Ergonomic Design of Dental Scaling Hand Tools to Alleviate the Prevalence of Carpal Tunnel Syndrome in Dental Practitioners

Vibha Bhatia
PG Student
Department of Industrial & Product Design
PEC University of Technology, Chandigarh India

Abstract—Ergonomics plays a major role in dentistry. This is due to the type of work done by dentists and the duration of the work done. The dental practitioners are mostly affected by the musculoskeletal disorders (MSDs) after the particular time span. MSDs usually occur due to the repetitive nature of work. One of the MSD which is quite common is Carpal Tunnel Syndrome. The prevalence of Carpal Tunnel Syndrome is common among the workers who perform the job using their hands, wrists, fingers or upper extremity body parts. All over the world, studies have shown the increase in the occurrence of the Carpal Tunnel Syndrome in the dentists. This disorder has by and large affected most of the dental practitioners and their work leading to the decline in their efficiency of work and affecting their lives badly. Although there are several methods by adopting which we can reduce the prevalence of CTS in dentists but in this review we will focus on the Dental hand tool design which are being used by dentists such as manual scaling hand tools or scalars. Scaling tool has been chosen as the parameter because scaling is often the repetitive task and is usually performed by most of the dentists for longer durations. Several studies have been done on the parameters affecting the scaling tool handle design which can reduce the muscle forces exerted by the dentists. Grip of the tool is also the parameter which determines the load on the muscles of fingers, hands and wrists. Lesser loads on fingers and hands are often taken as the safe parameter for designing hand tools. The loads and forces on muscles have been evaluated by using Electromyography techniques in most of the studies.

Key words: MSDs, CTS, Ergonomics, Scaling, Electromyography, Muscle Loads, Pinch Force

I. INTRODUCTION

With time human hand has also evolved and is capable of performing various important functions of day to day life. These include gripping which can be further classified into many types like power, pinch, and precision and so on. For holding larger objects power grips are found to be more suitable and for holding smaller objects pinch grips. For doing the work with high accuracy, the precision grip plays a role. The role of the thumb is to apply the force opposite to the force exerted by fingers to hold on the tool or object. Muscular structure of hand, hand shape and size, neurological control by hands determines how strong is the grip made of the fingers and thumb. Biomechanical aspect of hand anatomy plays an important role to the determination of the grip strength. In last few decades, many studies have been done on the hand grips which act as a function in assessing the muscle performances in rehabilitation, orthopedics and applied ergonomics. If the task is performed repetitively, it may become the reason of the occurrence of Musculoskeletal Disorders like carpal tunnel syndrome in hands and wrists.

Dental scaling is also a repetitive task in which the dentist pulls of the deposits of tartar from the tooth gingiva repetitively till the deposit pockets are clean. It requires an ample amount of the hand muscle force to scrap off the tartar and involves the upward pulling motion with hand and fingers. The periodontal tool is pulled up leading to forearm supination, flexion of fingers in opposition to the thumb. Relevant dental work place design, work study and dental instrument design that require continuous work and incessant use of fingers, hands and wrist may help in reducing upper extremity disorders due to work. This enhances the need to find out the muscle forces and loads while performing these tasks and the parameters affecting their values in order to get the best possible results out of it.

II. TYPES OF HAND GRIPS

Two main ways in which grips can be categorized as are

A. Power Grips

The thumb and the fingers overlap in the power grips. The upper extremity muscles are responsible for the movements and not the hand muscles. It is impossible to do precision works using power grips. The handle shape is responsible for the position that the fingers take during power grip. Fig.1 represents the Power Grip while holding a handle.

Fig. 1: Power Grip

B. Pinch Grips

Fig. 2: Pinch Grip
As shown in Fig.-2 the side of the index finger of the hand and the thumb is responsible for this kind of the grip. Holding can easily be done by pinch grips but control is not that accurate. To hold and use tweezers and forceps, pinch grip is used.

C. Precision Grips

During writing, the precision grips are used, shown in Fig.-3. It is used for doing works with accuracy and precision. Precision grip seems like a pinch grip but the thumb provides the extra support to the tool and also to the hand. Microelectronics and microsurgery are specific areas of its major use [2].

![Fig. 3: Precision Grip](image)

For holding dental scaling tools, modified pinch grip is used.

III. CARPAL TUNNEL SYNDROME

Carpal Tunnel Syndrome is also a kind of Musculoskeletal Disorder which occurs while doing same job with hand for prolonged time. CTS develop into the complete disorder when the median nerve from forearm to the palm of the hand is pressed or squeezed. The symptoms of CTS include pain in hands and fingers, numbness in fingers, tingling in hands, shown in Fig.-4.

CTS being the WRMSD which got into notice among researchers. The study [3] took two populations of the woman, one with the history of having CTS and one not. Both populations were made to do a common task of sewing and were evaluated and the job’s association with the CTS was assessed. The variables chosen were wrist position and hand force. It was found out some frequencies were associated with the history of CTS. The possible cause of the CTS is the excess pressure development in Carpal Tunnel and its impact on the median nerve function.

High force and repetitive work combination can be the main reason for the Carpal Tunnel Syndrome. The prevalence of the CTS among 652 workers in jobs with specific hand force and repetitiveness. Occurrence of CTS was 0.6% in low force less repetitive jobs and 5.6% in high force more repetitive jobs[4].

For the prediction of the incidence rate of Carpal Tunnel Syndrome for a given job, a model was developed in the study [5]. The model was made using the known biomechanical data, mechanical properties of the human tendons and reliability engineering techniques to simplify the problem. The effect of the grip force and posture of the wrist was evaluated and it was found out greater force and wrist angles increased the possibility of cumulative trauma. The bad effect of the wrist extension was found out to be more than the wrist flexion.

Dentists use small instruments with precision repetitively for days creating the stress in wrists, hands and forearms. Highly repetitive work is related to the occurrence of CTS [6]. This practice has made dental profession among those which suffers higher occurrence of CTS.

All the work in dentistry is done in a limited space of oral cavity and it needs precise motion of fingers and hands. CTS causes fatal loss to motor skill ability. As human oral cavity contains delicate nerves and slip of the dental tools is not affordable.

Root-planing and periodontal scaling need a high pinch force values. According to study [7], the mean pinch force is 11–20% of the pinch strength of maximum value while performing dental scaling task. For longer duration, the weird position of the wrist is required for being accessible to difficult to reach parts inside mouth.

![Fig. 4: Carpal Tunnel Syndrome](image)

IV. PREVALENCE OF CTS

Many studies assessing the prevalence of CTS have been done all over the world.

Study done by Anton et al[8] reported at least one musculoskeletal disorder occurrence of CTS was 42% if CTS was defined by only symptoms. Body Mass Index, Age and treated patients each day with important factors associated with CTS. It’s was concluded that risk was high among the dental practitioners.

In the study [8], 93% of the dentists reported at least one musculoskeletal disorder. Occurrence of CTS was defined by only symptoms. Body Mass Index, age, treated patient’s number for each day with important factors associated with CTS, it concludes the risk of CTS is high among the dental practitioners.

The pilot study [9] on 45 dentists was done using two questionnaires, video tapes, interviews and medical record review. Participants were also classified as dentists, dental assistants, special assistants and dental hygienists. Fischer exact probability test showed CTS symptoms in 75.6% of dental workers. Dental Hygienists and Dental assistant Exact Function were at highest risk of development of CTS in the various categories.

According to study done in Isfahan among dentists [10], of which 173 were males, and 67 were females, 16.2% and 17.9% females had symptoms of CTS. On an average 16.7% of the dentists were suffering from CTS.

Study done in Mangalore [11], India resulted out 20% of the dentists suffering from CTS and had direct relation with the years of practice done.

Age factors, work load, gender and geographical differences, might have shown the differences in range of values of the collection of data. The survey by American Dental Association (ADA,1997)[12]reported that 9.2% of the dentists were diagnosed with MSDs of upper extremity and needs surgery or making changes in work hour cycles.
V. TOOL PARAMETERS AFFECTING MUSCLE LOAD

The dental scaling and root planning tools if are ergonomically designed may help in decline in the occurrence of Carpal Tunnel Syndrome in dental personnel. The scaling task is done by scrapping off the tartar deposits with the scaling tool blade from the gum line to the tooth’s top on the surface of the tooth so that plaque can be removed. The cutting task is done by pulling the scaling tool handle along it’s vertical axis by supinating the forearm, extending the wrist and flexing the fingers. The returning push action is not associated with cutting but is responsible for repositioning the scaling blade to the gum line. Change in the shape of the tool handle if provides better coupling of the hands and fingers may help in reducing the pinch force applied during scaling task.

The study [13] analysed the effect of change in the cross sectional area of the grip of the scaling tool handle on the muscles associated with upper extremity and the pinching force in the simulation of the periodontal scaling task. Experimentation was done using four cross sectional shapes which are round and non-tapered shape, round and tapered shape, hexagonal and non-tapered shape, hexagonal and tapered shape. On providing taper to the end of the tool handle where gripping is done may reduce the value of pinch force by improvising coupling of the fingers to the periodontal tool handle while pulling the tool with high force. If the cross sectional shape of the handle is hexagonal like the cross sectional shape of the pencil, it may help the fingers in better resistance to the rotational forces while performing scaling task along the vertical axis of the handle. The cross sectional shapes were tested at 7mm and 10 mm diameters. Larger diameter tool of 10mm diameter handles with round tapered cross sectional shapes required minimum muscle effort and grip force while performing periodontal task. The similar study [14] demonstrated that the tool handle with larger diameter of 10mm and light weight of 15g needed least muscle effort and grip force while pinching. The smaller scaling tool handles were associated with higher muscle effort and pinch force.

Other factors like design and material of the dental scaling tool handle may relate to the subjective comfort and work efficiency. Nevala et. al.,[15] studied the effect of material of handles on comfort level and concluded that the thicker dental scaling instruments (Diameter between 12 to 14mm) made up of silicon material were associated with more usage value and reduction in the musculoskeletal. Also, the productivity of the thicker dental scaling tools was more than that of thinner tools used in dental scaling task.

VI. CONCLUSION

One of the many way in which Ergonomics related to the dental scaling task can be looked upon is by bringing in possible improvements in the design of the dental scaling tool handle. The changes in dental tool handle design parameters like, change in the diameter, cross sectional shape, material and providing taper or no taper can help in improving the design of the periodontal handle ergonomically and may lead to the reduction in the muscle loads and pinch forces. Mostly the larger diameter scaling tool handles with taper provided on them helped in reducing the muscular effort and pinch forces. Silicon material may also prove to be a good option for making periodontal tools as they were found to be associated with better productivity. The reduction in the muscular forces in the repetitive tasks may lead to the alleviation in the prevalence of musculoskeletal diseases like Carpal Tunnel Syndrome.

VII. FUTURE SCOPE

Dental practitioners are more susceptible to Musculoskeletal Disorders like Carpal Tunnel syndrome. There is much scope in the improvement of tool design handles. The study can be done considering real time clinical situations in mind in the presence of dynamic work environment. This can be done by taking the data while performing the actual task on the patient. Study can be done considering no time constraints and assessing the results in different time frames. The number of subjects can be increased substantially for getting more significant results. Other cross sectional shapes of dental tool handles (apart from round and hexagonal) may be considered for future study to get larger variability and clarity in results. The variation in taper angle can be provided and may be considered as the parameter for future study. Tools were not designed according to the hand anthropometry of population. Providing texture to the tool handles may give reduction in force values and hence can be considered for future parameter selection for study.

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