HuFriedyGroup
The Best In Practice

The Ergonomic Implications of Scaler Design for Hygienists and Patients

INTRODUCTION

For the approximately 215,150 dental hygienists[1] and more than 300,000 dental assistants[2] in the United States, musculoskeletal disorders (MSDs) are an occupational hazard, causing loss of income to dental practitioners of more than $41 million per year[3]. Dental practitioners are at an elevated risk of developing work-related MSDs because hand scaling requires repetitive motion, high pinch force and sustained awkward hand postures during patient treatment. Nearly 70% of hygienists report experiencing hand and wrist pain[4].

To utilize a hand scaler, hygienists use a modified pen grasp where the pad of the thumb is in opposition to the pads of both the index and middle fingers. The scaler handle rests on the radial side of the clinician's metacarpophalangeal joint. Scaling is performed by pulling the instrument across the tooth surface—with the fingers, wrist or forearm, or a combination of all three—along the long axis of the instrument handle. The terminal shank of the instrument is held parallel to the tooth surface during scaling. The sharp blade pulled across the tooth surface dislodges calculus from the tooth[5]. Insufficient sharpness or pressure can lead to burnishing of calculus rather than removal. Different surfaces of the same tooth are hand scaled by changing the clinician's wrist or torso posture or by using another instrument with a different working end design.

Since hand scaling and root planing account for approximately 31.3% of standard prophylactic appointment time[6], it is imperative that a hand scaler be ergonomically designed for the comfort of the hygienist and patient alike.

TrueFit™ Technology testing was developed based on the need to identify key measures of ergonomics with dental instruments. Years have been spent gathering feedback and qualitative data on ideal ergonomic design. This jump-started the development of a truly ergonomic design. Interestingly, the cumulative opinion-based input lacked a solution based on factual benefits that were subjected to scientific testing. HuFriedyGroup sought to distinguish objective parameters, such as pinch force and pressure on the tooth that could be used to develop the ideal handle design for an instrument.

In building the TrueFit Technology Testing System, we sought out leaders in technology and development to design a system that could adapt to practitioners and allow our engineers to create an iterative development process. HLB, an award-winning design firm, became our partner in this process. They collaborated with leading sensor technology firms to custom develop a system capable of quantifying touch sensitivity that was adaptable to all users and scaler designs, without interfering with the practitioners or instruments being tested.

OBJECTIVE

The goal of this study was to compare Harmony™ Ergonomic Scalers and Curettes from Hu-Friedy against other scalers and curettes on the market to understand how pinch force by a clinician and resultant force applied to the tooth are impacted by handle design.

DEVELOPMENT PROCESS— Design, Test, Revise

A development process, similar to software engineering, was adopted. We tested a gamut of handles currently available in the global market. Initial testing helped establish comparison points for iterative development. The new design concepts were tested and features that showed the strongest influence progressed on to future designs, whereas those elements that did not perform well were removed from our designs.

This step-by-step approach of design, test, revise, allowed us to make rapid progress on key factors like reduction of pinch force of the fingers and pressure on the tooth. The collected data amounted to 2,878,320 data points.

RESEARCH DESIGN AND PARTICIPANTS

This study compared the Harmony™ Ergonomic Scalers and Curettes from Hu-Friedy versus other scalers. It measured participants' pinch force on a given handle while scaling and the resultant associated pressure applied to the tooth surface. Pre- and post-scaling questionnaires documented participants' credentials and their subjective preferences for different scalers.

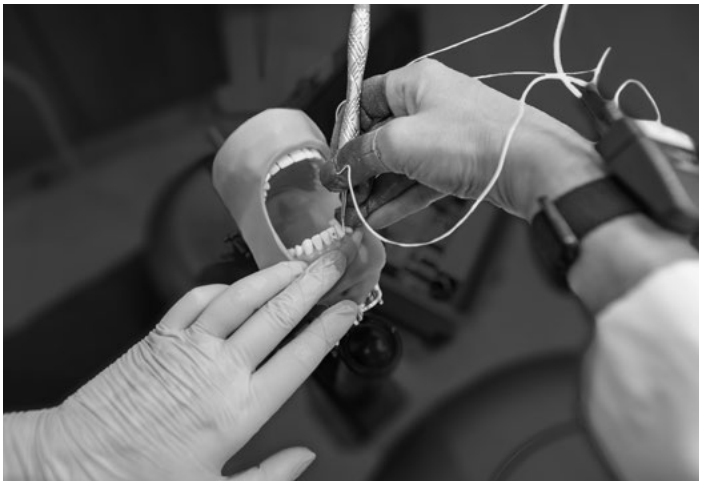
The study included 50 Registered Dental Hygienists (RDHs), aged 28-65 years, who had been practicing clinically for a minimum of 3 years, spanning two continents. Participants, who were recruited by independent third parties, were not aware of study sponsorship, and were not required to regularly use or be familiar with Hu-Friedy branded scalers. Participants had no existing injuries to their hands or arms which would inhibit them from scaling teeth.

MATERIALS AND METHODS

Workstation and Typodont Setup

Workstations allowed RDHs to adjust the operatory chair and their own chair to best accommodate their height while always keeping their feet on the floor. A custom mouth model (typodont) was mounted on an operatory chair with a clamp to simulate a patient's mouth during scaling (Figure 1).

Figure 1. Typodont and Hand Position with Location of Pressure-Sensing Pads



Materials

Each hygienist received new, unopened H6/7 scalers for the different samples tested.

Technology

A system to measure blade sharpness and durability, known as CATRA, was used to determine the preliminary sharpness of the different scalers. The blade of each instrument was tested by repeatedly pushing it into a specially calibrated silicone test strip. Less force required to penetrate the media indicates a sharper blade.

TrueFit™ Technology System utilizes highly sensitive capacitive-based sensors to reliably quantify forces applied by the human hand on objects. This sensor has the capacity to measure pressures as low as 0.01 PSI with a maximum reading of 2,000 PSI. Through wireless Bluetooth® connectivity, the sensors connect to a software where precise force and pressure data can be captured. The software imaging allows for high quality pressure mapping visualization. In addition to the hand sensors, there is a six-axis force/torque sensor which is embedded in the teeth of a typodont which measures six components of force and torque applied to the tooth (Fx, Fy, Fz, Tx, Ty, Tz).

The TrueFit Technology System was calibrated before each scaling. During testing, the system recorded 40 measurements per second.

Procedure

Participants used a modified pen grasp to hold the scalers while performing the exercise. All participants wore the pinch force sensors on their dominant scaling hand. There were four sensors: one on the thumb, one on the index finger, one the middle finger, and one on the ring finger. To improve accuracy of the readings, the hygienists' index finger and the thumb did not touch while scaling.

Once the sensors were positioned, the hygienists began to scale the first tooth utilizing the different scaler samples. Each scaler was used one at a time. The hygienists scaled with each scaler as if they were removing light to moderate calculus from the tooth. The hygienists repeated the scaling process for each scaler five times to simulate actual clinical practice with multiple strokes. This whole process was then repeated on a second tooth.

Primary Measurements

The primary measurements were:

- The resultant pinch force of an RDH on a given handle while scaling
- The associated pressure on the tooth surface

The following definitions were used for the purposes of this study:

Pinch Force: Pressure applied by the hand to the instrument handle. Measured in kPa.

Pressure Applied to the Tooth: Force applied by the scaler onto the tooth. Measured in N.

These definitions were selected to reflect commonly used terminology in the dental field, and may differ from exact engineering terms, which we have defined.

STATISTICAL ANALYSIS

To protect data integrity and ensure appropriate statistical analyses, HuFriedyGroup delivered the data to a third-party analytics firm, Hanover, a top 50 research firm for data review and analysis. Hanover is a leader in analytics and works with Fortune 500 global organizations to emerging companies and academic institutions. Founded in 2003, Hanover has over 300 employees, including a high-caliber staff of researchers, survey experts, analysts, statisticians, and grant professionals. They applied a rigorous scientific method to the data gathered with TrueFit™ Technology and assessed it without bias to determine key findings and statistical relevance.

The data included measures of force and pressure by all participants on two teeth for all scaler brands. It also captured information on scaler sharpness, weight, coefficient of friction, and handle diameter. All files were merged, and no captured data was removed from the study.

Statistical Tests

A number of descriptive, correlative and comparison tests were used to compare and contrast different scalers based on pinch force, pressure applied to the tooth, and sharpness, along with other metrics. A "find peaks algorithm" was used to identify the peak points of pressure applied to the tooth in the Fx, Fy, and

Fz direction for each clinician and scaler brand combination. The peak variable (maximum pressure on the tooth for Fx, Fy, & Fz) allowed computation of metrics for the subset of data where peak pressure was reached in the x, y, or z direction or for the entire scaling cycle. Note the peak pressure for x, y, and z typically occur at asynchronous intervals, so while the average of peak Fx, Fy, and Fz overall could be calculated, the correlations to other variables could not be connected specifically to x, y, or z.

Correlations

Pearson correlation coefficients, which showed the strength and direction of the linear relationship between two variables, were used to analyze Correlation to Brand and Correlation to Material data. Correlation values range from -1 to 1. A correlation of 1 means the variables are perfectly positively correlated, thus they both move in the same direction. A correlation of -1 indicates that they are perfectly negatively correlated, and thus move in opposite directions. Table 1 displays the interpretations associated with calculated correlation values.

Table 1. Correlation Coefficient Interpretations

Coefficient	Correlation Magnitude	Interpretation
0.6 to 1	Positive and Strong	Increases in one variable coincide with increases in the other variable, while decreases in one variable coincide with decreases in the other variable.
0.2 to 0.59	Positive and Moderate	
0.06 to 0.19	Positive and Weak	
0.0 to +/-0.05	None and Negligible	No Relationship
-0.19 to -0.19	Negative and Weak	Increases in one variable coincide with decreases in the other variable, while decreases in one variable coincide with increases in the other variable.
-0.59 to -0.2	Negative and Moderate	
-1 to -0.6	Negative and Strong	

RESULTS

Reduction in Average Pinch Force

Average pinch force (measured in kPA) represents the pinch force of all thumb, index, and middle finger readings at peak pressure applied to the tooth during scaling. Measurements ranged from a low of 29.75 kPa to a high of 86.19 kPA. The Harmony™ Ergonomic Scalers and Curettes from Hu-Friedy exhibits an average 55% reduction in total pinch force of the thumb, middle, and index fingers at peak pressure on the tooth compared to the average pinch force of all other scaler brands (Table 2).

Table 2. Average Pinch Force of Thumb, Pointer, and Middle Fingers—at Peak Pressure Points—by Scaler Brand

Brand	Avg. Total Pinch Force of Thumb, Pointer, and Middle Fingers (kPa)	Increase Over Harmony™ Scaler Handle
Hu-Friedy	29.75	Baseline
Competitor A	61.59	51.7%
Competitor B	86.19	65.5%
Competitor C	62.29	52.2%
Competitor D	63.13	52.9%
Competitor E	58.84	49.4%

Reduction in Average Pressure Applied to the Tooth

Average applied pressure represents peak pressure points from all directions in which pressure was applied. Readings ranged from a low of 1.20 N to a high of 1.91 N.

The Harmony™ Ergonomic Scalers and Curettes from Hu-Friedy exhibit a 31% reduction in the average of peak pressures compared to all other scaler brands.

Table 3. Average Peak Pressure Points of Fx, Fy, & Fz

Brand	Avg. Peak Pressure Points of Fx, Fy, Fz (N)	Increase Over Harmony™ Scaler Handle
Hu-Friedy	1.20	Baseline
Competitor A	1.49	19.5%
Competitor B	1.30	7.7%
Competitor C	1.79	33.0%
Competitor D	1.91	37.2%
Competitor E	1.52	21.1%

Correlations

- There is a negative and weak relationship between the weight of a scaler and the total pinch force in the hand (-0.098).
- There is a negligible relationship between the weight of the scaler and pressure applied to the tooth (0.013).

DISCUSSION

Previous Studies

Given the frequent occurrence and negative consequences of MSDs, surprisingly few studies have been performed to quantify the pinch force exerted by hygienists during scaling or the influence of instrument design in minimizing injury. Dong et al. measured hand muscle load and pinch force for eight custom-designed scaler handles with different cross-sectional shapes (round, hexagonal, tapered round, or tapered hexagonal) and handle diameters (7 mm or 10 mm)[7]. Scalers were modified with the addition of sensors. Investigators found that instruments with a tapered, round shape and a large diameter (10 mm) were most effective for reducing muscle load and pinch force. Compared with a non-tapered handle, the tapered handle reduced pinch force by 11% (from 16.8 to 14.9 N). Handle shape had a greater effect on muscle load and pinch forces in the larger (10 mm) vs. smaller (7 mm) diameter instruments. Operators expressed a preference for the round, non-tapered handles over other designs, perhaps because of familiarity. Note that this study altered handles with the addition of sensors and did not analyze the pressure exerted on a tooth or the effectiveness of scaling in removing calculus.

A Cochrane analysis examined the peer-reviewed literature for ergonomic interventions that might prevent MSDs in dental practitioners[8]. Only two studies met relevance and quality standards. The first compared multi-faceted ergonomic interventions (ergonomic awareness, training, workstation layout, posture correction, and physical exercise) to no intervention and found no difference over a 6-month period. The second, a randomized controlled trial, compared lightweight and wide-handled instruments to heavy-weight and narrow-handled instruments for scaling with regard to operator elbow and shoulder pain[9]. There was no clear difference between the two types of instruments, although the follow-up period of 4 months may have been too short for resolution of long-standing physical discomfort.

Frequently recommended practices for reducing MSDs among dental hygienists include using sharpened instruments with handles that are round, lightweight, and have large-diameter and cross-cut or knurled surfaces[10]. Similarly, Sanders and Michalak-Turcotte, on the basis of several case studies, assert that small-diameter handles, heavier instrument weight and dull blades contribute to increased pinch force[11], and thus the potential for repetitive injury.

The HuFriedyGroup Study

To our knowledge, no other studies have attempted to correlate pinch force, pressure applied to the tooth, and existing dental instrument designs as a prelude to designing ergonomic instrumentation that minimizes or prevents operator injuries. Furthermore, no studies have attempted to discover the ideal relationship between pinch force and peak pressures achieved by the hygienist and the necessary pressure delivered to the tooth surface for efficiently removing calculus.

Of all the scalers tested, only two had handle diameters of >5 mm, roughly half of the larger diameter of 10 mm recommended by Dong et al[7]. All correlations between handle diameter and pinch force were very weak and negative in this study (<0.15). A pilot study by Hayes found that silicon instrument handles significantly improved hand comfort (P<0.001) and theorized that they might reduce hand fatigue[12]. There is, however, evidence from a vibration study that the greater dynamic stiffness of metal improves tactile perception[13], which hygienists use to evaluate scaling effectiveness. The sensory vibration feedback of silicone handles was so diffused that users rated it as the worst of scaler handle materials.

Weights of the tested instruments ranged from 11.855 gm to 24.90 gm, as opposed to the instruments evaluated by Dong et al. that weighed 24 gm[7]. Correlations between weight and pinch force were negative and weak in our study, which suggests that more research is needed to determine how instrument weight relates to the ergonomics and functional efficiency of a handle design. For example, instrument orientation may influence both hand sensations and scaling efficiency. A heavier instrument held horizontally would theoretically tire the hand and wrist, although the same instrument held vertically might deploy the weight to advantage in removing calculus without exacerbating fatigue.

Study Strengths and Weaknesses

This was the most extensive study conducted to date to evaluate the interaction between a dental hygienist, a variety of commercially available scalers, and the resultant pressure applied to the tooth surface. Data spanning two continents provided an international perspective. To our best knowledge, for the first time, the study presents a body of objective evidence to compare with commonly made assumptions that have not been tested. The study also establishes a baseline for comparing future ergonomic instrument designs.

Efforts to control bias started with participant recruitment as site coordinators were guided to select participants without bias to their brand or product preference. To protect data integrity and ensure appropriate statistical analyses, all data was analyzed by a highly qualified third-party analytics firm. Participants were blinded to study sponsorship and used many scaler brands in a well-controlled setting. Participants were not blinded to scaler brand, as attempts to disguise the scalers would have altered their functional integrity.

We are also aware that many factors other than instrument design and use may affect MSDs, which have typically been studied in industrial, trade, or workers' compensation settings. In dentistry, awkward and static poses, poor operator seating and mobility, bad lighting, and ill-fitting gloves can contribute to muscle strain and injury[10]. A high number of patient appointments, plus their duration and frequency, increases the hygienist's physical vulnerability, and age and length in time of clinical practice have also been shown to increase the risk of MSDs[10]. In addition, ergonomically designed instruments may not align with preferences based on schooling and clinical familiarity.

HIGH TECH, RIGHT TOUCH

This HuFriedyGroup study explored the complexity of scaling, with attention to the hygienists' exertion and to the pinch force necessary to remove calculus from a tooth. The resultant Harmony™ Ergonomic Scalers and Curettes successfully reduces pinch force by up to 65% compared to other brands on the market, while also lowering the pressure applied to the tooth by up to 37%. Extensive testing demonstrated that a high-tech ergonomic design could deliver the right touch for comfort without sacrificing effectiveness.

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