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Biomechanical Analysis of Dental Polishing Postures: Comparing Naked-eye Dentistry and Microscope Dentistry, A Pilot Study

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Abstract: In recent history, there have been tremendous advances in ergonomics, specifically regarding the tools and technology within the dental profession. These advances aim to minimize the risks of widespread musculoskeletal disorders. Through the use of conventional loupes, and especially with naked eye dentistry, as many as 60-90 percent of practitioners report neck and back pain, representing the two body regions most exposed to painful disorders (Ohlendorf et al., 2020). In many cases, these disorders coincide with early retirement from the profession (Lietz et al., 2018; Rundcrantz et al., 1990).

Oftentimes, the ergonomics problems in dentistry are related to the lack of visual capacity and human eye resolution, resulting in awkward postures and less working precision. Although conventional loupes have grown exponentially in popularity in terms of the benefits that they have brought to all dental specialties, specifically magnification and portability, postural limitations mean their usability is also limited (Ludwig et al., 2017). The optical microscope is designed to place the operator in a neutral working posture by controlling the working distances using multiple magnification visual aids (Bud et al., 2021).

Proper positioning and biomechanics of the human body also affect the performance and well-being of dentists as they carry out dental tasks. These factors should be addressed more consistently in dental school programs and during professional careers.

Dental cleaning tasks are mostly performed by hygienists in the USA and by dentists in most countries worldwide. This activity demands working on multiple surfaces and areas of the mouth, involving changes in posture and positioning that sometimes lead to awkward postures in dental professionals.

The 3-D Static Strength Prediction Program (3D SSPP) is a strength prediction software that calculates strength capability, low back compression, and joint moments (among other factors) for tasks such as lifts, presses, pushes, and pulls. The program provides an approximate job simulation that includes posture data, force parameters and subject anthropometry in its calculations and compares the outcomes to NIOSH guidelines. This software was used to evaluate the postures assumed by the dental practitioner during a routine dental cleaning procedure. The postures assessed varied in terms of the positioning of the dentist relative to the patient. The postures were also assessed while using a dental microscope and while performing naked eye dentistry. This preliminary study suggests that microscope dentistry is beneficial to the cervical & lumbar spine as well as the torso & hips. Further, muscle contractions of the upper extremity were reduced when the dentist is positioned behind rather than beside the patient. Finally, the recovery durations required to avoid fatigue were reduced by using the microscope rather than naked eye dentistry.

Keywords: Dental Ergonomics, Microscope, Precision Work

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1. Methods

In this preliminary study, routine dental cleaning (tooth polishing) was performed on four different patients, on different days, while seated in the dental chair in a supine position. The procedures were performed using four different working positions:

1. Nine (9) o'clock: The practitioner is seated precisely to the right of the patient's head.
2. Ten (10) o'clock: The practitioner is seated in a position that is rotated 30-degrees toward the back of the patient's head.
3. Eleven (11) o'clock: The practitioner is seated in a position that is rotated 60-degrees toward the back of the patient's head.
4. Twelve (12) o'clock: The practitioner is seated in a position that is rotated 90-degrees toward the back of the patient's head, directly behind the patient.

Two different dentists performed the dental cleaning task in each of the four working positions described above. One dentist was a "Naked-Eye Dentist" with basic dental ergonomic knowledge training. The other dentist was a "Microscope Dentist" with certifications and advanced training in dental ergonomics. The microscope used was a Newton Microscope, Industria Argentina, which features a 5-step magnification drum, integrated high-intensity LED lighting, and high-quality Japanese optics.

The average duration of the dental cleaning procedures was 15 minutes. All procedures were performed by the two dentists using an ergonomic stool (Dynamic model, Back Quality Ergonomics, The Hague, Netherlands) with a convex backrest, an inclined seat, and telescopic and revolving armrests.

The operators reported no vision issues and no recent history of musculoskeletal disorders (MSDs).

A mobile phone video camera (Apple iPhone 11) was used to record the procedures from five different angles (two lateral views: right and left, and a front, back, and top view) following the National Institute for Occupational Safety and Health (NIOSH) protocol for video recording for job analysis and assessment for risk factors. The position of the camera was standardized for all the recordings. In addition, the working position adopted by the dentist was guided using duct tape floor markers and a compass. At the twelve o`clock position, the dentist was centered behind the middle of the patient headrest. At 90 degrees to the right of the patient's head marked the nine o'clock position.

For this preliminary study, the nine o`clock position and the twelve o`clock position was analyzed using the University of Michigan 3-D Static Strength Prediction Program (3D SSPP, 2020). The two extreme positions (nine o'clock and twelve o'clock) were chosen to highlight the differences between the working position to the side of the patient vs the working position behind the patient. The 95th percentile male anthropometry was selected as this would represent a worst-case scenario for joint moments and low back compressive forces. A static force application of five pounds was also assumed for each hand.

Body posture information was attained from the video of task performance. The biomechanical computer model considers the body's height and weight along with body posture, the load handled in the hands and the direction of the load acting upon the hands, e.g., lift, lower, push or pull, and gender. The model estimates back compression, population strength capability, joint moments, percent maximum voluntary muscle contraction (MVC), and stability, among other measures. Back compression and strength estimates can then be compared to back compression and strength capability criteria established by the National Institute for Occupational Safety and Health (NIOSH, 1981). NIOSH has both a lower criterion (Action Limit) and an upper criterion (Maximum Permissible Limit) for back compression and strength capability. The maximum endurance time was calculated for key body regions using the %MVC for a 25th percentile strength population (Bernard, 2020; Rohmert, 1973). The percent duty cycle and the corresponding recovery duration for a one-minute exertion were also calculated (ACGIH, 2016).

2. Results

An analysis of joint moments was performed for each position, both for naked eye dentistry and for microscope dentistry. The results are shown in Table 1, with microscope dentistry resulting in more favorable joint moments at the cervical spine, lumbar spine, and hips for both the nine o'clock and twelve o'clock positions. When the dentist used the microscope, the joint moments for the cervical spine were reduced by 54% to 66%. Joint moments for the lumbar spine were reduced 19% to 23% and the joint moments at the hips were reduced 33% to 38%. See Table 2 for details.

Table 1. Joint moments for naked eye dentistry vs. microscope dentistry at nine o'clock and at twelve o'clock.

	Dominant Joint Moment Component (in-lb)			
	Naked Eye Non-Ergo		Microscope	
	9:00	12:00	9:00	12:00
C1	-31.91	-31.91	-14.83	-14.83
C3/C4	-58.49	-58.49	-19.75	-19.75
C7/T1	-71.96	-71.96	-25.48	-25.48
L4/L5	-734.58	-704.35	-569.46	-572.57
L5/S1	-733.94	-703.71	-568.20	-571.31
Center of Hips	-433.54	-403.32	-267.69	-270.80

Table 2. Percent reduction in joint moments when using microscope.

	% Reduction: Joint Moments	
	Microscope	
	9:00	12:00
C1	54%	54%
C3/C4	66%	66%
C7/T1	65%	65%
L4/L5	22%	19%
L5/S1	23%	19%
Center of Hips	38%	33%

The percent maximum voluntary contraction (%MVC) for the torso and upper extremity were calculated by 3D SSPP for a 25th percentile strength population (Table 3). For the purposes of this preliminary analysis, the postures were assumed to be static while exerting five pounds with each hand. Using the solid curve in Figure 1, intended for 5-40% MVC, the values in Table 3 were converted to the maximum endurance times shown in Table 4. The results show a 31% increase in max endurance time for the shoulder at the twelve o'clock position vs. the nine o'clock position when performing naked eye dentistry (shown in green highlighting). The results also demonstrated a 40% increase in max endurance time for the torso when using microscope vs naked eye dentistry at the nine o'clock position and a 31% increase in max endurance time for the torso when using microscope vs naked eye dentistry at the twelve o'clock position (shown in blue highlighting).

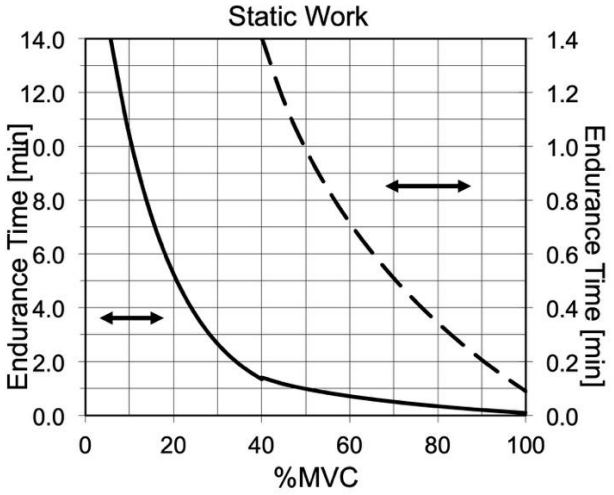

Figure 1. Maximum endurance time curves (Bernard, 2020; Rohmert, 1973)

Table 3. Percent MVC

	Naked Eye Non-Ergo		Microscope	
	9:00	12:00	9:00	12:00
Wrist	30	30	31	31
Elbow	22	22	22	22
Shoulder	29	25	29	29
Torso	23	22	18	18

Table 4. Maximum endurance time for 5-40% MVC (min.)

	Naked Eye Non-Ergo		Microscope	
	9:00	12:00	9:00	12:00
Wrist	2.7	2.7	2.5	2.5
Elbow	4.6	4.6	4.6	4.6
Shoulder	2.9	3.7	2.9	2.9
Torso	4.3	4.6	6.0	6.0

The percent duty cycle can also be calculated based on the %MVC values. Again, for the purposes of this preliminary analysis, the postures were assumed to be static while exerting five pounds with each hand. Even under these demanding conditions, the results show a 32% increase in percent duty cycle for the shoulder at the twelve o'clock position vs. the nine o'clock position when performing naked eye dentistry (shown in green highlighting). The results also demonstrated a 42% increase in percent duty cycle for the torso when using microscope vs naked eye dentistry at the nine o'clock position and a 32% increase in percent duty cycle for the torso when using microscope vs naked eye dentistry at the twelve o'clock position (shown in blue highlighting).

Table 5. Percent duty cycle (ACGIH, 2016)

	Naked Eye Non-Ergo		Microscope	
	9:00	12:00	9:00	12:00
Wrist	19.5	19.5	18.2	18.2
Elbow	34.1	34.1	34.1	34.1
Shoulder	20.9	27.6	20.9	20.9
Torso	31.8	34.1	45.1	45.1

The required recovery duration can also be calculated based on the percent duty cycle values. A one-minute contraction is assumed for the recovery durations shown in Table 6. Since dental work rarely requires static exertions of one minute, the recovery times presented attempt to show a worst-case scenario and are assumed to be overestimates. The results show a 31% decrease in recovery duration for the shoulder at the twelve o'clock position vs. the nine o'clock position when performing naked eye dentistry (shown in green highlighting). The results also demonstrated a 43% decrease in recovery duration for the torso when using microscope vs naked eye dentistry at the nine o'clock position and a 37% decrease in recovery duration for the torso when using microscope vs naked eye dentistry at the twelve o'clock position (shown in blue highlighting).

Table 6. Recovery duration for 1 minute contraction (min)

	Naked Eye Non-Ergo		Microscope	
	9:00	12:00	9:00	12:00
Wrist	4.1	4.1	4.5	4.5
Elbow	1.9	1.9	1.9	1.9
Shoulder	3.8	2.6	3.8	3.8
Torso	2.1	1.9	1.2	1.2

3. Discussion

The practical results of this pilot study were divided into three comparative results: strength capabilities, joint moments, and %MVC for both types of dentistry: naked-eye and microscope. The dentists in this study had either basic ergonomics training or professional ergonomics training. There were also two types of positioning: twelve o'clock (behind the patient's head) or nine o'clock (lateral positioning).

The data tables considered the worst case scenarios by using the most unfavorable anthropometries and assuming static postures, which would not exist in practice as there would be natural recoveries and micro recoveries through self-paced postural adjustment. Though none of the worst case values were concerning; the most favorable results generally occurred for microscope dentistry.

Biomechanically, there are no unfavorable numbers for the hand/wrist/elbow; However, the models for these body regions are probably the least reliable since the hand forces are relatively small and only one hand/wrist/elbow posture was modeled. In reality, the precision task of dental cleaning would yield several different hand/wrist/elbow postural combinations. In contrast, the large body regions, including the hips, torso, upper extremities, and head/neck remian mostly static throughout the procedure.

When breaking down the three areas of comparative results:

- The joint moment results show positive trends for the cervical/lumbar spine and hips for microscope dentistry.

- Both microscope postures show less low back compression (about 390 pounds of compression force for the microscope postures vs. 450-462 pounds of compression force for the naked eye postures) due to the more upright posture assumed when using the microscope.
- Torso fatigue was demonstrably reduced for the microscope postures.

In naked-eye dentistry, there is a tendency for lateral bending and rotation, especially in the neck and torso, which is not shown in microscope dentistry.

In the avatars and diagrams from the 3D SSPP software, postural symmetries at nine o'clock show more arm extension, abduction, and neck bending forward in naked eye dentistry.

The results of this study show significant differences between nine or twelve clock positions for the shoulder moreso than any other body region. In addition, microscope dentistry was also shown to be more favorable in terms of joint moments and endurance (avoiding fatigue).

4. Conclusions

The results of this study suggest that the dental microscope promotes near-neutral and symmetric postures in the neck and torso, with low compression forces on the lower back and decreasing the lateral bend in rotation of the neck and torso area. This positively affects work practices and body biomechanics with the lowest joint moments for the cervical spine, lumbar spine, and hips. The microscope also offered improvements in %MVC for the shoulders and the torso.

The positioning comparison of the diagrams and avatars from the 3D SSPP showed increased neck flexion and arm abduction/extension specifically at the nine o'clock position while performing naked eye dentistry.

Both participants' ergonomic training promoted better postural awareness and probably positively affected the results. Conducting the same study in a non-ergonomics trained population could be interesting.

This comparative pilot study can be used to guide a future large scale study of dentist or dental hygienist students. Such a study could show how work practices, ergonomics considerations, and technology aids (such as the dental microscope or ergonomic loupes) can change working posture and affect dental worker musculoskeletal health.

For the purposes of this preliminary analysis, the postures were assumed to be static while exerting five pounds with each hand. In practice, the dental cleaning procedure is highly dynamic. Future studies may incorporate time study data and measured force data to more accurately calculate the %MVC, time to fatigue, percent duty cycle, and the required rest/recovery time for each posture and for naked eye vs. microscope dentistry. Other factors such as the influence of ergonomic stool and a greater study population could serve to further validate the results of this pilot study.

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