INFLUENCE OF SCALER TIP DESIGNS ON TOOTH SURFACE ROUGHNESS, TOOTH SUBSTANCE LOSS, AND PATIENTS' PAIN PERCEPTION

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ABSTRACT

Background: Ultrasonic scalers have been shown effective in removing subgingival calculus. However, it may cause alteration to the tooth surface as well as discomfort to patients. Advances in scaler tip designs may reduce these effects. Limited studies have investigated the influence of scaler tip designs on tooth surface and patients' comfort. This study comprised of *in vitro* and clinical investigations, aimed to evaluate the influence of scaler tip designs on tooth surface roughness, tooth substance loss, and patients' pain perception. **Materials and Methods:** The *in vitro* study involved extracted single-rooted sound teeth that were mounted, sectioned, and scaled using PM200 EMS® Piezon, Switzerland; with either (i) Perio Slim (DS-016A) (test) or (ii) conventional scaler tips (FS-407) (control). Tooth surface roughness (n=20) and tooth substance loss (n=46) were measured using a 3D surface texture analyser (Alicona, InfiniteFocus Real3D, Belgium) and scanning electron microscope (SEM) (Quanta-FEG 50, FEI, Germany) respectively, at baseline and following scaling. The clinical study involved a split-mouth design, with 30 participants diagnosed with gingivitis and/or mild chronic periodontitis. The participants were randomly allocated for scaling on quadrant 1 (teeth #13 to #11) and quadrant 2 (teeth #21 to #23); using Perio Slim and conventional scaler tips. Pain perception was recorded using Visual Analogue Scale. **Results:** Scaling with both scaler tips demonstrated significant reduction in tooth surface roughness following scaling ($p < 0.05$); but there was no significant difference between the two scaler tips ($p > 0.05$). Scaling with Perio Slim scaler tip demonstrated significantly less tooth substance loss ($p < 0.05$) when the initial thickness of the tooth was <1000µm. In the clinical study, the participants reported significantly less pain when scaling was carried out using the Perio Slim scaler tip (median: 3) compared to the conventional scaler tip (median: 5) ($p < 0.05$). **Conclusion:** Slimmer scaler tip design (Perio Slim) caused less tooth substance loss and

less pain than the wider (conventional) scaler tip when used for ultrasonic scaler at medium power setting.

Keywords: tooth roughness, tooth substance loss, pain perception, scaler tips

ABSTRAK

Latar belakang: Skaler ultrasonik telah terbukti berkesan untuk membuang kalkulus. Namun, ia boleh memberi kesan kepada permukaan gigi dan juga menyebabkan ketidakselesaan kepada pesakit. Kemajuan dalam rekabentuk tip skaler mungkin dapat mengurangkan kesan ini. Terdapat kajian terhad yang menyelidik pengaruh rekabentuk tip skaler pada permukan gigi dan tahap keselesaan pesakit. Kajian ini meliputi kajian *in vitro* dan klinikal, bertujuan menilai pengaruh rekabentuk tip skaler ke atas kekasaran permukaan gigi, kehilangan bahan gigi dan tahap kesakitan pesakit. **Bahan dan kaedah:** Kajian *in vitro* ini menggunakan gigi yang berakar tunggal yang dicabut, berkeadaan baik, tertanam dan dipotong; diskale menggunakan PM200 EMS® Piezon, Switzerland; sama ada dengan skaler tip (i) Perio Slim (DS-016A) atau (ii) konvensional (FS-407). Kekasaran permukaan gigi (n = 20) dan kehilangan bahan gigi (n = 46) diukur menggunakan *3D* penganalisa tekstur permukaan (Alicona, InfiniteFocus Real3D, Belgium) dan mikroskop elektron pengimbas (SEM) (Quanta-FEG 50, FEI, Germany) mengikut turutan, sebelum dan selepas penskaleran. Kajian klinikal melibatkan rekabentuk separa mulut, dengan 30 peserta berpenyakit gingivitis dan/atau kronik periodontitis (*chronic periodontitis)* tahap awal. Peserta dibahagikan secara rawak untuk penskaleran di kuadran 1 (gigi #13 hingga #11) dan kuadran 2 (gigi #21 hingga #23); menggunakan tip skaler Perio Slim (DS-016A) dan konvensional (FS-407). Tahap kesakitan pesakit diukur menggunakan Skala Analog Visual. **Keputusan:** Kedua-dua rekabentuk tip skaler menunjukkan pengurangan tahap kekasaran permukaan gigi (p < 0.05) yang signifikan selepas penskaleran. Namun, tiada perbezaan yang signifikan di antara kedua-dua tip skaler (p > 0.05). Kehilangan bahan gigi yang signifikan ditunjukkan penskaleran menggunakan tip skaler Perio Slim (p < 0.05) bagi ketebalan awal <1000µm. Bagi tahap kesakitan, peserta kekurangan sakit yang signifikan bila penskaleran dijalankan menggunakan tip skaler Perio Slim (median: 3) berbanding tip skaler

konvensional (median: 5) ($p < 0.05$). **Kesimpulan:** Rekabentuk tip skaler yang lebih nipis (Perio Slim) menyebabkan kehilangan bahan gigi yang lebih rendah dan tahap kesakitan yang lebih rendah berbanding tip skaler yang lebih lebar (konvensional) selepas penskaleran pada kuasa sederhana.

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LIST OF ABBREVIATIONS

PPD	:	Probing pocket depth
R	:	Recession
GBI	:	Gingival bleeding index
VPI	:	Visible plaque index
NSPT	:	Non-surgical periodontal therapy
OHE	:	Oral hygiene education
RSD	:	Root surface debridement
VAS	:	Visual analogue scale
SEM	:	Scanning electron microscope
PS	:	Perio Slim
RLTSI	:	Roughness loss of tooth substance index
SD	:	Standard deviation
DAS	:	Dental anxiety score
SRP	:	Scaling and root planing
MWF	:	Modified Widman flap
GV	:	Gingivectomy
OF	:	Osseous reduction

LIST OF APPENDICES

CHAPTER 1: INTRODUCTION

1.1 Background

Scaling is a common procedure performed by general dental practitioners and dental specialists. Unfortunately, scaling has been associated with unpleasant dental treatment and to some extent, a painful experience (Berggren & Meynert, 1984). Studies also have demonstrated that scaling using ultrasonic scalers can cause tooth surface roughness (George et al., 2016) and tooth substance loss (Jepsen et al., 2004; Kawashima et al., 2007). Rough tooth surface will increase retention of plaque and has been shown associated with early biofilm formation (Teughels et al., 2006). Subsequently, this would increase the risk for development and progression of periodontal disease. Whereas, tooth substance loss may lead to exposed dentinal tubules, and subsequently root sensitivity. Root sensitivity was reported to affect half of patients receiving periodontal therapy (Von Troil et al., 2002). This led to discomfort among patients and avoidance to dental treatment in future.

Advanced development in scaler tip designs has provided opportunities to deliver scaling treatment that is less aggressive to tooth surfaces and most importantly, to reduce the discomfort to patients. The design of the scaler tip has influenced the performance of ultrasonic scalers characterised by the displacement amplitude (Lea et al., 2003b). Displacement amplitude is the lateral movement of scaler tip that is thought to contribute to the aggressiveness of scaling procedure. Several studies have investigated the factors that may influence displacement amplitude, such as power setting and type of generator (Lea et al., 2003a), tip wear (Lea et al., 2006) and scaler tip designs (Lea et al., 2003a). However, to date, there were limited studies that investigated the effect of ultrasonic scaler tip design particularly slim and wide scaler tip on tooth surface roughness, tooth substance loss, and patients' pain perception.

In a clinical setting, if there were two treatment methods that provide similar levels of effectiveness but different levels of discomfort and damage to tooth surface patient will opt for the more comfortable and conservative method. Therefore, this study investigated the influence of scaler tip designs on tooth surface roughness, tooth substance loss, and patients' pain perception following scaling.

1.2 Aim of study

To investigate the influence of scaler tip designs on tooth surface roughness, tooth substance loss, and patients' pain perception.

1.3 Objective of study

1.3.1 *In vitro* study

- To compare tooth surface roughness following scaling using conventional and Perio Slim (PS) scaler tips.
- To compare the amount of tooth substance loss following scaling using conventional and Perio Slim (PS) scaler tips.

1.3.2 Clinical study

- To compare patients' perception of pain during scaling between two different types of scaler tip; conventional and Perio Slim (PS) scaler tip.

1.4 Null hypotheses

There is no difference in patients' pain perception during scaling using conventional scaler tip or Perio Slim (PS) scaler tips.

There is no difference in tooth surface roughness and tooth substance loss following scaling using conventional scaler tip or Perio Slim (PS) scaler tip.

CHAPTER 2: LITERATURE REVIEW

2.1 Periodontal diseases

Periodontal disease is highly prevalent among adults (Dye, 2012; Petersen & Ogawa, 2012), with 95% of the world population had mild form of periodontal disease (Petersen & Ogawa, 2012). Severe periodontitis is the sixth most prevalent disease with 11.2% or 743 million people affected worldwide (Kassebaum et al., 2014). In Malaysia, 94% of the adult population had some form of periodontal condition; with 18.2% was affected with severe chronic periodontitis. An increasing trend in the prevalence of severe chronic periodontitis could also be observed over the last 20 years; 6% (1990), 5.5% (2000), and 18.2% (2010) (NOHSA, 2010). Although this trend could be attributed to people living longer, it could also indicate that periodontal diseases in Malaysia deserves serious attention.

Gingivitis and chronic periodontitis are the two most common types of periodontal diseases (Armitage, 1999). Gingivitis results from an inflammatory response towards incoming plaque accumulation and it resolves with reinstitution of oral hygiene (Löe et al., 1965). Gingivitis involves only soft tissues and it is characterised by marked redness in colour, oedema and bleeding upon probing (Löe et al., 1967). On the other hand, chronic periodontitis results from long-standing gingivitis in susceptible individuals (Löe et al., 1986; Page & Schroeder, 1976). Chronic periodontitis shares similar features to gingivitis, with an extension of hard tissue involvement such as alveolar bone loss and clinical attachment loss (Page & Schroeder, 1976). Diabetes mellitus and smoking are modifying factors that increased risks for development and progression of periodontal disease (Emrich et al., 1991; Haber et al., 1993). The management of periodontal diseases comprised of non-surgical and surgical component. The non-surgical component includes scaling and root surface debridement (RSD). For this literature review, focus will be given to the scaling and RSD as this would be related to the scope of the study.

2.2 Scaling and root surface debridement

Biofilm is an organized bacterial community in a polymerized matrix attached to surfaces and interfaces (Donlan & Costerton, 2002). Loe and co-researchers (1965) have proven that accumulation of dental biofilm caused gingivitis. Through this experimental gingivitis study, the removal of plaque by reinstitution of oral hygiene brought back gingival health with resolution of gingivitis (Loe et al., 1965). Furthermore, Marsh (1994) proposed an ecological hypothesis where periodontal disease resulted from a change in key environmental factors that favors site for pathogenic bacteria. This was the rationale of the main periodontal therapy performed, scaling and root surface debridement.

In the past, non-surgical treatment of periodontal disease includes root planing. The principle of root planing was based on the concept that bacterial endotoxin penetrates into cementum, thus infected cementum needs to be removed (Hatfield & Baumhammers, 1971). It was later proven that bacterial endotoxin was loosely bound to root surface (Hughes & Smales, 1986). Therefore, cementum removal is no longer needed to achieve periodontal healing.

Scaling removes soft and hard deposits from tooth surfaces (Lang & Lindhe, 2015). In contrast, RSD is performed at sites where periodontal pocket depths are $\geq$5 mm. RSD has been shown effective at reducing probing pocket depth and improving clinical attachment level (Van der Weijden & Timmerman, 2002). The long-term success of periodontal treatment is however, dependant on the standard of plaque control performed by the patients themselves (Lindhe et al., 1984).

2.2.1 Treatment outcomes of RSD

The treatment outcomes of RSD are limited by patient and non-patient related factors. Patient factors include diabetic status (Emrich et al., 1991), smoking habits (Grossi et al.,

1997) and patients' compliance (Lindhe et al., 1984; Wilson, 1996). Diabetics subjects were reported to have three-fold increased risk for developing periodontitis (Emrich, 1991). However, metabolically well-controlled diabetics were reported to respond as well as the healthy ones (Christgau et al, 1998). Smokers were reported to have less healing and less reduction in periodontal pathogens following mechanical therapy (Grossi et al., 1997). Patients' compliance, in terms of plaque control played a decisive role in the long-term success of a periodontal therapy (Lindhe et al., 1984). Subjects who had low frequency of plaque-free tooth surfaces exhibited more sites with attachment loss following periodontal therapy compared to subjects who had more plaque-free tooth surfaces (Lindhe et al., 1984). Patients' compliance to dental visits was affected by several factors including dental fear, lack of information, socio-economic status and perception towards clinician (Wilson, 1996). Berggren & Meynert (1984) in his study on dental fear reported that it was caused by painful treatment, besides other factor such as 'rough dentist'. This showed that painful treatment negatively affects patients' compliance, and subsequently led to periodontal therapy failure.

For this review, focus will be given more on the non-patient related factors. Among all, the non-patient related factors are clinician factor (Kozlovzky et al., 2018) and choice of instrument (Tunkel et al., 2002).

2.2.1.1 Clinician factor

Skills of clinician vary due to different levels of training and clinical experience. Brayer et al., (1989) investigated the effect of clinician level of training to the effectiveness of scaling and RSD. They compared the amount of residual calculus on tooth surfaces after scaling and RSD between certified periodontists and periodontal residents. There was a significantly greater number of calculus free teeth observed in subjects treated by certified periodontist compared to periodontal residents. However, there was no difference observed in the effectiveness of scaling and root planing by different experience levels in

initially shallow pockets (Brayer et al., 1989). Moreover, Badersten et al., (1985) compared healing outcome as indicated by clinical parameters following non-surgical periodontal therapy carried out by six operators. Re-evaluation visits every three months for two years demonstrated that the subjects treated by periodontists had less number of sites with bleeding on probing and greater attachment gain compared to the subjects treated by dental hygienist. However, the difference was not significant (Badersten et al., 1985). This minimal difference could be due to dental hygienists involved in the study were experienced, and their professional experience ranged between three to fourteen years.

2.2.1.2 Choice of instruments

Busslinger et al., (2001) compared the amount of calculus removal following scaling using (i) manual curette (Deppeler, Switzerland), (ii) Sonosoft 5® piezoelectric scaler with modified inserts from KaVo (Biberach, Germany) and (iii) Cavitron®™ Jet SPS™ magnetostrictive ultrasonic scaler with Slimline® inserts (Dentsply, USA). Thirty extracted teeth were grounded and mounted on SEM mounts (Baltec AG, Balzers, Liechtenstein) and scaled within a specified experimental surface. Although there was a significant reduction in percentage of calculus removed with each instrument, however, it failed to reach a significant difference when compared between different instruments (Busslinger et al., 2001).

It is accepted that both manual and power-driven devices are effective at removing calculus (Coldiron et al., 1990; Tunkel et al., 2002). However, they differ in time required for the same amount of calculus to be removed. Hand instruments allow better tactile sensation (Ryan et al., 2005), however, it takes slightly longer time for calculus removal compared to the power-driven device (Badersten et al., 1984; Busslinger et al., 2001). This is due to hand instrument requires multiple pull strokes to scale at a specific area

(Coldiron et al., 1990), while the power-driven device used mechanical vibration.

Despite differences in the technical properties and shorter time taken for treatment when treated using power-driven devices, types of instrument used in therapy whether manual or power-driven devices do not have significantly different clinical outcomes in single-rooted teeth (Tunkel et al., 2002). Ultrasonic scaler has the advantage of small scaler tip that allows accessibility to furcation entrance in multirooted tooth. It has been shown that the face width of hand curette is larger than furcation entrance, thus making it inaccessible to furcation entrance (Bower, 1979). A randomised clinical trial on 30 generalised advanced chronic periodontitis subjects, compared the clinical parameters as well as microbiological profiles following root planing between hand curette and ultrasonic scaler (Ioannou et al., 2009). At 3 months, both hand curette and ultrasonic scaler demonstrated improvement in clinical parameters and reduction in periodontal pathogens, with no significant difference. However, there was a significant reduction in *Tannerella forsythia* and *Treponema denticola* at six months post instrumentation using hand curette (Ioannou et al., 2009).

2.3 Instrument

Mechanical debridement was performed using scalers, whether manual or power-driven scalers. Before the invention of ultrasonic scalers, manual scalers were widely used. This include sickle, curette, hoe, chisel, and file. The first use of ultrasonic instrument in dentistry was reported in 1952 where an industrial ultrasonic impact grinder was used to prepare cavities on extracted human teeth (Balamuth, 1962). This has led to the invention of ultrasonic dental drill to prepare cavities (Nielsen and Richards, 1954) and subsequently, the invention of ultrasonic scaler to remove dental plaque and calculus (Suppipat, 1974). Each instrument category was discussed in detail in the following subtopics.

2.3.1 Manual scaler

2.3.1.1 Types of manual scalers

The most commonly used instruments are sickle scaler and curettes. Sickle scalers are mainly used for supragingival calculus removal while curettes are used for subgingival calculus removal (Oda et al., 2004). There are two types of curette; universal curette, and area-specific curette, the Gracey's curette. Columbia curette and Gothenburg curette are examples of universal curette.

Singer et al., (1992) investigated the effectiveness of a newly designed curette to remove calculus on incisor teeth compared to the conventional Gracey's curette. This new curette was designed to have a shorter curvature with an altered angle, able to adapt to teeth with smaller dimensions. It was shown that the percentage of calculus removed by modified curette was significantly higher than conventional curettes at all surfaces (Singer et al., 1992). The examples of modified curette are Mini Gracey and After Five®.

2.3.1.2 Effectiveness of manual scalers

Manual scalers have been shown effective to remove calculus as well as cementum (Coldiron et al., 1990). Calculus has rough surfaces, thus ideal for bacterial retention and colonisation (Waerhaug, 1952). In addition, study using light microscope and SEM has shown that calculus harbour viable bacteria within its internal channels and lacunae (Tan et al., 2004). Coldiron et al., (1990) investigated the effect of root planing using curette on calculus and root surface removal on 92 extracted teeth. The total amount of cementum removed and number of strokes required to produce a measurable defect were measured. The result showed that complete cementum removal was achieved with a minimum of 20 strokes. It was concluded that root planing using hand curette was effective at removing cementum (Coldiron et al., 1990).

Oosterwaal et al., (1987) compared the effectiveness of hand and ultrasonic instrumentation on teeth with pocket depth between 6 mm to 9 mm. Following oral hygiene instruction, teeth were instrumented and clinical parameters as well as microbiological parameters were recorded. The results showed that both curette and ultrasonic scaler were effective in improving clinical parameters (probing pocket depth and bleeding on probing) as well as reduction in subgingival microbiota, consistent with periodontal health (Oosterwaal et al., 1987).

The findings by Oosterwaal et al., (1987) were supported by a systematic review by Tunkel et al., (2002). This systematic review included 419 abstracts and 27 articles that compared the efficacy of power-driven device to manual instruments. There was no significant difference in probing pocket depth, clinical attachment level or bleeding on probing following debridement on single-rooted teeth using power-driven device compared to the manual counterparts (Tunkel et al., 2002).

2.3.1.3 Limitations of manual scalers

Badersten et al., (1984) compared the time consumed for instrumentation between hand and ultrasonic instruments among subjects with severe periodontitis. It was reported that time taken for hand instrumentation per tooth was 9.4 minutes compared to 7.6 minutes using the ultrasonic device (Badersten et al., 1984). Similarly, Busslinger et al., (2001) compared the time needed for instrumentation using ultrasonic scaler and hand curette. It was revealed that hand curette took significantly longer time for instrumentation on per section of tooth (2.1 minutes) compared to ultrasonic scalers (1.2 minutes) (Busslinger et al., 2001).

Bower (1979) conducted a study on 114 maxillary and 103 mandibular first molars to investigate the influence of furcation morphology on instrumentation using curettes.

Majority of the furcation (81%) had entrance diameters <1.0 mm, and in 58% of furcation, the entrance diameter was <0.75 mm (Bower, 1979). However, regardless of the types or manufacturers, the curette's blade face width ranges between 0.75 mm to 1.0 mm. This disparity between the width of blade and furcation entrance suggest a need to refine the instrument design in order to provide access into the furcation area.

2.3.2 Power-driven device

The first power-driven device, ultrasonic scaler was invented in 1955, and designed to remove calculus (Zinner, 1955). These ultrasonic scaler are reported to be superior to manual scalers; less time taken to remove calculus, does not harm cementum and more effective in removing stain than manual counterparts (Johnson & Wilson, 1957). Subsequently, sonic scaler was introduced into the dental market in the 1970s as a less expensive option for scaling and RSD. The use of sonic scaler in conjunction with manual scaler was reported as more effective than either method alone (Gellin et al., 1986).

2.3.2.1 Ultrasonic scalers

Power-driven devices work by vibrations or oscillations of metal probe tip guided over tooth surfaces to break the bond between calculus and teeth. The types of powered devices are differentiated by how the vibrations are generated and by the frequency of tip oscillations. Ultrasonic oscillation can be generated by magnetostriction or piezoelectricity method. Piezoelectric scaler incorporates a crystal of piezoelectric material in the handle. This material oscillates in the presence of electromagnetic field and the vibrations will be transmitted to the tip. Similarly, in the magnetostrictive scaler, vibration will be transmitted to working tip, but from a nickel-based magnetostrictive stack that is inserted into a coil in the handle. In contrast to a piezoelectric scaler, a magnetostrictive working tip is attached to the magnetostrictive stack in the handle (Figure 2.1). The generated vibration at ultrasonic scaler tip for both piezoelectric and

magnetostrictive oscillates at 25 to 42 kHz (Table 2.1) (Arabaci et al., 2007; Lea et al., 2009).

After over 20 years in the market, the use of ultrasonic scaler has been acknowledged as an effective, easy to use device and it reduces patients' discomfort and time taken for treatment. Ultrasonic scaler has been recognized as an established clinical device in dentistry (Walmsley, 1988).

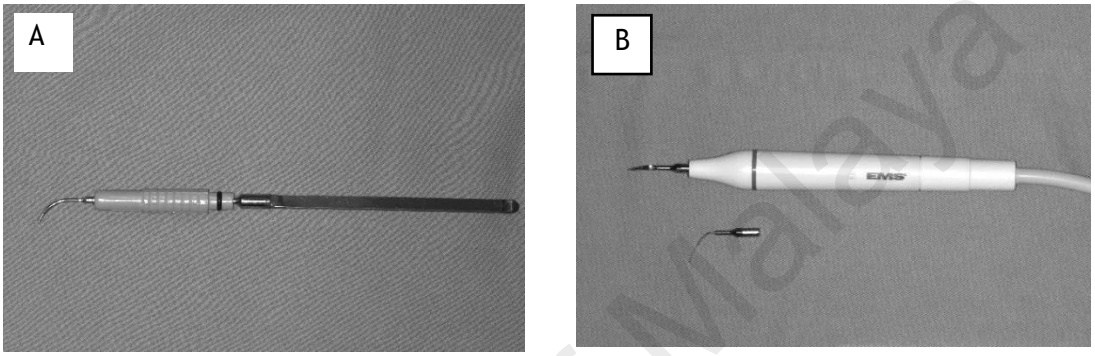

Figure 2.1: Ultrasonic scalers. (a) Magnetostrictive design (b) Piezoelectric design

2.3.2.2 Sonic scalers

The oscillations of sonic scaler tip are generated by passage of air over a vibrated eccentric rod. These vibrations are transmitted to working tip. Sonic scaler oscillates between 6 to 8kHz. Table 2.1 summarised the differences between sonic and ultrasonic scalers. In comparison to ultrasonic, sonic scaler results in no difference in clinical response to ultrasonic scaler (Gellin et al., 1986).

Table 2.1: Characteristics of sonic and ultrasonic scalers

Characteristics	**Sonic**	**Ultrasonic**	
		Magnetostrictive	**Piezoelectric**
Oscillating pattern	Circular	Elliptical	Linear
Vibration frequency	6-8 kHz	25-42 kHz	25-42 kHz

2.3.3 Scaler tip design

Powered devices operate by vibrations produced at scaler tips. There were some variations reported in the vibrations produced by powered device scaler tips (Lea et al., 2003a; Lea et al., 2003b). Scaler tip vibrations were measured by the displacement amplitude and oscillation pattern.

2.3.3.1 Displacement amplitude

Lea et al., (2003a) investigated the displacement amplitude of scaler tips from four different generators; (i) Cavitron SPS, (ii) Cavitron Select, (iii) Piezon Master and (iv) Mini Piezon with their respective designs of scaler tips. The scaler tip designs used were the conventional scaler tips; TFI-10 and TFI-3, and slightly longer in shape scaler tips, P-tip. For each design, five scaler tips were used to measure the displacement amplitude as the power setting was gradually increased. The result showed that displacement amplitude increased as the power setting increased and there were differences in displacement amplitude between generators. Further analysis showed that different tips of similar design demonstrated significant variations in the displacement amplitude. The range of displacement amplitude for Mini Piezon with P-tip was 13 to 44 µm, Piezon Master with P-tips 16 to 36 µm, Cavitron SPS with TF-10 tip 8 to 30 µm and Cavitron Select with TF-10 tip 13 to 34 µm (Lea et al., 2003a).

The study by Lea et al., (2003a) needs to be carefully interpreted as it was based on non-functional displacement amplitude of scaler tips (i.e. vibration in the air). This was not similar to the clinical situation where scaler tips would come in contact with tooth surface and some load would be introduced. Similar study design (Lea et al., 2003a) was repeated to investigate the effect of scaler tips when subjected to 0.25N, 0.5N and 1.0N loads (Lea et al., 2003b). For Piezon Master and Mini Piezon, when used with P-tip at increased power setting from 5 to 10, and subjected to 0.25N and 0.5N load respectively, no

increment in displacement amplitude was observed. Whereas with other generators, Cavitron SPS and Cavitron Select using TF-10 and TF-3 tips, a reduced but more linear increment in displacement amplitude was observed when power setting increased (Lea et al., 2003b). In conclusion, there was reduction in displacement amplitude when scaler tip was used under load, with lighter tip such as P-tip being the most affected. Factors that influenced the displacement amplitude of scaler tips include generator type, power setting, scaler tip design and loading (Lea et al., 2003a; Lea et al., 2003b).

2.3.3.2 Oscillation pattern

In addition, Lea et al., (2009) investigated the oscillation pattern of ultrasonic scalers. Comparisons were made between conventional scaler tip design (A type) to the slim design (P type) (EMS, Nyon, Switzerland); and between conventional TFI-3 and the slimmer type, Slimline designs (Dentsply, York, USA). In terms of scaler tip shapes, broader and shorter scaler tip designs have been shown to have a close to linear oscillation pattern, while longer and slimmer tip designs were shown to be more elliptical. Thinner scaler tips were less rigid and were prone to lateral displacement. It was also shown that loading would flatten the elliptical pattern of the ultrasonic scalers. Furthermore, the displacement amplitude of slimmer scaler tip design was significantly affected by loading, compared to conventional design (Lea et al., 2009). Loading has been shown to increase the stability of slimmer scaler tips and at the same time reduces the lateral motion. In short, loading would dampen the scaler tip displacement amplitude.

2.4 Tooth surface roughness

An increase in surface roughness facilitates biofilm formation (Teughels et al., 2006). The rate of bacterial colonisation and speed of plaque maturation are positively correlated with surface roughness (Quirynen et al., 1991). The tooth surface roughness (R_a) is a measurement of irregularities on the surfaces of teeth.

The influence of tooth surface roughness following instrumentation on microbial colonisation was investigated in five beagle dogs (Leknes et al., 1994). In this split-mouth study design, maxillary and mandibular canines were instrumented with either diamond burr or curette. The dogs were fed with soft, plaque-accumulating diet for 70 days. Then, the dogs were sacrificed and tissue blocks containing teeth, bone, and soft tissue were removed. Soft tissues were then removed gently and teeth were dyed with toluidine blue. The tooth surface instrumented with curette appeared smooth, whereas the surface instrumented with diamond burr had some irregularities. The surface roughness was judged by a descriptive method and no measurement was taken. Bacterial counting was done by dividing tooth surface into three zones; cervical, middle, and apical zones, using SEM. The results showed that there was a significantly less total mean percentage of zones containing plaque following curette (53%) compared to diamond burr (76%) instrumentation. Similarly, the total mean percentage of zones containing microorganism was also less in curetted surface (91%) than diamond-treated surface (99%) (Leknes et al., 1994). This study emphasised the impact of tooth surface roughness following instrumentation to microbial colonisation.

Several studies investigated the influence of hand and power-driven devices on surface roughness (Busslinger et al., 2001; Folwaczny et al., 2004; Kawashima et al., 2007; Vastardis et al., 2005; Wilkinson & Maybury, 1973). Wilkinson & Maybury (1973) compared tooth surface roughness between hand curette and ultrasonic scaler under SEM following root planing. Teeth were subjected to hand curette demonstrated smoother surface compared to the ultrasonic scaler. The surfaces of teeth subjected to ultrasonic scaler were ‘stippled’ and had irregular ridges (Wilkinson & Maybury, 1973). These findings were in agreement with other similar studies that have compared the outcome of tooth surface roughness between piezoelectric scalers and hand instruments (Busslinger et al., 2001; Folwaczny et al., 2004).

On the other hand, Vastardis et al., (2005) reported that scaling with ultrasonic scaler produced smooth root surfaces as compared to hand instrumentation (Vastardis et al., 2005). In addition, Kawashima et al., (2007) also reported that ultrasonic scaler resulted in less rough surface compared to hand scaler. This was measured by roughness loss of tooth substance index (RLTSI) where the surface was assessed visually under microscope by the researcher and index were given based on the viewer assessment. The detail on this index was discussed in the following subtopic. However, the results should be carefully interpreted since these studies were not standardised in terms of amount of load applied, scaler tip designs, angle of instrumentation and instrumentation endpoint (Lea & Walmsley, 2009).

There was no other study that compare the influence of ultrasonic scaler tip design on tooth surface roughness. However, the effect of different scaler tip designs on surface roughness has been studied on polished restorative materials. A study by Arabaci et al., (2007) evaluated the surface roughness in R_a values on restorative materials such as amalgam, composite, and porcelain following instrumentation with piezoelectric ultrasonic scalers. Three scaler tips (EMS®, Switzerland) of different shapes were used; (i) instrument A (wide and short), (ii) instrument PS (long and slim) and (iii) instrument PI (for implant). For instrument A, the R_a values were 2.73 µm, 2.01 µm, and 2.12 µm for amalgam, composite and porcelain respectively. The R_a values for instrument PS were 1.92 µm, 1.46 µm, and 1.34 µm for amalgam, composite, and porcelain respectively.

Lower R_a values were observed among instrument PI; 0.83 µm, 0.21 µm, and 0.31 µm for amalgam, composite, and porcelain respectively. In all restorative materials, instrument A produced highest surface roughness compared to other instruments (Arabaci et al., 2007). Furthermore, there were chips, scratches and loss of material on amalgam surface following instrumentation with instrument A. On the other hand, instrument PS caused roughness but less loss of material on amalgam surface. Instrument A has a wider

diameter, thus, there will be more lateral displacement and increased the impact on tooth surface.

Other factors that are associated with tooth surface roughness are angulation and wear of the tip, as well as the power setting (Arabaci et al., 2013). Arabaci et al., (2013) investigated the effect of worn scaler tips on root surface roughness under different working parameters. Eighty extracted teeth were divided into two groups; i) scaled with new scaler tip ii) scaled with worn scaler tip. Four subgroups were created in both groups that receive combination of these working parameters; i) 0^0 tip angulation with medium power setting ii) 0^0 tip angulation with high power setting iii) 45^0 tip angulation with medium power setting iv) 45^0 angulation with high power setting. The root surface roughness was measured before and after scaling with a profilometer (Mitutoyo SJ-301, Japan) and the difference was calculated and determined as "roughness change" (Rc). Rc dictates an increase in surface roughness. The results showed that the Rc was significantly higher among worn scaler tips when used at 45^0 angulations. It was also reported that Rc was significantly higher when used with 45^0 angulations compared to 0^0 angulation at any power setting. High power setting significantly increased Rc value at 45^0 angulations. There was no statistically significant difference in Rc value between power setting when used at 0^0 angulation (Arabaci et al., 2013). It was concluded that tip wear significantly increased surface roughness when used at high power setting and at 45^0 angulations.

2.4.1 Methods of evaluation

Based on the literature, the instruments that was used in the assessment of surface roughness include scanning electron microscope (George et al., 2016; Kawashima et al., 2007; Lie & Leknes, 1985) and profilometer (Arabaci et al., 2007; Busslinger et al., 2001; Vastardis et al., 2005).

2.4.1.1 Scanning electron microscope

The scanning electron micrograph obtained following scanning the surface was assessed whether by description of the tooth surface topography, or by using RLTSI.

(i) Tooth surface topography

Assessment of surface roughness can be made by comparing tooth topography using SEM (Wilkinson & Maybury, 1973). The tooth is prepared through a graded series of ethyl alcohol and air dried for 24 hours. The dehydrated tooth is then mounted, flashed with carbon and coated with aluminum. Subsequently, the specimen will be examined using SEM operated at 20kV with a 200µ final aperture. Representative images will be recorded at magnifications ranging from x200 to x5000. The surface is then described and compared, subjectively. This method yields descriptive outcomes, thus does not provide quantitative values for comparison purpose.

(ii) RLTSI

Alternatively RLTSI can be used to compare surface roughness and loss of tooth substance (George et al., 2016; Kawashima et al., 2007; Lie & Leknes, 1985). This technique also provides a subjective assessment and it uses an index to grade surface roughness based on assessment under SEM. The index is characterised as follows:

Grade 0: smooth surface
Grade 1: slightly roughened
Grade 2: corrugated surface but cementum still present
Grade 3: considerable loss of tooth substance

2.4.1.2 Profilometer

Advances in technology have allowed a more precise measurement for surface roughness. At present, the measurement for surface roughness can be carried out with a profilometer

(Arabaci et al., 2007; Busslinger et al., 2001; Folwaczny et al., 2004; Vastardis et al., 2005). The profile of a surface will be traced using tracing device and the roughness will be determined by the undulations of the profile relative to some baselines (Leitäo & Hegdahl, 1981). This baseline was determined by the profilometer. There are two types of profilometers; contact and non-contact profilometers. Generally, a contact profilometer uses a stylus as tracing device which moves along the surface, recording all peaks and recesses. Deviations from baseline will be recorded. R_a value is calculated by a mathematical definition using the deviations from baseline. Generally, the surface roughness will be determined as mean roughness (R_a) in micrometre, defined as the average of peak and valley distances measured along the center line of one cut-off length (Leitao & Hegdahl, 1981).

The non-contact profilometer has scanning device where profile can be scanned without tracing device. An example of non-contact profilometer is optical surface texture analyser (Alicona, Belgium). An area of surface roughness (S_a) will be measured, instead of a line profile roughness (R_a).

2.5 Tooth substance loss

Previously, removal of contaminated cementum by root planing was an acceptable practice in periodontal therapy. Since endotoxins has been proven to adhere loosely to root surfaces and does not penetrate into cementum (Hughes & Smales, 1986), thus it was concluded that removal of tooth substance was unnecessary and did not provide an extra benefit to periodontal therapy. Besides, tooth substance loss inevitably contributes to exposed dentinal tubules and subsequently root sensitivity. It was reported that half of the patients who received periodontal therapy experienced root sensitivity post-therapy (Von Troil et al., 2002). Therefore, aggressive scaling and removal of tooth substance are considered unnecessary (Cobb, 1996).

2.5.1 Factors associated with tooth substance loss

During scaling, there were many factors that may contribute to the aggressiveness of scaling. Available studies have reported the influence of type of instrument (Kawashima et al., 2007; Rupf et al., 2005), working parameters (Flemmig et al., 1998), and scaler tip designs (Jepsen et al., 2004) on tooth substance loss.

2.5.1.1 Type of instrument

Coldiron and co-workers reported that 60µm of cementum layer was removed for each scaling stroke with a manual curette (Coldiron et al., 1990). When a comparison was made between two ultrasonic scalers (Vector™ and Enac® scaler) with a manual scaler, the teeth scaled with ultrasonic scalers had significantly less substance removal indicated by lower RLTSI compared to teeth scaled with manual scalers (Kawashima et al., 2007). The residual cementum following scaling was 45.0 µm, 30.5 µm, and 8.7 µm for Vector™ scaler, Enac® scaler and manual scaler respectively. This finding was in agreement with a study by Rupf and co-workers where scaling using Vector™ scaler has less effect on the cementum, characterised by percentage loss of cementum (1%) compared to hand curette (12%) (Rupf et al., 2005).

2.5.1.2 Working parameters

Each clinician exerts different pressure during scaling procedure. The pressure exerted against tooth structure during scaling is called lateral force. High lateral force produces a high volume of defect on tooth surface during scaling. Flemmig et al., (1998) investigated the effect of lateral force during scaling with an EMS Piezon Master piezoelectric ultrasonic scaler (EMS®, Switzerland) using slim (DS-016) scaler tip. Scaler was attached to a sledge device and lateral forces of 0.5N, 1.0N and 2.0N was applied by means of weight attached to the scaler handle. It was shown that there was an increasing defect volume with an increasing lateral force. Generally, the defect volume was moderate for

all lateral forces (Flemmig et al., 1998).

Flemmig et al., (1998) has also investigated the effects of tip angulation on tooth defect. Tip angulation was shown to has a greater effect on the defect depth as compared to lateral force. There was an increase in defect depth following scaling with an increasing angulation from 0^0 to 45^0 (Flemmig et al., 1998). Further analysis showed that instrumentation at 0^0 angulation did not result in severe root defect regardless of the amount of lateral force used. It was also shown that the highest defect volume and depth was produced when a combination of 2.0N and 45^0 angulations was used (Flemmig et al., 1998).

2.5.1.3 Scaler tip design

Scaler tip designs can also influence the amount of tooth substance loss following scaling (Jepsen et al., 2004). An *in vitro* study was conducted to compare the influence of narrow and wide scaler tip; of both piezoelectric and magnetostrictive ultrasonic devices; on tooth substance loss. Magnetostrictive ultrasonic scaler (Cavi-Med 200, Dentsply, York, USA) was used with either regular (TFI-10) or narrow, probe-shaped (Slimline) scaler tip. For piezoelectric ultrasonic scaler (Piezon Master 400, EMS®, Nyon, Switzerland), Perioprobe and Type-A was used representing narrow and conventional types respectively. Standardised root instrumentation was performed by moving mounted ultrasonic handpiece with a computer operated stepper motor over test specimens in a horizontal direction. The defect size was then measured by depth, width and volume using a non-contact profilometer system. Magnetostrictive scaler with narrow scaler tip resulted in mean defect of 254 µm, 6 µm, and 23 µm for width, depth and volume respectively. The corresponding value for the wide scaler tip was higher; 759 µm, 24 µm, and 160 µm respectively. Similar trend was also seen in the piezoelectric scalers. This study concluded that wider scaler tip design produced larger defect and hence, suggestive to be more

aggressive than slimmer scaler tip designs (Jepsen et al., 2004).

2.5.2 Methods of evaluation

There are two common methods to assess scaling; either to scale until the root surface is judged to be smooth, or by counting the number of strokes, also known as controlled scaling. The former technique is subjected to many variables such as individual judgement, length of time and force applied whereas the latter technique can be performed with standardised time, force, and tip angulation, thus it provides a more definitive result (Jepsen et al., 2004). The assessment of scaling is commonly evaluated using SEM, in combination with RLTSI (Lie & Leknes, 1985).

A standardised root instrumentation can be performed using computer operated stepper motor. This is carried out by mounting the ultrasonic handpiece and using a stepper motor to move the scaler over mounted teeth (Jepsen et al., 2004). For standardisation of the lateral force, a spring balance with predetermined force is attached to the resin blocks with mounted teeth by mean of a hinge. This highly robotic method produces a definite defect size that could be measured under a laser profilometer. This allows comparison of defect sizes following highly standardised scaling procedure and lateral force (Jepsen et al., 2004).

2.6 Patients' pain perception

2.6.1 Pain in dentistry

One of the challenges faced by dentists is treating patients who were fearful to dentistry. Among the common causes of dental fear are traumatic experience and painful past treatment (Berggren & Meynert, 1984). Based on a survey, painful dental work has been listed as the most commonly mentioned reason for fear in dentistry among adults (Berggren & Meynert, 1984; Kleinknecht et al., 1973). Painless dentistry, less scolding from dentists and patient given perceived control on the dental procedure are among

factors that have been identified helpful in overcoming fear of dentistry (Jerry, 2015).

2.6.2 Pain assessment

There are two types of pain assessment that have been used as reported in the literature: intermodal intensity comparison (Braun et al., 2010; Braun et al., 2007; Braun et al., 2003) and visual analogue scale (VAS) (Kocher et al., 2005; Muhney & Dechow, 2010).

Intermodal intensity measures pain represented by pressure intensity exerted by patient. The display for the pressure intensity is observed with a camera. During assessment, patient is required to press the bulb of a manometer in proportion to intensities of pain experienced. Display of the manometer readings are recorded and evaluated in one second intervals (Braun et al., 2003). The advantage of this method is pain experience can be recorded during the entire treatment procedure.

VAS is a ratio scale that measures chronic and experimental pain (Price et al., 1983). It consists of a line with ten scales. Far-left scale indicates the no pain and the far-right scale indicates the worst pain possible. Patient scores VAS based on their pain perception. For pain perception during scaling, VAS records pain only at the end of the treatment. Patient needs to remember the pain and immediately score after scaling. Proper instruction must be given prior to the VAS scoring to ensure the validity of the assessment (Price et al., 1983). VAS represents a simple pain assessment that is able to differentiate between pain levels and intensities (Price et al., 1983).

2.6.3 Pain during scaling procedure

Scaling causes pain and discomfort to patients (Steenberghe et al., 2004). Canakci & Canakci, (2007) in a split-mouth design study compared pain experience following (i) scaling and root planing (SRP), (ii) surgical periodontal procedures including modified Widman flap (MWF), (iii) gingivectomy (GV) and (iv) osseous reduction (OF) using VAS scores and Dental Anxiety Score (DAS). The results demonstrated a range between

41% to 43% of subjects who reported pain following four treatment modalities; with no significant difference reported between all treatments (Canakci & Canakci, 2007). It has been reported that when using VAS, patients aged 18 to 34 years old were 1.7 times more likely to experience pain than those older patients (45 years old or more). There has been a general trend observed, i.e. as the age increases, the pain decreases. This could be due to elderly people are more tolerant to pain.

DAS is measured by using a set of questionnaires where a higher score means that the anxiety level is higher. In addition, patients who presented with high DAS scores were 2.5 times more likely to report high pain response compared to patients with low DAS scores (Canakci & Canakci, 2007). This showed that anxiety could contribute to the reported pain among patients.

The association between anxiety and reported pain was also supported by Sanikop et al., (2011). Pain perception during scaling was evaluated and the relationship with anxiety were assessed among one hundred patients (Sanikop et al., 2011). VAS scores were recorded following supragingival scaling by a periodontist and anxiety level was scored by DAS. The mean VAS score was 17.3, using VAS that ranged between zero to one hundred scale. It was also observed that VAS scores increased when DAS score increased. There was a statistically significant correlation between dental anxiety and pain during scaling (Sanikop et al., 2011). It can be concluded that patient may experience low pain during scaling, but the level of anxiety could have increased the patient's pain perception.

2.6.4 Modifiable factors associated with pain

Several techniques have been used by clinicians to reduce pain during scaling. For example, the use of topical anaesthesia cream was shown to significantly reduce pain during scaling (Chung et al., 2011). Svensson et al., (1994) demonstrated that the use of topical anaesthesia was efficacious in clinical situation. However, there were residual pain that might be due to non-anaesthetised nociceptive fibres in tooth pulp. Despite this,

patients accepted the anaesthetic procedure well, and it was recommended as a simple pharmacologic therapy to reduce unpleasantness during scaling (Svensson et al., 1994).

An intermodal intensity assessment was used to compare the subjective pain intensities during instrumentation with either (i) hand scaler, (ii) conventional ultrasonic scaler or (iii) Vector™ scaler (Braun et al., 2003). It was shown that Vector™ caused significantly less pain during scaling compared to conventional ultrasonic and hand scaler ($p < 0.05$). This could possibly due to the linear oscillation with no vertical movement produced with Vector™ scaler.

It was also reported that patients experienced discomfort when scaled using piezoelectric scalers, compared to magnetostrictive scalers (Muhney & Dechow, 2010). Periodontal debridement was performed on seventy-five subjects in a split mouth design. Two quadrants were treated using piezoelectric scalers (EMS®, Switzerland) and the other two quadrants with magnetostrictive scalers (Dentsply Cavitron® SPS™). VAS scores were recorded immediately after each method. The median VAS scores for discomfort level were 14 and 20 for piezoelectric and magnetostrictive scalers respectively, and the difference was statistically significant. The differences in discomfort level might be due to the more pronounced vibrations among magnetostrictive scalers.

In addition, Braun et al., (2007) investigated the influence of scaler tip shape (wide and slim) on subjective pain intensities during scaling. Twenty patients were treated using piezoelectric scaler (Sirosonic L, Sirona, Germany) with wide, conventional (Instrument No. 3, Sirona, Germany) and slim-line (Perio Pro Line Instrument SI-11, Sirona, Germany) style scaler tips. During scaling, the pain level assessed by intermodal intensity comparison was significantly lower when slim-line scaler tip was used. Regarding the oscillation produced, there was similar frequency among two scaler tips. However, the displacement amplitude was160 µm and 120 µm for conventional and Slim-line scaler

tips. The differences in the amplitude were due to the design of the scaler tip. Less pain experienced during scaling with Slim-line scaler tip was probably due to the smaller displacement amplitude produced (Braun et al., 2007).

2.7 Problem statement

Scaling is the routine treatment provided for patients with periodontal disease. Following scaling, tooth surface roughness and tooth substance loss may take place. Consequently, these will facilitate biofilm accumulation (Teughels et al., 2006). In addition, discomfort and sometimes pain during scaling may negatively impact patients' experience during dental treatment. If two treatment methods will result in similar clinical improvement, clinicians will opt for the treatment that is less aggressive to tooth and less painful to patients. There have been studies reported that slimmer scaler tip caused less pain experience to patient (Braun et al., 2007) and caused less tooth substance loss (Jepsen et al., 2004) compared to the conventional scaler tip. To date, there was no study that has investigated the influence of scaler tip design on tooth surface roughness. Whether slimmer scaler tip caused less tooth surface damage in terms of tooth surface roughness and tooth substance loss, and less pain experience among patients compared to the conventional scaler tip, need to be investigated.

CHAPTER 3: MATERIALS AND METHODS

This study was divided into two parts; *in vitro* and clinical study.

3.1 *In vitro* study

3.1.1 Study design

This was an *in vitro* investigation conducted in the Biomaterial Research Laboratory, Faculty of Dentistry, University of Malaya. Ethical approval was obtained from the Medical Ethics Committee, Faculty of Dentistry, University of Malaya prior to conducting the study [DF RD1719/0063(P)].

3.1.2 Study sample

Samples used were human permanent teeth extracted within the last six months of the study. The sample size used was based on a study by Kawashima et al., (2006) where 10 teeth were used in each experimental group. Teeth were obtained from Bangsar Government Dental Clinic in Kuala Lumpur.

3.1.3 Inclusion criteria

a) Human permanent maxillary and mandibular teeth which were single-rooted i.e.; incisors or premolars
b) Sound teeth or teeth with minimal caries lesion and/or restorations, with minimal calculus.
c) Teeth extracted within the last 6 months

3.1.4 Exclusion criteria

a) Teeth with crack lines
b) Teeth with non-carious tooth loss i.e.; abrasion or erosion

c) Hypomineralised teeth and teeth with amelogenesis and dentinogenesis imperfecta

3.1.5 Teeth preparation

Prior to the *in vitro* investigation, teeth samples were prepared in the laboratory. The teeth were disinfected using 0.5 % Chloramine-T trihydrate (Across, Belgium) for a week. All teeth were then stored in distilled water, and placed in a fridge at 4°C before analysis. Then, 4mm of apical portion of each tooth was embedded in a clear cold-curing epoxy resin (Mirapox® 950-230 A, Balakong, Malaysia) to facilitate cutting (Figure 3.1a). On root surface 1 mm apical to the CEJ, an area of 3 mm (width) x 5 mm (height) was selected and marked using a permanent marker. The selected area was indicated by R (Figure 3.2). The tooth was cut in apico-coronal direction using a slow speed precision cutter (Metkon®, Bursa, Turkey) (Figure 3.1b).

Two indentations, 1mm in depth were made using scaler tip on the dentine layer which correlates to the area for surface roughness assessment as shown in Figure 3.1(c) and Figure 3.2. The indentations represented upper reference point and lower reference point as shown in Figure 3.2. These reference points were used to measure the amount of tooth substance loss.

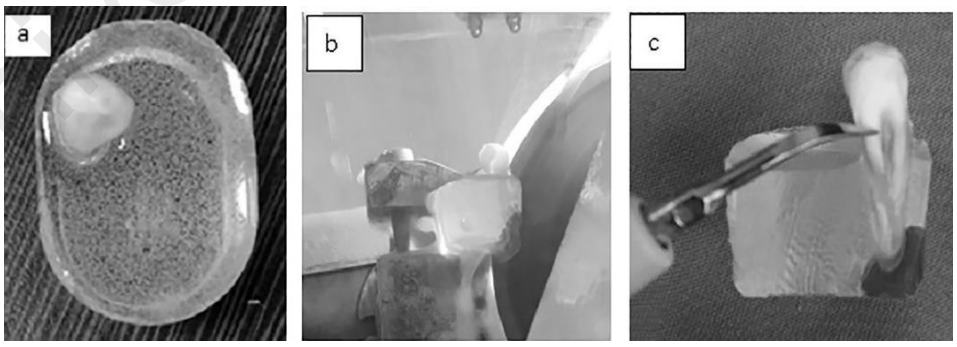

Figure 3.1: Sample preparation prior to the scaling procedure. (a) Teeth embedded in epoxy resin, (b) cut in an apico-coronal direction and (c) markings made on dentine

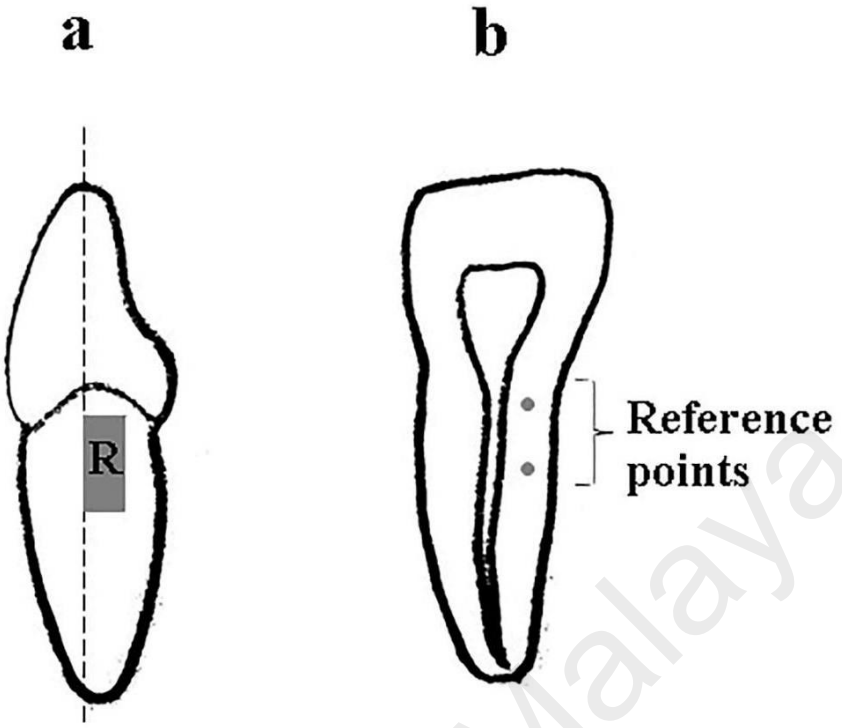

Figure 3.2: Diagram showing teeth preparation as described in section 3.1.5. (a) The mesial view of an incisor sectioned indicated by dotted line. An area of 3mmx5mm area was marked apical to CEJ for roughness assessment as indicated by R. Scaling was performed at R. (b) The cross-sectional view of the incisor tooth showing two reference points marked using a scaler tip.

3.1.6 Scaling procedure

A portable ultrasonic scaler device (PM200, EMS®, Switzerland) (Figure 3.3) was used for scaling treatment using new scaler tip either (i) conventional (FS-407, EMS® Piezon, Switzerland) or (ii) Perio Slim (DS-016A, EMS® Piezon, Switzerland) (Figure 3.4 and Figure 3.5). Medium power-setting and maximum water coolant were used as recommended by the manufacturer. This portable ultrasonic scaler has power setting from '1' to '8'. Therefore, medium power setting was set at '4'.

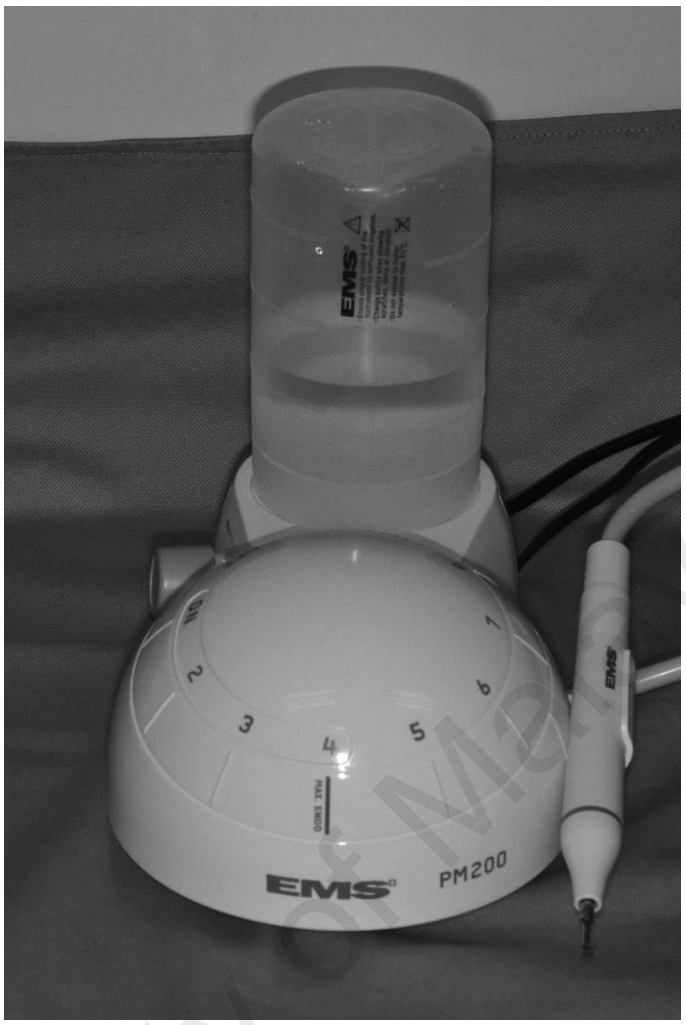

Figure 3.3: Portable ultrasonic scaler unit (PM200, EMS®, Switzerland)

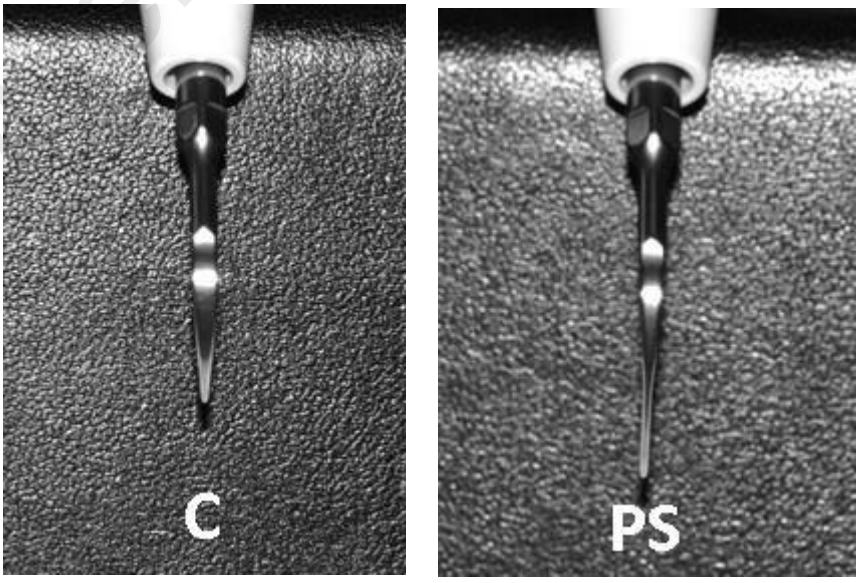

Figure 3.4: Frontal view of conventional (C) and Perio Slim (PS) scaler tips (EMS® Piezon, Switzerland).

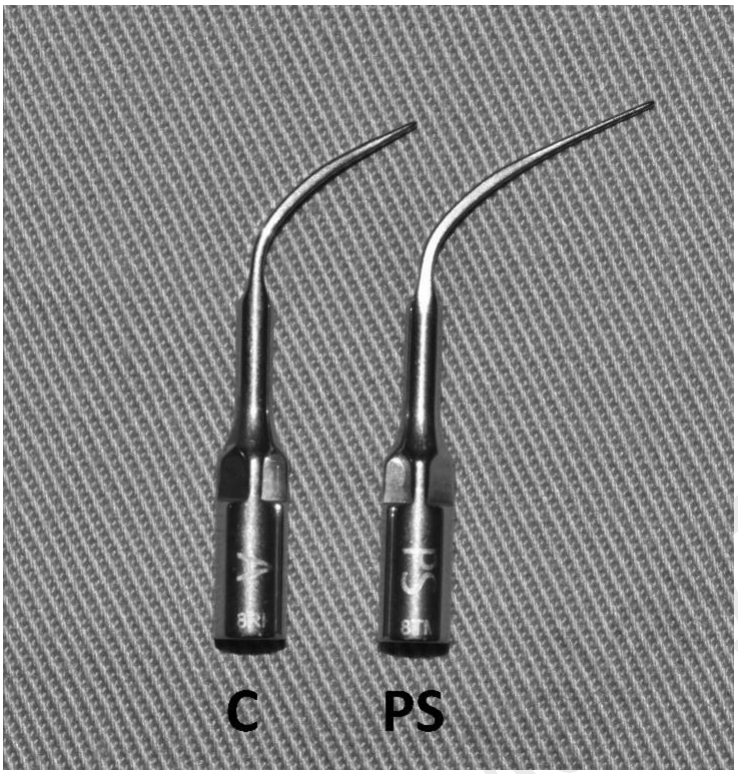

Figure 3.5: Lateral view of conventional (C) and Perio Slim (PS) scaler tips (EMS® Piezon, Switzerland).

Teeth were divided into control (conventional scaler tip) and test (PS scaler tip) groups randomly. For every 10 teeth, 5 teeth were assigned to control group and 5 teeth to test group. This was repeated until enough samples obtained. Teeth in control group were scaled using the conventional scaler tip whereas teeth in test group were scaled using Perio Slim scaler tip.

Standardised working parameters was used for the scaling procedure. Scaler tip was placed parallel to the tooth surface and angulated at zero degree during scaling. Scaling was done in 3 continuous strokes with light force. The same protocol was subjected to all samples. These working parameters was practised prior to the actual procedure. During practice, scaling was repeated 10 times on 10 teeth using the correct working parameters until the operator felt comfortable. The procedure was performed by a single operator (NA).

3.1.7 Measurements

3.1.7.1 Tooth surface roughness

Surface roughness of the marked area was measured using a 3D Optical Surface Texture Analyzer (Alicona, InfiniteFocus Real3D, Belgium) (Figure 3.6). Alicona was calibrated daily. This ensures the reproducibility of the measurements. Measurements were taken in S_a values, in triplicates and reported as a mean, before and after scaling. The magnification was set at x200 and 80µm working length for all samples. The workflow for the surface roughness measurement was summarised in Figure 3.7.

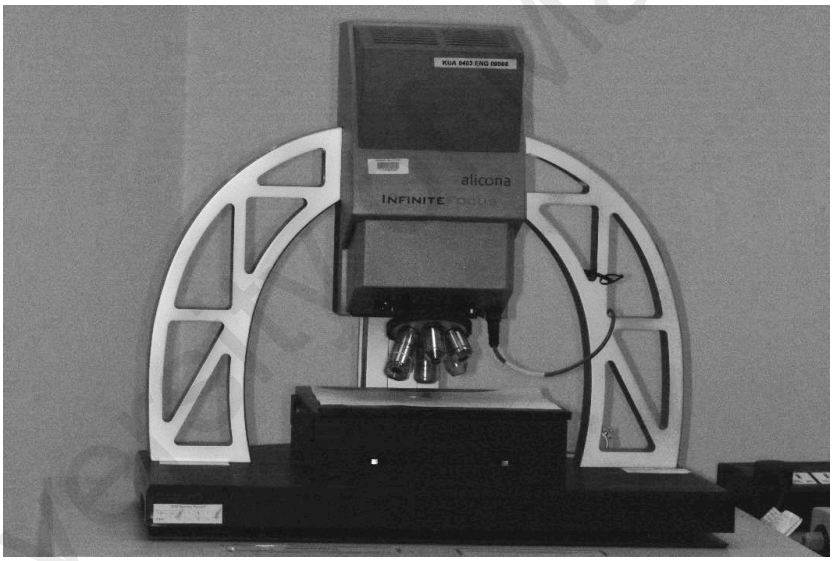

Figure 3.6: 3D Optical Surface Texture Analyzer (Alicona, InfiniteFocus Real3D, Belgium).

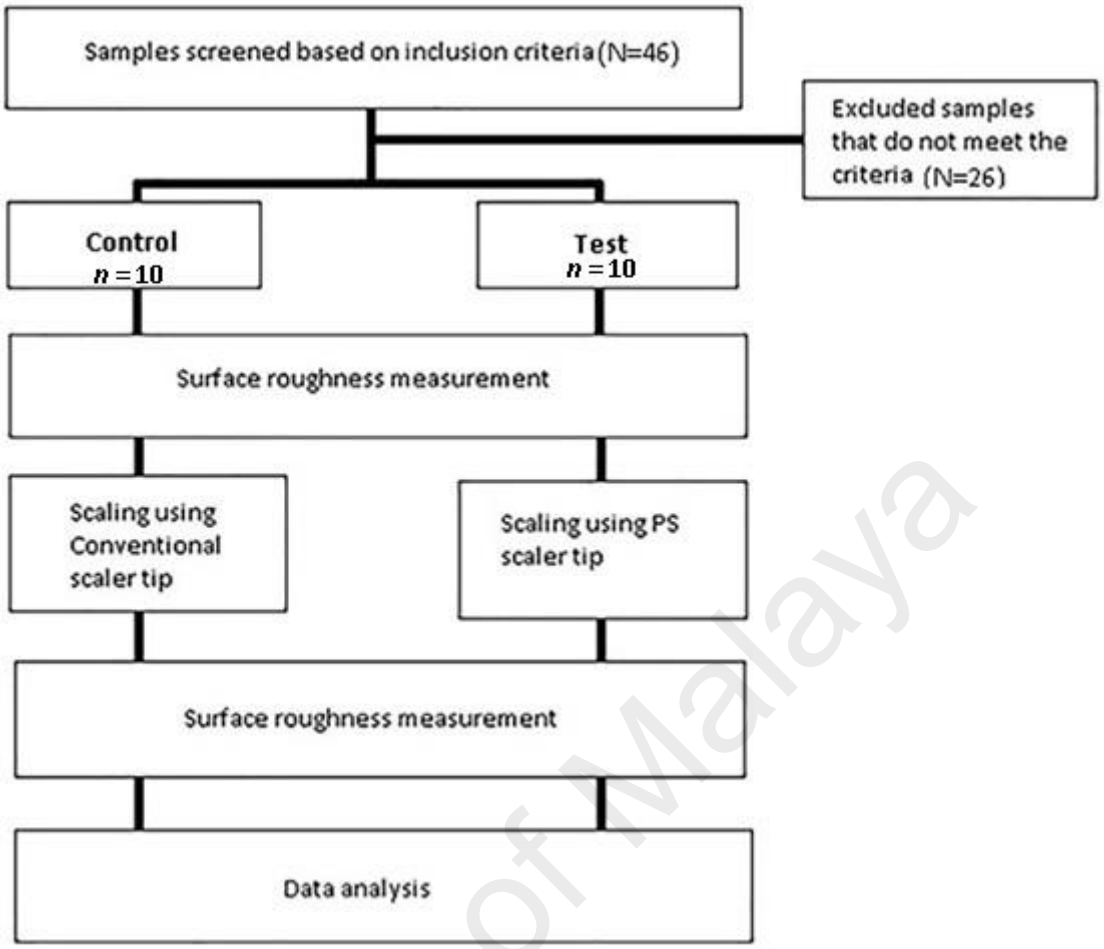

Figure 3.7: Workflow for i*n vitro* study for surface roughness assessment.

3.1.7.2 Tooth substance loss

Teeth were scanned using a low vacuum Scanning Electron Microscope (SEM) (Quanta-FEG 50, FEI, Germany) on the cross-sectional tooth surface which includes both upper and lower reference points. The shortest distance between reference points to outer tooth surface was measured in micrometre (µm) and referred to as "tooth thickness". Tooth thickness was measured in triplicates and reported as a mean. Tooth substance loss was measured by the difference in tooth thickness, before and after scaling. Magnification was set at 50x and working distance, 10.0 mm. The workflow for tooth substance loss assessment was summarised in Figure 3.8.

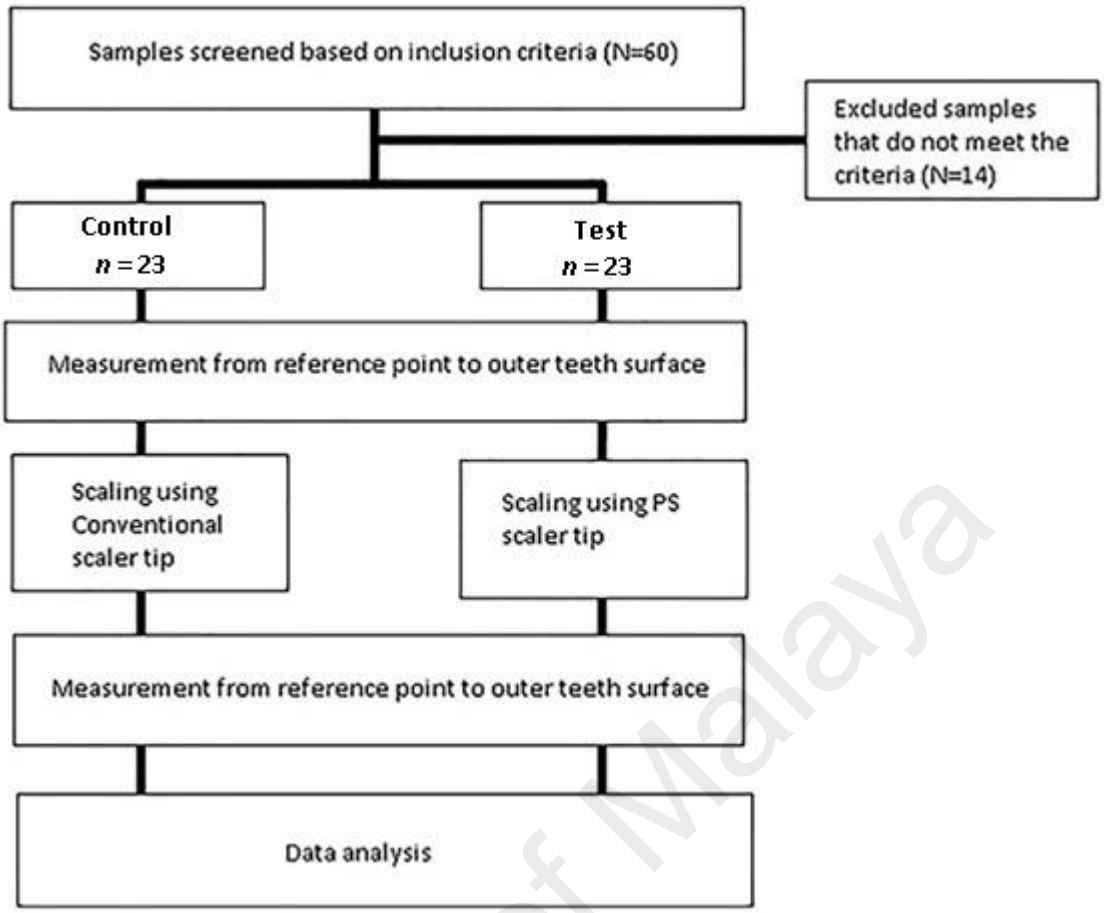

Figure 3.8: Workflow for *in vitro* study for tooth substance loss assessment

3.2 Clinical study

3.2.1 Study design

This was a randomized cross-over split-mouth study. The study design was described in detail in a previous pilot study (Mat Nazri et al., 2018). The results of the pilot study showed that there was less pain during scaling using PS scaler tip compared to conventional scaler tips. In order to investigate further on the effect of scaler tip design on tooth surface, an *in vitro* study was added to this current study. Ethical approval was obtained from the Medical Ethics Committee, Faculty of Dentistry, University of Malaya prior to conducting the study [DF RD1719/0063(P)].

3.2.2 Sample population

The participants were those who came to the Primary Care Unit, Faculty of Dentistry, University of Malaya for periodontal treatment. Those who fulfilled the inclusion and exclusion criteria were invited to participate in the study.

3.2.3 Sample size

Data were analysed using G Power version 3 statistical software (Erdfelder et al., 1996). The significance value was set at α value 0.05 with 80% power of the study. From the previous journal (Kocher et al., 2005), the calculated effect size was 0.79. The calculated sample size was 30 after including a 20% dropout rate.

3.2.4 Inclusion criteria

a) Patients who had anterior maxillary teeth from teeth #13 to #23
b) Patients who aged between 20 and 40 years old
c) Patients who were fit and healthy
d) Patients who were diagnosed with chronic gingivitis or mild chronic periodontitis with pocket depths of 3mm to 5mm (at least five sites with pocket depths of 4mm)
e) Patients who presented with positive bleeding on probing at least on one tooth and minimal calculus on teeth #13 to #23

3.2.5 Exclusion criteria

a) Patients who were smokers
b) Patients who had dentinal hypersensitivity in one or more teeth in each quadrant
c) Patients who had crowns, large restorations or non-vital teeth involving teeth #13 to #23.
d) Patients who suffered from acute dental infections such as abscesses, pulpitis or cervical lesions requiring immediate treatment
e) Patients who were on long term non-steroidal anti-inflammatory drug therapy.

f) Patients who were undergoing orthodontic treatment or using removable partial dentures involving teeth from teeth #13 to #23.

3.2.6 Randomisation

Randomisation was carried out using SPSS statistical program (Version 12.0.1, SPSS Inc., Chicago, USA) to remove the ordering effect. Subjects were divided into two groups based on order of recruitment into either group A or group B.

3.2.7 Measurements

Questionnaire was distributed and clinical measurement and visual analogue scale (VAS) were measured in this study.

3.2.7.1 Questionnaire

The questionnaire comprised of questions on sociodemographic information and oral hygiene habits. There were questions on age, gender, education, ethnicity and lifestyle habits. Participants were also asked questions on the frequency of tooth brushing, use of interdental toothbrush and mouth rinse.

3.2.7.2 Clinical measurement

Written consent was obtained from all participants prior to the examination. Periodontal parameters were recorded on teeth #13 to #23 using William's probe (Hu-Friedy, Chicago, USA). The periodontal parameters were:

a) Visual plaque index (VPI) (Ainamo & Bay, 1975)

VPI was carried out at four sites of each tooth (mesiobuccal, mid-buccal, distobuccal and palatal surfaces). The visible detection of plaque was marked as presence '1' or absence '0' by running William's probe on the tooth surfaces.

0 = no visible plaque

1 = visible plaque

b) Gingival bleeding index (GBI) (Ainamo & Bay, 1975)

GBI was carried out at four sites of each tooth (mesiobuccal, mid-buccal, distobuccal and palatal surfaces). The assessment was considered as presence '1' if there was bleeding within 10 seconds and absence '0' if there was no bleeding, after probing of the gingiva. William's probe was used for this bleeding assessment.

0 = no visible bleeding

1 = visible bleeding

c) Probing pocket depth (PPD)

PPD was measured from the gingival margin to the base of the pocket using William's probe (Hu-Friedy, Chicago USA) with calibrated markings. Probe was inserted into periodontal pocket parallel to the long axis of the tooth. PPD was measured at six sites of each tooth #13 to #23, at mesio-buccal, mid-buccal, disto-buccal, mesio-palatal, mid-palatal and disto-palatal surfaces, to the closest millimetre (mm).

d) Recession

Recession was measured from the visible level of CEJ to the gingival soft tissue margin. Measurements closest to millimetre (mm) were recorded using William's probe with calibrated markings, by placing the probe parallel to the long axis of the tooth. Recession was measured at six sites per tooth for teeth #13 to #23 at mesio-buccal, mid-buccal, disto-buccal, mesio-palatal, mid-palatal and disto-palatal surfaces.

e) Clinical attachment level (CAL)

CAL was measured from the CEJ to the base of pocket. The level of CAL is the sum of

PPD and R.

3.2.7.3 Visual analogue scale (VAS)

VAS scale consists of a line numbered from 0 till 10. Scale '0' indicates no pain while scale '10' indicates the worst possible pain. Participants were asked to choose any number between these two ends that described best the pain they experienced during treatment (Figure 3.9).

Figure 3.9: Visual Analogue Scale (VAS)

3.2.8 Data collection

At the beginning of the study, all participants were given an explanation on the nature of study and written informed consents were obtained. Questionnaire forms were then given to participants to be filled prior to the intervention. Periodontal examination and scaling were performed by a single operator (NA) who was trained and standardised to an experienced periodontist. Supra and subgingival scaling were only performed at teeth #13 to #23.

A portable ultrasonic scaler device as described in section 3.1.6 was used for scaling treatment using either (i) conventional (FS-407, EMS® Piezon, Switzerland) or (ii) Perio Slim (DS-016A, EMS® Piezon, Switzerland) scaler tip. Medium power setting and maximum water coolant were used for both scaler tips for all participants as recommended by the manufacturer. During scaling, the scaler tips were always held parallel to the long axis of the tooth and were performed in a systematic method.

Based on the randomisation, group A participants were treated first with Perio Slim scaler tip at teeth #13 to #11 while group B participants were treated first with conventional scaler tip at teeth #13 to #11. Participants were given one-hour break before proceeding to quadrant 2. Subsequently, group A was treated with conventional scaler tip at teeth #21 to #23 while group B was treated with Perio Slim® scaler tip at teeth #21 to #23. Scaling was performed for 2 minutes with each scaler tip. Participants were blinded to the type of scaler tips used for both half sextants. Full mouth scaling was given to subjects at the end of the experiment.

For group A, scaling started from disto-buccal surface of tooth #13, and to all buccal surfaces up to mesio-buccal of tooth #11. Then, scaling was proceeded to mesio-palatal tooth #11 and all palatal surfaces till the disto-buccal surface of tooth #13. For group B, scaling began at mesiobuccal of tooth #21, then to all buccal surfaces up to distobuccal of tooth #23. Scaling then proceeded to disto-palatal of tooth #23 and all palatal surfaces up to mesio-palatal surface of #21. Immediately following calculus removal for each half sextant, participants were given a VAS to score their pain perception using the respective scaler tips. Detailed information about the procedure and how to score VAS was explained clearly to all participants prior to treatment. The data collection flow chart is shown in Figure 3.10.

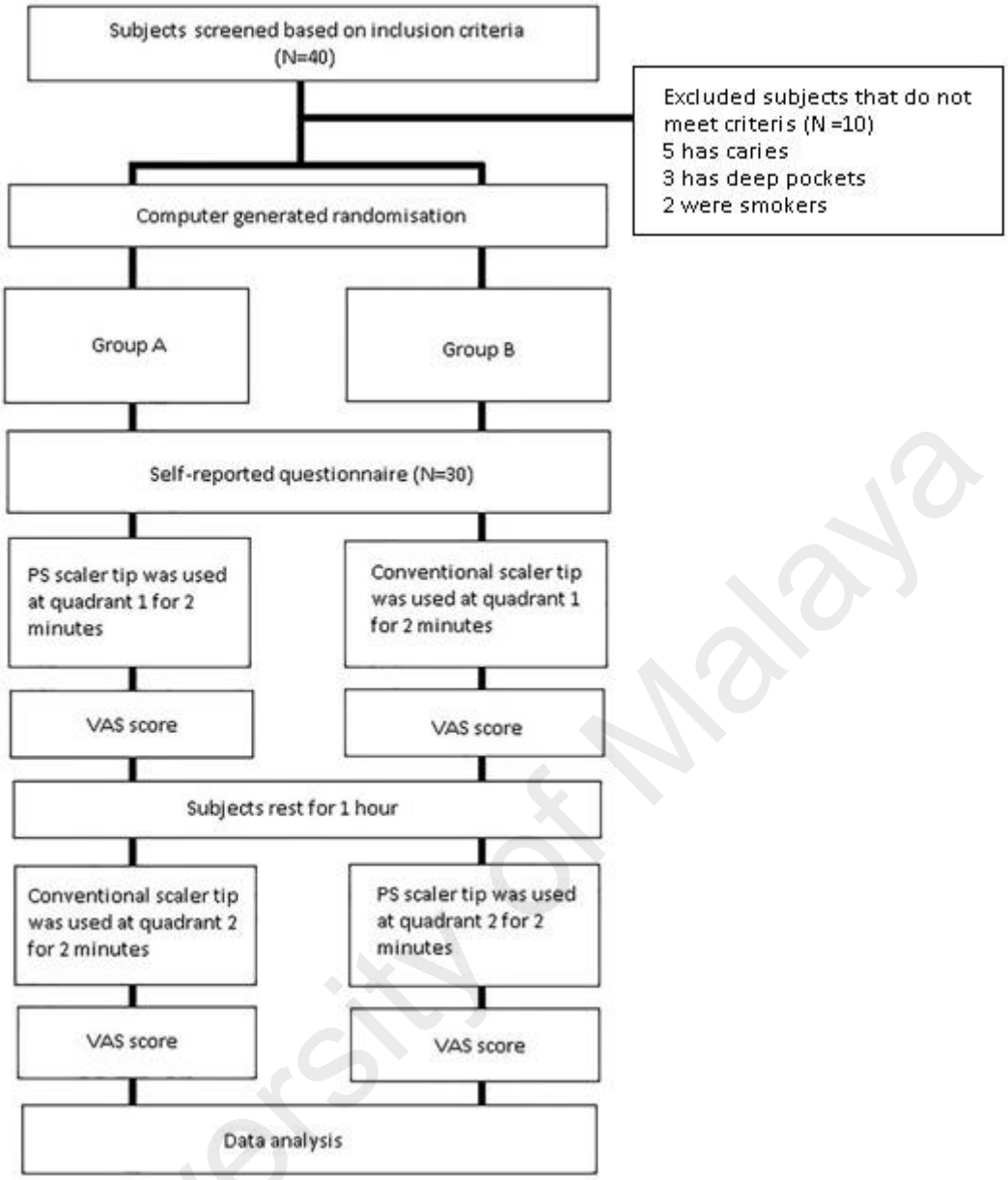

Figure 3.10: Flow chart for the clinical study

3.3 Statistical analyses

Data were analysed using SPSS statistical program (Version 16.0, SPSS Inc., Chicago, USA). Level of significance was set at $p < 0.05$.

3.3.1 *In vitro* study

The normality of data was analysed using Shapiro-Wilk test. For tooth surface roughness, the data distribution was not normal. Therefore, Wilcoxon signed-rank test was used to

compare the data between before and after scaling. Independent *t* test was used to compare data between PS and conventional group.

While for tooth substance loss, paired *t* test and independent *t* test was used to analyse data that were normally distributed. For data that were not normally distributed, Wilcoxon signed-rank test and Mann-whitney test was used.

3.3.2 Clinical study

The sociodemographic comparison between groups was analysed using Mann-whitney test. The baseline clinical parameters were analysed using paired sample *t* test. Based on Shapiro-Wilk test, VAS data distribution was not normal. Therefore, the differences in the VAS score after therapy between the 2 groups were compared using Wilcoxon signed-rank test.

CHAPTER 4: RESULTS

4.1 *In vitro* study

4.1.1 Tooth surface roughness

Tooth surface roughness was measured in S_a value in micrometre (µm) unit. Table 4.1 shows the mean surface roughness in S_a values following scaling with either PS or conventional scaler tips, before and after scaling. Mean S_a before scaling was 9.8 (±4.7) µm and 10.0 (±3.2) µm in PS and conventional groups, respectively. Following scaling, the S_a values were significantly reduced in both groups ($p < 0.05$). However, a significant difference was not observed between PS and conventional groups.

Table 4.1: Mean surface roughness in S_a values before and after scaling using PS or conventional scaler tips.

Surface roughness		Before (n = 10)	After (n = 10)	Mean difference (SD)	p value	p value
Mean µm (SD)	PS	9.8 (4.7)	6.7 (3.3)	3.1 (2.5)	0.005*	0.167
	C	10.0 (3.2)	5.3 (3.5)	4.7 (3.3)	0.005*	

C for Conventional tip, PS for Perio Slim tip.
Intragroup comparison was analysed using Wilcoxon signed-rank test.
Intergroup comparison was analysed with independent *t* test.
*indicates statistically significant difference ($p < 0.05$).

4.1.2 Tooth substance loss

4.1.2.1 Descriptive analysis

The distance (D) between outer tooth surface (T) and upper reference point (UR) or lower reference point (LR) is referred to as “tooth thickness”. Tooth thickness before scaling will be referred to as ‘thickness before’ and tooth thickness after scaling will be referred to as ‘thickness after’. Figure 4.1 shows representative scanning electron micrograph of cross-section of a tooth.

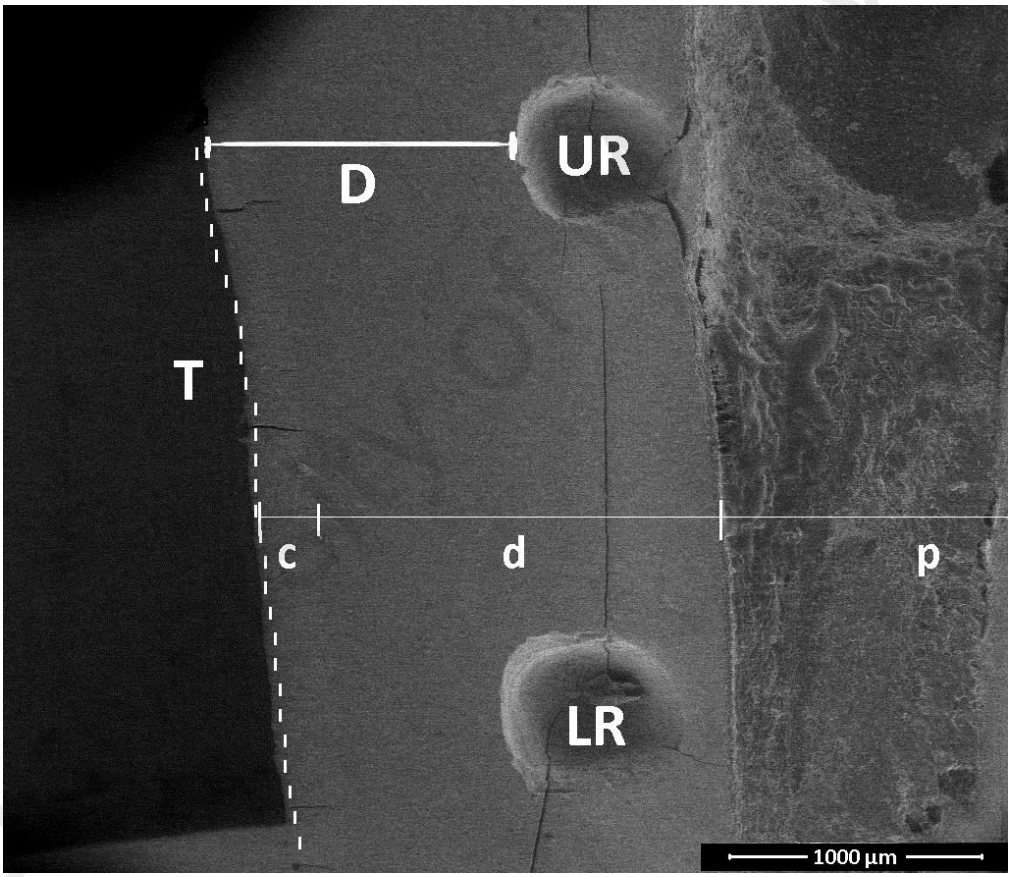

Figure 4.1: Scanning electron micrograph showing cross-section of a tooth before scaling at x50 magnification. Two reference points were shown; upper reference point (UR) and lower reference point (LR). Tooth thickness (D) was measured from the outer tooth surface (T) represented by dotted lines, to the reference points. c is cementum, d is dentine and p is pulp.

4.1.2.2 Quantitative analysis

(i) Tooth thickness at upper reference point

The tooth thickness measurements were divided into two categories; <1000 µm and ≥1000 µm. Table 4.2 shows the summary of tooth substance loss following scaling with either Perio Slim or conventional scaler tips at upper reference point. For teeth with initial tooth thickness of <1000 µm, the mean thickness before scaling was 790.9 (±130) µm in the PS group and 745.0 (±197) µm in the conventional group. Following scaling with EMS scaler tips, the thickness decreased to778.7 (±130) µm in the PS and 724.8 (±212) µm in the conventional groups respectively. The mean difference tooth thickness following scaling was significantly less in the PS group with initial thickness <1000 µm ($p < 0.05$).

For teeth with initial thickness of ≥1000µm, the mean thickness before scaling was 1280.1 (±190) µm in the PS group and 1267.9 (±121) µm in the conventional group. Following scaling, the thickness decreased to 1265.8 (±189) µm in the PS and 1223.7 (±113) µm in the conventional groups respectively. The mean difference tooth thickness following scaling compared between PS and conventional groups for teeth with initial thickness ≥1000 µm was not significant ($p > 0.05$).

Table 4.2: Tooth substance loss indicated by mean difference of tooth thickness (µm) at upper reference point before and after scaling using Perio Slim or conventional scaler tips.

Tooth thickness			Before	After	Mean difference	*p* value	*p* value
Mean µm (SD)	<1000	PS *n*=9	790.9 (130)	778.7 (130)	12.2 (8)	0.002*	0.038*
		C *n*=8	745.0 (197)	724.8 (212)	20.2 (25)	0.058	
	≥1000	PS *n*=14	1280.1 (190)	1265.8 (189)	14.3 (10)	0.0001*	0.058
		C *n*=15	1267.9 (121)	1223.7 (113)	44.2 (51)	0.005*	

Intragroup comparison was analysed with paired *t*-test.
Intergroup comparison for <1000µm was analysed with independent sample *t* test.
Intergroup comparison for ≥1000µm was analysed with Mann-Whitney test.
C for Conventional, PS for Perio Slim.
*indicates statistically significant different ($p < 0.05$).

(ii) Tooth thickness at lower reference point

Table 4.3 shows the summary of tooth substance loss following scaling with either Perio Slim or conventional scaler tips. For teeth with initial tooth thickness of <1000 µm, the mean thickness before scaling was 811.9 (±179) µm in the PS group and 802.4 (±269) µm in the conventional group. Following scaling with EMS scaler tips, the thickness decreased to796.0 (±178) µm in the PS and 780.5 (±280) µm in the conventional groups respectively. The mean difference tooth thickness following scaling was significantly less in the PS group with initial thickness <1000 µm ($p < 0.05$).

For teeth with initial thickness of ≥1000µm, the mean thickness before scaling was 1131.0(±25) µm in the PS group and 1218.0 (±200) µm in the conventional group. Following scaling, the thickness decreased to 1113.0 (±254) µm in the PS and 1177.0 (±191) µm in the conventional groups respectively. The mean difference tooth thickness following scaling compared between PS and conventional groups was not significant ($p > 0.05$).

Table 4.3: Tooth substance loss indicated by mean difference of tooth thickness (µm) at lower reference point before and after scaling using Perio Slim or conventional scaler tips.

Tooth thickness			Before	After	Mean difference	*p* value	*p* value
Mean µm (SD)	<1000	PS *n*=9	811.9 (179)	796.0 (178)	16.0 (13)	0.007*	0.0375*
		C *n*=8	802.4 (269)	780.5 (280)	21.9 (16)	0.007*	
	≥1000	PS *n*=14	1131.0 (25)	1113.0 (254)	17.3 (11)	0.001*	0.16
		C *n*=15	1218.0 (200)	1177.0 (191)	41.3 (49)	0.006*	

C for Conventional, PS for Perio Slim.
Intragroup comparison analysed with paired *t* test.
Intragroup comparison for ≥1000µm (PS) analysed with Wilcoxon signed-rank test.
Intergroup comparison for <1000µm analysed with independent sample *t* test.
Intergroup comparison for ≥1000µm analysed with Mann-whitney test.
* Statistically significant difference ($p < 0.05$).

4.2 Clinical Study

4.2.1 Socio-demographic data

Table 4.4 summarises the socio-demographic characteristics of the participants. Based on the characterization of the participants, there were slightly more male than female in both groups; 53% and 60% in Group A and Group B respectively. The majority of the participants belong to the Malay ethnicity, with 87% in the Group A and 93% in the Group B. For both groups, majority of the participants (80%) were between 20-30 years oldage range. Almost all subjects (93-100%) had at least tertiary education. There was no statistically significant difference between Group A and Group B with regards to gender, ethnicity, age, and level of education ($p > 0.05$).

Table 4.4: Socio-demography characteristics of participants in group A and group B.

Characteristics		Group A (n = 15) n (%)	Group B (n = 15) n (%)	p value
Gender	Male	8 (53)	9 (60)	0.71
	Female	7 (47)	6 (40)	
Ethnicity	Malay	13 (87)	14 (93)	0.50
	Others	2 (13)	1 (7)	
Age	20 – 30	12 (80)	12 (80)	0.72
	31- 40	3 (20)	3 (20)	
Level of education	Primary	0 (0)	0 (0)	0.32
	Secondary	1 (7)	0 (0)	
	Tertiary	14 (93)	15 (100)	

Group A: Perio Slim PS scaler tip at Q1 followed by Conventional scaler tip at Q2.
Group B: Conventional scaler tip at Q1 followed by Perio Slim PS scaler tip at Q2.
Intergroup comparison was analysed using Mann-whitney test.

4.2.2 Oral hygiene habits

Table 4.5 summarises oral hygiene habits among participants. About 33% of the participants had regular dental visit in the group A and 27 % in the group B. The majority of the participants brushed their teeth more than once daily, with 87% and 80 % in the A and B groups respectively. A few of the participants use floss (20%) and (33%), dental toothpick (7%) and (33%) and mouth-rinse (47%) and (13%) in the A and B groups respectively.

Table 4.5: The oral hygiene habits for participants in group A and group B.

Activity			Group A (n = 15) n (%)	Group B (n = 15) n (%)
Dental visit	Regular		5 (33)	4 (27)
	Irregular		10 (67)	11 (73)
Oral hygiene habits	Frequency of toothbrushing	<1x	0	0
		1x	2 (13)	3 (20)
		>1x	13 (87)	12 (80)
	Interdental cleaning	Floss	3 (20)	5 (33)
		Dental toothpick	1 (7)	5 (33)
		Interdental toothbrush	0 (0)	0
	Mouth rinse		7 (47)	2 (13)

Group A: Perio Slim PS scaler tip at Q1 followed by Conventional scaler tip at Q2.
Group B: Conventional scaler tip at Q1 followed by Perio Slim PS scaler tip at Q2.

4.2.3 Baseline periodontal parameters

The baseline periodontal parameters in terms of PPD, CAL, GBI, and VPI were summarised in Table 4.6. The mean PPD was 2.76±0.18 mm and 2.77±0.23 mm for PS and conventional group respectively. There was no statistically significant difference between PS and conventional groups with regards to PPD, CAL, GBI, and VPI ($p > 0.05$).

Table 4.6: Baseline periodontal parameters comparison based on the type of scaler tip used; Perio Slim (PS) or Conventional.

Clinical Parameters	**PS** (n = 30)	**Conventional** (n = 30)	***p* value**
	Mean (SD)	**Mean (SD)**	
Mean PPD (mm)	2.76 (0.18)	2.77 (0.23)	0.60
Mean CAL (mm)	2.96 (0.22)	2.99 (0.23)	0.68
Mean GBI (%)	0.57 (0.17)	0.56 (0.18)	0.67
Mean VPI (%)	0.47 (0.13)	0.50 (0.24)	0.79

Intergroup comparison was analysed using paired sample *t* test.

4.2.4 VAS score

4.2.4.1 Scores frequency distribution

Figure 4.2 shows the frequency distribution of VAS scores for Perio Slim and conventional scaler tips. The most frequent score was 3 and 6 in PS and conventional group respectively.

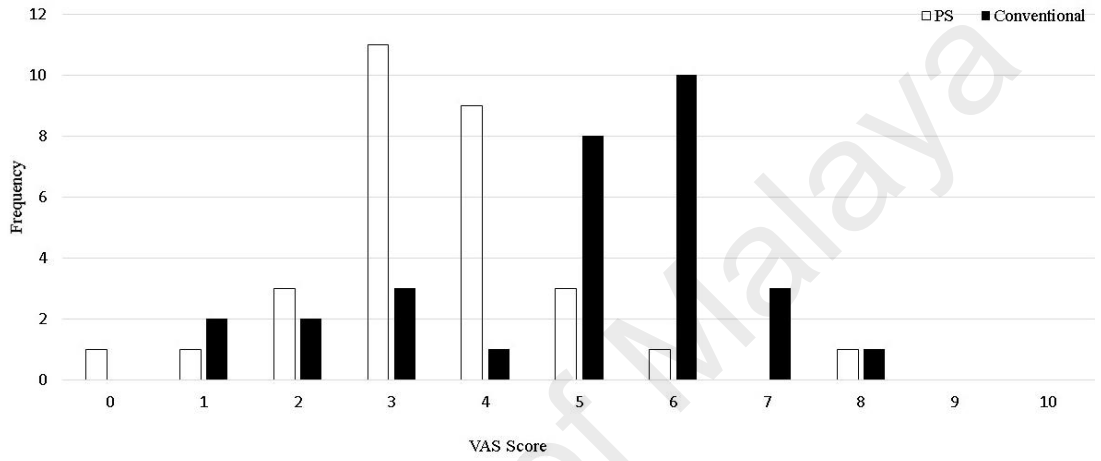

Figure 4.2: Frequency distribution of VAS scores for Perio Slim (PS) and conventional scaler tips.

4.2.4.2 Mean pain score and comparison between groups

Table 4.7 summarises the mean pain scores for both groups. Mean pain scores were 3.5 ($\pm$1.5) and 4.9 ($\pm$1.8) for PS and Conventional group respectively. The median pain scores were 3 and 5 for PS and conventional group respectively. There was a significantly higher pain score in conventional group compared to PS group ($p < 0.05$).

Table 4.7: Mean (standard deviation) and median (IQR) pain scores comparison between Perio Slim (PS) and conventional scaler tips.

Scaler tip	VAS Score		
	Mean (SD)	**Median (IQR)**	***p* value**
PS	3.5 (1.5)	3 (1)	0.003*
Conventional	4.9 (1.8)	5 (2)	

Intergroup comparison was analysed using Wilcoxon signed-rank test.
*indicates statistically significant difference ($p < 0.05$).

CHAPTER 5: DISCUSSION

5.1 *In vitro* study

This study compared tooth surface roughness and tooth substance loss following scaling using piezoelectric ultrasonic scaler with either PS or conventional scaler tip. It was observed that both scaler tips resulted in reduction in surface roughness after scaling. However, there was no significant difference between PS or conventional scaler tip. In addition, the slimmer scaler tip (PS) caused less tooth substance loss than wider (conventional) scaler tip.

5.1.1 Inclusion criteria and working parameter

This *in vitro* study involved extracted human teeth. In order to standardise baseline measurement, only single-rooted tooth with minimal calculus and free of caries were included. Since the assessment for surface roughness requires a tooth with flat surfaces, thus multirooted tooth that usually has less flat surface is best excluded. Besides, presence of caries and calculus will increase the irregular topography of the tooth. Standardisation of these criteria is important to allow fair comparison for surface roughness between test and control groups in the current study. Furthermore, it is worth noting that roughness measurement uses micrometer unit, thus the results still revealed large standard deviation in surface roughness at microscopic level between samples even though standardisation has been made at macroscopic level.

Working parameters such as tip angulation, lateral force, and power setting were known to affect surface roughness and tooth substance loss (Flemmig et al., 1998). The deepest defect was observed when a combination of 45^0 tip angulation and 2N lateral force were used (Flemmig et al., 1998). In the current study, parallel technique was used where tip angulation is close to zero degree. Flemmig et al., (1998) reported that when instrument angulation was set at zero, regardless of the amount of lateral force and power setting,

instrumentation does not lead to severe root damage. Severe root damage did not occur at lateral force of 1.0N or below. A threshold of 2.0N was suggested by Flemmig et al., (1998) for scaling to cause severe root damage. Unit conversion of 2.0N is 200g. The operator in the current study is a periodontal resident and is trained to exert light force during periodontal treatment. Light force is practiced to be close to the probing force of not more than 25g (Ainamo, 1982). Besides, scaling procedure was done by a single operator to minimise variation in lateral force.

Furthermore, Flemmig et al., (1998) reported that power setting has the least effect on root surfaces compared to angulation and lateral force. However, an increased power setting can cause an increased displacement amplitude in both piezoelectric and magnetostrictive ultrasonic devices (Lea et al., 2003a). In the current study, medium power setting was used in accordance to manufacturer's instruction. Overall, standardisation with respect to treatment modalities and assessment is important in studies on tooth surfaces. Therefore, it is important to establish standard protocol for *in vitro* studies on scaler tips to ascertain the validity of the research findings.

In the current study, the operator was not blinded to the scaler tip design. There could be risk of bias in terms of pressure exerted during scaling. Flemmig et al., (1998) reported that there was no significant difference in the amount of root damage following scaling with lateral pressure of 0.5N compared to 1.0N, when parallel technique was used. Parallel technique refers to the scaler tip angle being close to zero to tooth surface. Besides, operator was trained to use light pressure during scaling procedure. The strict scaling protocol used in the study was aimed to reduce the effect of variation in lateral pressure during scaling.

There are two ways to determine the endpoint of scaling; scaling until smooth root surface was achieved clinically (Kawashima et al., 2006), or by the number of scaling strokes (Jepsen et al., 2004). However, evaluating a smooth root surface may give inconsistent

results due to such subjective assessment. In this study, three scaling strokes were applied in a specified area. Three scaling strokes were chosen because of the small experimental area, and ease in maintaining light pressure during scaling. It was also based on the study by Coldiron et al., (1992) that reported 60µm layer of tooth substance were lost following 20 scaling strokes (Coldiron et al., 1992). Since current study used a macroscopic reference point which is made by scaler tip, the remaining tooth substance that is present for experiment was minimal. A minimal scaling strokes (three) was thus, chosen.

5.1.2 Tooth surface roughness assessment

The current study used profilometer with S_a value to measure surface roughness. S_a measures and calculates surface roughness for a determined area. This is a more accurate measurement as whole surface area was taken into measurement. However, S_a value was a new unit, and to our knowledge, no study has reported on S_a value for surface roughness analysis yet. In the current study, optical surface texture analyser (Alicona, Belgium) was used to calculate S_a value which gives a three-dimensional measurement for the whole surface area. Therefore, S_a is an accurate value to measure surface roughness.

For the evaluation of surface roughness, subjective and objective assessments have been reported by several authors (Arabaci et al., 2007; George et al., 2016; Kawashima et al., 2007). RLTSI is a subjective assessment that measures roughness based on surface irregularities and amount of tooth substance loss, whereas profilometer is an objective assessment that measures roughness in R_a values.

George et al., (2016), Kawashima et al., (2007) and Lie & Leknes (1985) have used RLTSI to compare the roughness based on surface irregularities and amount of tooth substance loss. This measurement however, was subjective and subjected to high variation dependant on the operator. Provided that the intra-operator consistency is high, index may be used as an accurate assessment method. This measurement may be used in

conjunction with other objective measurement.

Another method of assessment that was widely used for roughness measurement was profilometer. Arabaci et al., (2007), Busslinger et al., (2001), Folwaczny et al., (2004), and Vastardis et al., (2005) reported roughness in R_a values, measured by profilometer. The surface roughness was determined as mean roughness (R_a), defined as the average peak and valley distances measured along the centreline of one cut-off length (Arabaci et al., 2007). Usually, a few R_a measurements were performed and mean R_a value was calculated. If the lines hit irregular topography, the R_a will give a high value. Therefore, several lines are needed at different position so that the measurements taken represent the most accurate roughness for the specified area. This method was not chosen simply because of availability of more advanced profilometer (Alicona, Belgium) that give S_a value which is more convenient and more accurate. S_a value measures roughness of a surface area, which is more accurate to measure surface roughness compared to R_a.

5.1.3 Tooth surface roughness following scaling

To our knowledge, there has not been any study that compares tooth surface roughness following scaling with piezoelectric ultrasonic scalers either PS or conventional scaler tips. The closest study was by Arabaci et al., (2007) who reported surface roughness caused by ultrasonic device (EMS®, Switzerland) using different scaler tip designs on polished restorative materials. The surface roughness after scaling with a wider, conventional type A instrument was more than the slimmer type PS instrument (Arabaci et al., 2007).

In the current study, even though there was no significant difference in surface roughness between the two different tip designs, the surface roughness following scaling using PS scaler tip was less than the conventional scaler tip. This could be due to variations in displacement amplitude between the two scaler tip designs (Lea et al., 2003a). Slimmer design was subjected to dampening effect which reduces the displacement amplitude

during function (Lea et al., 2003a). The less lateral movement could explain the less surface roughness produced by the slimmer design. It is worth to note that, in the current study, the effect of scaler tip design on tooth surface roughness was non-significant. This could suggest that the effect of scaler tip designs on tooth surface roughness is minimal. For piezoelectric ultrasonic scalers, tip wear, power setting and angulation (Arabaci et al., 2013) have been shown to increase in displacement amplitude (Lea et al., 2006). As such, in this study, new scaler tips were used and were always held parallel to tooth surface. Parallel technique (zero-degree angulation) will ensure that any increase in the lateral force will not cause tooth surface defects (Flemmig et al., 1998). In the current study, the operator has practiced a standardised three scaling strokes using parallel technique (zero-degree angulation) and exert light pressure to ensure that the effect of lateral force was reduced to the minimum.

Other studies have compared between type of instruments (Busslinger et al., 2001; Kawashima et al., 2007; Vastardis et al., 2005) reported that hand curette produced smoother root surfaces than sonic and periotor scaler. This finding should be interpreted with caution as instrumentation done with curette was intended to root plane the tooth in contrast to power-driven device where only debridement was performed. Therefore, the result of the study cannot be directly compared to the present study. However, it would be useful to acknowledge the effect caused by different types of instruments so that clinicians are aware on the effects of the instruments being used.

5.1.4 Tooth substance loss measurement

In the current study, tooth substance loss was measured using SEM from a predetermined reference point made on dentine. This method was chosen because it can be done conveniently in our laboratory setting. Besides, the reference point made was clear, and measurement can be made accurately. In comparison to taking cementum-dentine junction as reference point, there will be difficulties to determine the reference point and

thus, measurement of tooth substance loss can be hampered.

Other study measured tooth substance loss in two and three-dimensional form (Jepsen et al., 2004). Ultrasonic scaler in this study however was moved by a computer-operated stepper motor in a standardised direction and lateral force. Rupf et al., (2005) on the other hand measured relative loss of cementum after scanning using SEM (Rupf 2005). Similar method was also used by Coldiron et al., (1992). Another measurement of tooth substance loss is RLTSI (Lie & Leknes, 1985) which was used for tooth substance loss estimation (Kawashima et al., 2007).

5.1.5 Tooth substance loss following scaling

The current study demonstrated that slimmer scaler tip caused less tooth substance loss than wider scaler tip. This finding was consistent with a study by Jepsen et al., (2004), where slim scaler tip caused less tooth substance loss compared to wide scaler tip. This could be attributed to the slim design of the scaler tip, the light force, as well as 0^0 tip angulation used. It was reported that when the least tooth substance loss produced when scaling was done at 0^0 angulation and using light force (Flemmig et al., 1998).

The influence of scaler tip design on tooth substance loss might be explained by the flattened oscillation pattern produced among slim scaler tip design. Flattened pattern has less lateral motion therefore, less impact and less removal of tooth substance. During function, longer and slimmer tips are more prone to flattening effect to the oscillation pattern (Lea et al., 2003b). Besides, differences in the scaler tip designs influenced the displacement amplitude where longer tips are more prone to variation in amplitude (Lea et al., 2003a). This might explain the lesser amount of tooth substance loss among PS scaler tip compared to conventional scaler tips.

In general, tooth substance loss produced by ultrasonic device as in the current study is considered minimal, especially when used with slim scaler tip that has a close to linear

oscillation pattern (flattened). It was reported that hand instrument and ultrasonic scaler (Acteon, Germany) caused more tooth substance loss compared to a liner oscillating device, Vector^{TM} scaler (Duerr Dental, Germany) (Rupf et al., 2005). This finding was also supported by Kawashima et al., (2007) where hand curette has a higher RLTSI (Lie & Leknes, 1985) score compared to Vector^{TM} scaler (Kawashima et al., 2007). Vector^{TM} produced a linear oscillating pattern. It can be deduced that ultrasonic device that has a close to linear oscillation (reduced displacement amplitude and flattened oscillating pattern) results in less tooth substance loss. This is in accordance with the results from the current study where slim scaler tip that has a flattened oscillating pattern caused less tooth substance loss than wider scaler tip.

5.2 Clinical study

5.2.1 Study design and sampling method

This study used a split-mouth design whereby two scaler tips were assigned to one side of the mouth randomly, in order to allow evaluation of pain perception. This design was aimed to reduce differences in pain threshold between participants. Split-mouth study design is commonly used in other patients' pain perception studies (Braun et al., 2003; Braun et al., 2007; Muhney & Dechow, 2010). The limitation of this design is there is a possibility that the first pain experience may be extended to second pain experience. This is because the patient may still remember the pain experienced from the first scaling. Subsequently, this could have lowered the second pain score because of desensitisation caused by repeated exposure (Campbell et al., 2014). It was also possible that patient remembered the pain experience from the first scaling.

In order to overcome this, for the current study, both scaler tips had the chance to be scored during first and second round. The study was designed so that the subjects were equally distributed into two groups. A wash-off period of one-hour was allowed before

second procedure so that they forget the first pain experience. One-hour was chosen for the length of wash-off period because it is practical and convenient for both patient and clinician. A new paper-bow for VAS was given after each treatment to reduce the influence of previous results.

Braun et al., (2007) also used split-mouth study design but did not mention any interval between the two methods. It was mentioned that a new paper-bow was given after each treatment to reduce influence of first score. Similarly, Braun et al., (2003) has used split-mouth design and a new paper-bow for each treatment to reduce influence of previous score. In addition, Braun et al., (2003) reported giving VAS score immediately after each method. The pain perception was not summarised after all methods has been used. This is again, an attempt to obtain most accurate pain score related to the treatment used. This immediate-scoring method was also used in the current study for accuracy purpose.

This study used convenient sampling method where subjects were recruited from those who came for dental treatment in the Primary Care Unit. This method was chosen as it is time and cost effective. Therefore, the results of this study have to be interpreted with care and cannot be generalised to the general population. Nevertheless, the findings of this study will provide an insight about patients' discomfort during scaling treatment and will be meaningful to create awareness among clinicians.

5.2.2 Periodontal parameters

Baseline periodontal parameters was assessed in the current study from tooth 13 to 23. This was to ensure that the participants met the inclusion criteria; chronic gingivitis and/or mild chronic periodontitis. Von Troil et al., (2002) reported that half of patients that underwent periodontal therapy experienced root sensitivity. Root sensitivity might interfere with the pain assessment done in the current study. Therefore, participants involved were the ones that had at most mild chronic periodontitis. In addition,

participants that had similar baseline periodontal parameters would allow a fair comparison to be made.

5.2.3 Visual analogue scale

In this study, VAS method was used to evaluate pain perception. It was chosen because it is easily available and a convenient method for pain assessment for patients. Although VAS only records pain experience retrospectively, yet it is a valid measure for pain experience (Price et al., 1983). VAS has been shown to respond to experimental pain and able to differentiate between different levels of intensities. The VAS scores were tested to be consistent, and matched chronic pain (Price et al., 1983). VAS method is widely used in dentistry and has been reported in several studies (Braun et al., 2003; Braun et al., 2007; Braun et al., 2010; Kocher et al., 2005; Muhney & Dechow, 2010).

In this study, patients were given thorough instruction prior to scaling and patient was asked to remember the pain and score immediately after scaling. This is because VAS scores only summarised pain perception after treatment, thus there are risks of less precision of pain measurement. In addition, the current study allowed a one-hour interval between treatment cycles. This measure was taken to make sure that patient was not affected by first scaling procedure, during pain assessment for second scaling with another scaler tip.

Besides, scaling procedure was carried out within 2 minutes and thus, less probability that the patient will forget the pain experience. Since the current study involved patients with gingivitis and/or mild chronic periodontitis, and scaling procedure involved six anterior teeth only. Therefore, two minutes was allocated and estimated sufficient for scaling. Full mouth scaling was performed after experimental procedure, to remove residual calculus, if any. Braun et al., (2010) allocated 20 seconds per surface area for scaling and maximum of two minutes per tooth. This could be due to the study involved subjects with chronic

periodontitis that probably have abundant amount of calculus. On the other hand, Muhney & Dechow, (2010) performed scaling until all calculus has been removed, and the estimated time for scaling (half mouth) is 30 minutes. However, there were studies that determined the endpoint of scaling by complete calculus removal without a specified time-frame (Braun et al., 2003; Braun et al., 2007).

VAS has been used together with intermodal intensity to confirm the pain measured by intermodal intensity (Braun et al., 2003; Braun et al, 2007). To our knowledge, there was no validation study that reported on use of intermodal intensity comparison utilising manometer bulb. Thus, VAS was used to ensure the validity of the results (Braun et al., 2003; Braun et al., 2007).

5.2.5 Pain perception during scaling

The findings demonstrated that PS scaler tip design caused less pain during scaling compared to conventional scaler tip. These findings were in agreement to previous study by Braun et al., (2007). Braun et al., (2007) compared the subjective pain intensity during ultrasonic (Sirosonic L, Sirona, Germany) scaling between conventional scaler tip (Instrument No. 3, Sirona, Germany) and slim-line style (Perio Pro Line Instrument SI-11, Sirona, Germany) scaler tip using intermodal intensity technique. Braun et al., (2007) reported that pain sensation was less when using slim compared to conventional scaler tip, with a median pain score of 1.4U and 7.8U for slim-line and conventional scaler tip respectively. Interestingly, VAS was used to confirm the pain perception as measured by intermodal intensity technique. However, the details of VAS score were not reported.

In the current study, patient reported VAS median pain score of 3.5 and 4.9 for PS and conventional scaler tip respectively and the difference was statistically significant. These VAS scores were considered low to medium pain intensity. The “pain” during scaling has been interchangeably described as “discomfort”. This is caused by vibration of the scaler tip. Less pain experienced when slim scaler tip was used could be due to the flattened

oscillation pattern under load (during function) (Lea et al., 2003b). Flattened pattern means less lateral movement and force towards tooth. In the clinical settings, scaler tip touches tooth structure and some amount of load was placed.

In this study, only one power generator was used and it was set up at medium power setting. The protocol was designed as such because factors such as power generators, power setting, and scaler tip designs may affect the displacement amplitude (Lea et al., 2003a). The displacement amplitude increases with increasing power setting; and variations does exist between different generators; magnetostrictive and piezoelectric. Large variations in displacement amplitude were also observed among similar and different scaler tip designs especially slim scaler tip designs (Lea et al., 2003a). It was important to note that displacement amplitude is subjected to high variations and standardisation is crucial in order to obtain accurate results. However, to date, there were no available studies that investigate the association between displacement amplitude to pain perception.

Generally, there were limited amount of study that compare the influence of scaler tip design on patients' pain perception. Available studies only discussed comparison of pain perception between different instruments (Braun et al., 2003; Braun et al, 2010), different generators (Muhney & Dechow, 2010), and sonic or ultrasonic scalers (Kocher et al., 2005). Therefore, findings could not be directly compared with this study.

CHAPTER 6: CONCLUSION

6.1 Conclusion

Within the limitations of the study, following conclusions were drawn:

- Scaling using piezoelectric ultrasonic scalers caused reduction in surface roughness irrespective of the scaler tip design used
- Scaling using PM200 EMS Piezon, Switzerland; with either Perio Slim (DS-016A) or conventional scaler tips (FS-407) resulted in comparable surface roughness reduction.
- Tooth substance loss following scaling with Perio Slim (DS-016A, EMS® Piezon, Switzerland) scaler tips were less than conventional (FS-407, EMS® Piezon, Switzerland) scaler tip.
- Pain perception during scaling with slimmer scaler tip, Perio Slim (DS-016A, EMS® Piezon, Switzerland) was less than wider, conventional (FS-407, EMS® Piezon, Switzerland) scaler tip. Slimmer scaler tip was less aggressive than wider scaler tip.
- The findings from this study highlight the advantage of using Perio Slim scaler tip for patients undergoing supportive periodontal therapy. Less aggressive and less painful treatment using PS scaler tip will improve patients' compliance to periodontal visits and improve long term success of a periodontal therapy.

6.2 Recommendations

Based on the findings of this study, several recommendations were proposed:

- A highly standardised scaling method using computer-operated stepper motor with attached spring balance is recommended to standardise the applied lateral force.
- A pressure gauge attached to scaler tip can be used to measure lateral force applied during scaling if scaling is to be performed by operator. This can be used for the clinical part of the study.

- A combination of subjective and objective method for assessment of tooth surface roughness and tooth substance loss using RLTSI (Lie & Leknes, 1985) and profilometer respectively is recommended to confirm readings from profilometer.
- Assessment of pain perception during treatment such as intermodal intensity comparison using manometer bulb is recommended in addition to VAS.

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