considered as the most strenuous surface.

One limitation of this study is that since the crown preparations were performed in a phantom, it does not reflect exact clinical conditions, such as the patient's tongue and cheek which might have led to an underestimation of the results. Moreover, since the field of view of microscopes is relatively small, frequent adjustments of the microscope is necessary, which may lead to increased muscle workload than of that observed in this study. Furthermore, since only right-handed dentists participated in this study, studies including left-handed dentists should also be conducted. Also, since this study did not evaluate crown preparation quality, comparison of preparation quality according to visual aid is also needed. Lastly, since this is a pilot study and posture during crown preparation varies greatly according to operators, studies involving more participants seem to be necessary.

V. CONCLUSION

As a conclusion, the muscle activity of bilateral upper trapezius, cervical erector spinae, and sternocleidomastoid differed significantly according to type of visual aid. Within the limitation of this pilot study, although significant differences in the muscle activity of erector spinae was observed, it remained to be the muscle with the highest activity.

References

Branson BG, Abnos RM, Simmer-Beck ML, King GW, Siddicky SF (2018). Using motion capture technology to measure the effects of magnification loupes on dental operator posture: A pilot study. Work 59(1): 131-139.

Carpentier M, Aubeux D, Armengol V, Pérez F, Prud'homme T, Gaudin A (2019). The Effect of Magnification Loupes on Spontaneous Posture Change of Dental Students During Preclinical Restorative Training. J Dent Educ 83(4): 407-415.

Cherniack MG, Dussetschleger J, Bjor B (2010). Musculoskeletal disease and disability in dentists. Work 35(4): 411-418.

Dable RA, Wasnik PB, Yeshwante BJ, Musani SI, Patil AK, Nagmode SN (2014). Postural Assessment of Students Evaluating the Need of Ergonomic Seat and Magnification in Dentistry. J Indian Prosthodont Soc 14(Suppl 1): 51-58.

De Bruyne MA, Van Renterghem B, Baird A, Palmans T, Danneels L, Dolphens M (2016). Influence of different stool types on muscle activity and lumbar posture among dentists during a simulated dental screening task. Appl Ergon 56: 220-226.

Floratos S, Kim S (2017). Modern Endodontic Microsurgery Concepts: A Clinical Update. Dent Clin North Am 61(1): 81-91.

García-Vidal JA, López-Nicolás M, Sánchez-Sobrado AC, Escolar-Reina MP, Medina-Mirapeix F, Bernabeu-Mora R (2019). The Combination of Different Ergonomic Supports during Dental Procedures Reduces the Muscle Activity of the Neck and Shoulder. J Clin Med 8(8).

Haddad O, Sanjari MA, Amirfazli A, Narimani R, Parnianpour M (2012). Trapezius muscle activity in using ordinary and ergonomically designed dentistry chairs. Int J Occup Environ Med 3(2): 76-83.

Hansraj KK (2014). Assessment of stresses in the cervical spine caused by posture and position of the head. Surg Technol Int 25: 277-279.

Hayes MJ, Osmotherly PG, Taylor JA, Smith DR, Ho A (2016). The effect of loupes on neck pain and disability among dental hygienists. Work 53(4): 755-762.

Kumar DK, Rathan N, Mohan S, Begum M, Prasad B, Prasad ER (2014). Exercise prescriptions to prevent musculoskeletal disorders in dentists. J Clin Diagn Res 8(7): Ze13-16.

Lietz J, Ulusoy N, Nienhaus A (2020). Prevention of Musculoskeletal Diseases and Pain among Dental Professionals through Ergonomic Interventions: A Systematic Literature Review. Int J Environ Res Public Health 17(10).

López-Nicolás M, García-Vidal JA, Medina-Mirapeix F, Sánchez-Onteniente JP, Berná Mestre JD, Martín-San Agustín R, et al. (2019). Effect of different ergonomic supports on muscle activity of dentists during posterior composite restoration. PeerJ 7: e8028.

Mansoor SN, Al Arabia DH, Rathore FA (2022). Ergonomics and musculoskeletal

disorders among health care professionals: Prevention is better than cure. J Pak Med Assoc 72(6): 1243-1245.
Ng A, Hayes MJ, Polster A (2016). Musculoskeletal Disorders and Working Posture among Dental and Oral Health Students. Healthcare (Basel) 4(1).
Pazos JM, Regalo SCH, de Vasconcelos P, Campos J, Garcia P (2022). Effect of magnification factor by Galilean loupes on working posture of dental students in simulated clinical procedures: associations between direct and observational measurements. PeerJ 10: e13021.
Pazos JM, Wajngarten D, Dovigo LN, Garcia P (2020). Implementing magnification during pre-clinical training: Effects on procedure quality and working posture. Eur J Dent Educ 24(3): 425-432.
Pejcić N, Jovicić M, Miljković N, Popović DB, Petrović V (2016). Posture in dentists: Sitting vs. standing positions during dentistry work--An EMG study. Srp Arh Celok Lek 144(3-4): 181-187.
Pope-Ford R, Jiang Z (2015). Neck and shoulder muscle activation patterns among dentists during common dental procedures. Work 51(3): 391-399.
Strimpakos N, Georgios G, Eleni K, Vasilios K, Jacqueline O (2005). Issues in relation to the repeatability of and correlation between EMG and Borg scale assessments of neck muscle fatigue. J Electromyogr Kinesiol 15(5): 452-465.
Tapanya W, Puntumetakul R, Neubert MS, Hunsawong T, Boucaut R (2021). Ergonomic arm support prototype device for smartphone users reduces neck and shoulder musculoskeletal loading and fatigue. Appl Ergon 95: 103458.
Thakar S, Shivlingesh K, Jayaprakash K, Gupta B, Gupta N, Anand R, et al. (2015). High levels of physical inactivity amongst dental professionals: a questionnaire based cross sectional study. J Clin Diagn Res 9(1): Zc43-46.
Valachi B, Valachi K (2003). Preventing musculoskeletal disorders in clinical dentistry: strategies to address the mechanisms leading to musculoskeletal disorders. J Am Dent Assoc 134(12): 1604-1612.
Voruganti K (2009). Practice dentistry pain-free: evidence-based strategies to prevent pain and extend your career. British Dental Journal 206(3): 181-181.

Appendix 1. Muscle activity of different types of visual aid according to tooth position

Muscle	Tooth Number					Overall p-value	post-hoc					
	Total (n=24)	#16 (n=6)	#26 (n=6)	#36 (n=6)	#46 (n=6)		#16 vs. #26	#16 vs. #36	#16 vs. #46	#26 vs. #36	#26 vs. #46	#36 vs. #46
Rt. Trapezius	17.47±9.00	16.70±11.04 [a,b,c]	17.38±7.83 [I, II, III]	18.52±10.34 [α,β]	17.28±8.98 [1,2,3]	0.99	0.999	0.988	>.999	0.997	>.999	0.996
Lt. Trapezius	12.74±5.46	8.56±2.46 [b, c]	11.66±2.37 [II, III, IV]	16.73±7.07 [α,β]	13.99±5.68 [1,2,3]	0.051	0.69	0.039	0.244	0.297	0.837	0.763
Rt. SCM	8.67±5.18	7.99±4.87 [b, c]	8.12±5.06 [III, IV]	9.93±5.52 [α,β,γ]	8.67±6.41 [1,2,3]	0.925	>.999	0.927	0.996	0.94	0.998	0.978
Lt. SCM	10.02±4.36	11.33±4.96 [b, c]	11.87±5.89 [II, III, IV]	8.51±3.22 [β,γ]	8.39±2.39 [2,3]	0.383	0.996	0.678	0.649	0.548	0.519	>.999
Rt. Erector Spinae	21.75±9.36	19.46±8.12 [a, b]	20.61±8.51 [I, II]	23.05±10.66 [α]	23.87±11.65 [1]	0.851	0.997	0.921	0.864	0.973	0.939	0.999
Lt. Erector Spinae	21.53±10.99	24.13±11.34 [a]	23.22±8.73 [I]	18.27±10.29 [α,β]	20.50±14.82 [1,2]	0.81	0.999	0.815	0.947	0.878	0.976	0.987
Rt. Ant Deltoid	8.34±5.00	6.04±2.98 [c]	6.26±4.72 [III, IV]	9.33±5.40 [α,β,γ]	11.72±5.31 [1,2 3]	0.148	>.999	0.628	0.189	0.677	0.217	0.813
Lt. Ant Deltoid	3.16±1.68	4.02±2.12 [c]	3.90±1.93 [IV]	2.36±0.78 [γ]	2.37±1.01 [3]	0.136	0.999	0.289	0.294	0.349	0.354	>.999

Values are mean ± SD. N= 6 teeth for each muscle (6 participants, the average %MVIC of the tooth surfaces and visual aid was used).

Lower case alphabets, Roman numbers, and lower case Greek alphabets indicate significant differences of muscle activity during crown preparation without visual aid, using loupe, and using microscope respectively.

Appendix 2. Muscle activity of different types of visual aid according to tooth surfaces

Tooth position		Visual Aid (mean±sd)				Overall	post-hoc		
		Total	Naked Eye (N)	Loupe (L)	Microscope (M)	p-value	N vs. L	N vs. M	L vs. M
#16 (each surface, n=48)	Occlusal	12.140±10.587	13.541±9.235	13.666±13.319	9.214±8.077	0.0628	>.9999	0.1334	0.1163
	Buccal	11.490±12.404	14.231±13.896	12.333±14.036	7.906±7.517	0.0363	>.9999	0.0366	0.233
	Palatal	12.242±11.765	15.689±13.785	13.488±12.498	7.550±6.222	0.0018	>.9999	0.0017	0.0338
	Proximal	13.241±11.843	16.203±13.921	14.291±11.398	9.228±8.746	0.0108	>.9999	0.0109	0.1004
#26 (each surface, n=48)	Occlusal	13.167±11.391	16.633±12.135	13.119±10.236	9.749±10.889	0.0116	0.3712	0.0086	0.419
	Buccal	12.536±12.947	17.287±16.282	13.113±12.147	7.207±6.706	0.0005	0.2999	0.0003	0.0617
	Palatal	12.460±10.948	16.677±13.419	12.732±9.683	7.973±7.213	0.0004	0.1974	0.0002	0.0805
	Proximal	13.345±11.111	16.229±12.058	16.033±11.586	7.774±6.958	<.0001	>.9999	0.0004	0.0005
#36 (each surface, n=48)	Occlusal	14.161±13.859	18.791±17.609	13.702±13.324	9.991±7.546	0.0069	0.1991	0.0051	0.5381
	Buccal	12.953±11.867	14.921±12.555	13.972±13.796	9.967±8.146	0.0941	>.9999	0.1221	0.2917
	Lingual	12.558±11.097	14.876±11.191	13.068±11.538	9.731±10.119	0.0694	>.9999	0.069	0.4149
	Proximal	13.672±12.625	18.510±15.282	12.727±11.046	9.778±9.440	0.0022	0.0642	0.0018	0.7119
#46 (each surface, n=48)	Occlusal	13.538±11.976	15.924±12.836	14.249±12.687	10.441±9.721	0.0703	>.9999	0.0742	0.3517
	Buccal	13.060±11.766	16.049±12.776	14.119±10.994	9.013±10.493	0.0094	>.9999	0.0094	0.0923
	Lingual	12.182±12.485	14.312±12.605	12.980±11.856	9.254±12.679	0.1202	>.9999	0.1421	0.4283
	Proximal	14.615±12.501	18.321±12.838	14.504±12.368	11.021±11.424	0.0156	0.3848	0.012	0.495

Abstract (IN KOREAN)

크라운 삭제 시 루뻬와 현미경 사용이 치과의사의 목 주변 근육의 근활성도에 미치는 영향 평가 - pilot study

홍 수 현

연세대학교 대학원

치의학과

(지도교수 박 정 원)

본 연구의 목적은 (1)육안 (별도의 보조장비 없는 상태) (2)루뻬 사용 (3)현미경을 사용하여 대구치 크라운 삭제를 하였을 때 치과의사의 양측 위등세모근, 목빗근, 목척주세움근 및 앞어께세모근의 근활성도 변화를 평가하고 치아 위치 및 치아면에 따른 차이가 있는지 알아보는 것이다.

강남 세브란스병원 치과 보존과에 근무하는 6 명의 오른손잡이 치과의사들을 대상으로 진행하였으며 근활성도를 측정하기 위해 무선 표면 근전도 측정 시스템을 사용하였다. 대상자들은 실습모형의 모든 사분악의 제 1 대구치 (#16, #26, #36, #46)의 크라운 삭제를 먼저 육안으로 시행한 후 같은 과정을 루페와 현미경을 사용하여 반복하였다. 대상근육, 치아 위치 및 치아면에 따른 시각 보조 기구에 대한 근활성도를 비교하였다.

시각 보조 기구에 따른 각 근육들의 활성도 비교 결과 통계학적으로 유의한 차이를 보였다 ($p < 0.05$). 육안으로 치료하는 것보다 루페를 사용하는 경우, 및 루페를 사용하는 것보다 현미경으로 사용하는 경우 근활성도가 감소하였으나 육안과 현미경을 사용 시의 근활성도 차이가 유의미한 경우가 가장 많았다. 모든 시각 보조 기구에서 목척주세움근의 근활성도가 가장 높았고, 위등세모근이 뒤를 이었다. 좌측 위등세모근을 제외하고는 치아 위치에 따른 유의미한 근활성도 차이는 없었으며, 시각 보조 기구에 따른 영향을 가장 많이 받은 치면은 인접면이었다 ($p < 0.05$).

따라서 크라운 삭제 시 육안으로 치료하는 것보다 루페 및 현미경을 사용하는 것이 치과의사의 자세에도 도움이 된다.

핵심되는 말 : 치과의사, 근활성도, 무선 표면 근전도, 현미경, 크라운 삭제, 루페