Association between Mandibular Incisor to Mandibular Plane Angle (IMPA) and Periodontal Health Status Based on Loss of Clinical Attachment Level (CAL): A Cross-sectional Study

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BACKGROUND: IMPA (mandibular incisor to mandibular plane angle) is a routinely used cephalometric measurement to determine the position of the mandibular incisors. As orthodontic treatment tends to increase the mandibular incisor inclination, there have been several studies that examine post-orthodontic IMPA and periodontal involvement limited to gingival recession via clinical examination. However, there has not been a study where the mandibular incisor inclination is evaluated regarding the loss of clinical attachment level (CAL), defined as the distance from cemento-enamel junction (CEJ) to the probe tip, which gives more objective evaluations than pocket probing depth. It is hypothesized that the patients with a greater clinical attachment loss (CAL) are likely to have a higher IMPA.

OBJECTIVE: The purpose of this study is to evaluate whether the IMPA is associated with periodontal involvements, measured by the loss of CAL.

MATERIAL AND METHODS: In this study, the IMPAs of two groups of adult patient populations were compared (n = 10 each): a periodontally healthy group from the orthodontics department who were periodontally cleared to proceed with orthodontic treatment and a periodontally unhealthy group from the periodontics department who were diagnosed as stage II (3-4mm CAL) and stage III periodontitis (>5mm CAL) as defined by the American Academy of Periodontology. Statistical analyses were performed to evaluate the association between CAL and IMPA and were adjusted for confounding factors such as age and sex.

RESULTS: The periodontally healthy group had the average CAL on the mandibular central incisors of 0.318 ± 0.380mm facially and 0.268 ± 0.318mm lingually with the average IMPA of 94.627 ± 5.329 degrees. The periodontally unhealthy group had the average CAL on the mandibular central incisors of 3.858 ± 0.781mm facially and 3.018 ± 1.129mm lingually with the average IMPA of 96.733 ± 8.992 degrees. The difference in IMPA between the two groups was not statistically significant. There was a significant correlation between age and CAL but not between IMPA and CAL. Sex was not correlated with either CAL or IMPA.

CONCLUSION: No significant association was found between CAL and IMPA. Age and sex were not confounding factors.

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Preface

I would like to thank Dr. John Buzzatto, Dr. Ali Seyedain, and Dr. Nilesh Shah for guiding me throughout the research project. With their help, I was able to execute and complete this study. Also, I would like to thank Dr. Curtis Dugas for being the periodontics department liaison for this study.

1.0 Introduction

1.1 Orthodontic Cephalometry

1.1.1 History of Orthodontic Cephalometry

The evolution of cephalometric imaging techniques has greatly enhanced the present-day orthodontic diagnosis. X-ray was first discovered by Wilhelm Roentgen in 1895 and was reported in his paper "On a New Kind of Rays" (Röntgen, 1896). Following the discovery, various researchers attempted to standardize the method to obtain reproducible cephalometric radiographs to study craniofacial growth and development and changes related to orthodontic treatment. In the early 20^{th} century, Holly Broadbent and Wingate Todd developed a roentgenographic craniostat, which was later refined as the Broadbent-Bolton cephalometer in 1931 (Hans et al., 2015). This allowed standardization in taking the radiograph as the head was positioned between two ear rods with three reference planes. In the early years, researchers mainly used the cephalographs to study craniofacial growth and development as they collected numerous subjects from the growth centers until Downs first proposed a cephalometric analysis by studying the skeletal and dental relationships in 1948 (Hans et al., 2015). Today, lateral cephalograms are routinely used as an aid in orthodontics to diagnose and treatment plan malocclusion as it is taken in a standardized and reproducible head position to show the dental and skeletal relationships in a sagittal plane.

1.1.2 Tweed Analysis

Among the earliest orthodontists, Charles H. Tweed was one of the pioneers who analyzed lateral cephalograms and incorporated them into diagnosing and treatment planning cases. He conducted prospective clinical research, where he followed patient subjects over twenty-five years to study the relationship between facial harmony and the skeletal and dental relationships (C. H. Tweed, 1962).

In the Tweed analysis, the mandibular plane is defined as the line passing through the lower border of the mandible, which is the Gonion to Menton (Go-Me) line (Meza, 2016). Gonion is defined as the most posterior inferior point of the angle of the mandible and Menton is defined as the most inferior point of the mandibular symphysis as illustrated in *Table 1*. Hence, the mandibular incisor to the mandibular plane (IMPA) is defined as the angle formed by the long axis of the mandibular incisor to Go-Me. His study revealed that the "average non-orthodontic normal subjects" with facial balance and harmony had the mandibular incisor inclination of 90 degrees. In fact, the non-orthodontic normal subjects ranged from 85 degrees (most distally tilted mandibular incisor) to 95 degrees (most mesially tilted mandibular incisor) (C. H. Tweed, 1962). Moreover, as shown in *Table 1* and *Figure 1*, he concluded that the average Frankfort-mandibular angle (FMA) ranged from 16 to 35 degrees with 25 degrees as the norm, and Frankfort-mandibular incisor angle (FMIA) with 65 degrees as the norm (C. Tweed, 1954).

Cephalometric Measurements	Caucasian Norm	
	Mean	Range
FMA, degrees	25	16-35
FMIA, degrees	65	56-80
IMPA, degrees	90	85-95

Table 1 Caucasian Norms of FMA, FMIA, IMPA by Charles H. Tweed (C. H. Tweed, 1962)

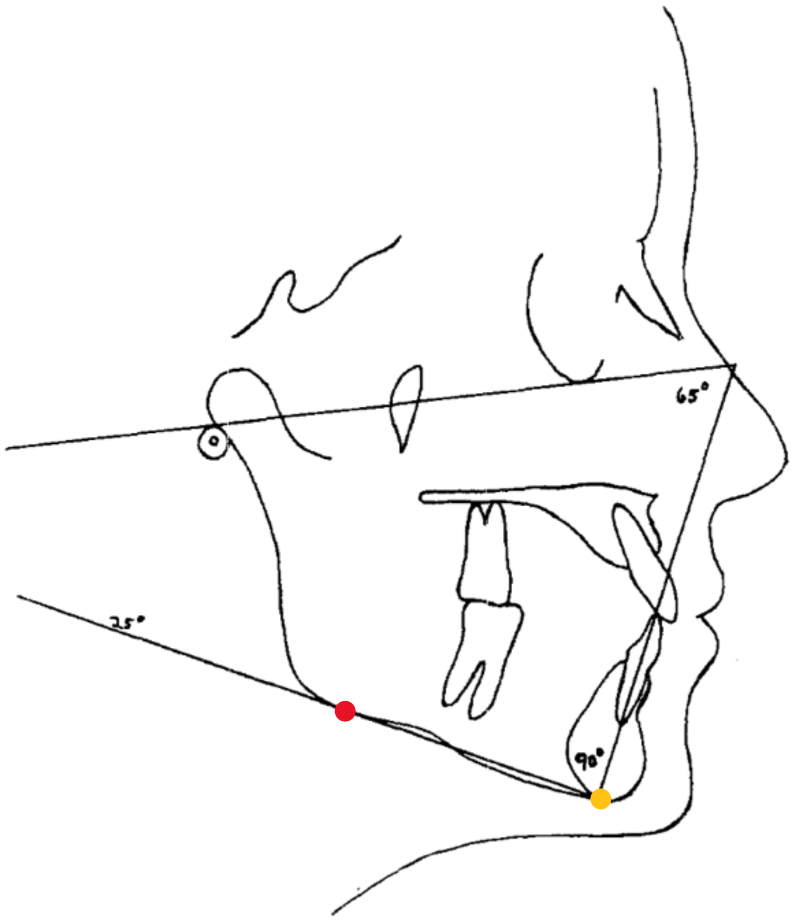

Figure 1 Illustration of Tweed Triangle (Priewe, 1962)
Red point: Gonion, Yellow point: Menton

1.2 Periodontal Evaluation via Clinical Attachment Level

1.2.1 Definition of Clinical Attachment Loss and Diagnosis of Periodontitis

Probing depth (PD) is defined as the distance from the gingival margin (GM) to the probe tip at the base of the gingival sulcus, while clinical attachment loss (CAL) is defined as the distance from the cemento-enamel junction (CEJ) to the probe tip at the base of the gingival sulcus (Lang & Lindhe, 2015). In other words, CAL provides an estimate of the periodontium that supports the tooth for its stability. For instance, in a periodontally healthy tooth, the gingival margin lies slightly coronal to the CEJ, therefore making the clinical attachment loss 0-1mm. In a periodontally compromised tooth, the gingival margin may follow the bone loss, which results in visible gingival recession, or significant probing depth from the gingival margin. Probing depth has been found to have a low positive predictive value for periodontal disease despite having a high negative predictive value in its absence (Isidor et al., 1984). CAL is a more clinically and diagnostically relevant measurement than the probing depth alone in examining a patient's periodontal health, as it incorporates variable factors such as gingival recession and gingival hyperplasia as depicted in *Figure 2*. This examination can be reliably done chairside and it is minimally invasive, compared to radiographic evaluations.

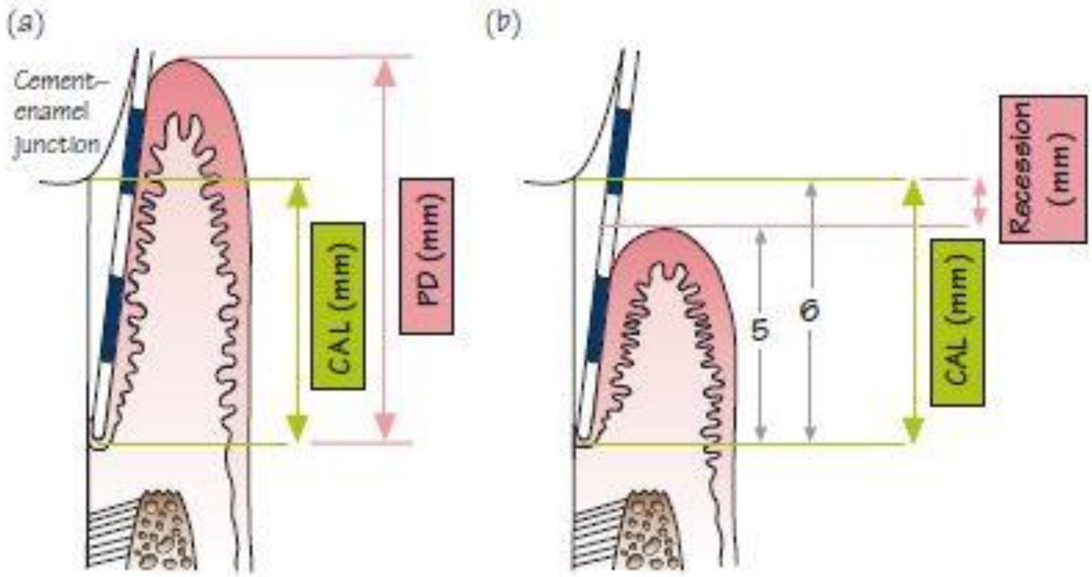

Figure 2 Examples of Clinical Attachment Loss (Periodontal Epidemiology, 2015)

(a) Clinical attachment loss (CAL) and probing depth (PD), (b) CAL and recession

According to the most recent guidelines by the American Academy of Periodontology (AAP), as shown in *Figure 3 and Figure 4*, diagnosing periodontitis requires two parts: staging and grading. The staging refers to the severity of the periodontitis and it is initially determined by interdental clinical attachment loss (CAL); it defines stage II periodontitis as CAL above 3mm but less than 5mm and stage III periodontitis as CAL above 5mm (*Chairside Guide to Periodontitis Staging and Grading*, 2017). The grading indicates the rate of progression and includes the risk factors such as smoking and diagnosis of diabetes.

PERIODONTITIS: STAGING

Staging intends to classify the severity and extent of a patient's disease based on the measurable amount of destroyed and/or damaged tissue as a result of periodontitis and to assess the specific factors that may attribute to the complexity of long-term case management.

Initial stage should be determined using clinical attachment loss (CAL). If CAL is not available, radiographic bone loss (RBL) should be used. Tooth loss due to periodontitis may modify stage definition. One or more complexity factors may shift the stage to a higher level. See **perio.org/2017wwdc** for additional information.

	Periodontitis	Stage I	Stage II	Stage III	Stage IV
Severity	**Interdental CAL** *(at site of greatest loss)*	1 – 2 mm	3 – 4 mm	≥5 mm	≥5 mm
	RBL	Coronal third (<15%)	Coronal third (15% - 33%)	Extending to middle third of root and beyond	Extending to middle third of root and beyond
	Tooth loss *(due to periodontitis)*	No tooth loss		≤4 teeth	≥5 teeth
Complexity	**Local**	• Max. probing depth ≤4 mm • Mostly horizontal bone loss	• Max. probing depth ≤5 mm • Mostly horizontal bone loss	In addition to Stage II complexity: • Probing depths ≥6 mm • Vertical bone loss ≥3 mm • Furcation involvement Class II or III • Moderate ridge defects	In addition to Stage III complexity: • Need for complex rehabilitation due to: – Masticatory dysfunction – Secondary occlusal trauma (tooth mobility degree ≥2) – Severe ridge defects – Bite collapse, drifting, flaring – < 20 remaining teeth (10 opposing pairs)
Extent and distribution	**Add to stage as descriptor**	For each stage, describe extent as: • Localized (<30% of teeth involved); • Generalized; or • Molar/incisor pattern			

Figure 3 Chairside Guide to Periodontitis Staging, 2017

PERIODONTITIS: GRADING

Grading aims to indicate the rate of periodontitis progression, responsiveness to standard therapy, and potential impact on systemic health.

Clinicians should initially assume grade B disease and seek specific evidence to shift to grade A or C.
See **perio.org/2017wwdc** for additional information.

	Progression		Grade A: Slow rate	Grade B: Moderate rate	Grade C: Rapid rate
Primary criteria *Whenever available, direct evidence should be used.*	Direct evidence of progression	Radiographic bone loss or CAL	No loss over 5 years	<2 mm over 5 years	≥2 mm over 5 years
	Indirect evidence of progression	% bone loss / age	<0.25	0.25 to 1.0	>1.0
		Case phenotype	Heavy biofilm deposits with low levels of destruction	Destruction commensurate with biofilm deposits	Destruction exceeds expectations given biofilm deposits; specific clinical patterns suggestive of periods of rapid progression and/or early onset disease
Grade modifiers	Risk factors	Smoking	Non-smoker	<10 cigarettes/day	≥10 cigarettes/day
		Diabetes	Normoglycemic/no diagnosis of diabetes	HbA1c <7.0% in patients with diabetes	HbA1c ≥7.0% in patients with diabetes

Figure 4 Chairside Guide to Periodontitis Grading, 2017

1.2.2 Etiology and Complications of Clinical Attachment Loss

The etiology of clinical attachment loss is multifactorial in nature. It may be due to plaque-induced periodontitis or oral habits and conditions. In other words, it can represent both active inflammatory disease and gingival recession from the non-inflammatory origin; and the progression of clinical attachment loss confirms the periodontal disease. The direct cause of inflammatory periodontitis is plaque accumulation and poor oral hygiene, but there are various confirmed risk factors such as patient's medical history, age, smoking habits, and various other genetic and environmental factors, which exacerbate periodontal disease susceptibility and progression (Lang & Lindhe, 2015). Non-inflammatory causes of loss of clinical attachment include traumatic occlusion, bruxism, abfraction from excessive brushing habits amongst other oral habits.

As a tooth loses its foundational periodontium, it can exhibit mobility, pathologic migration, and even loss of the tooth. Pathologic tooth migration (PTM) occurs when there is an imbalance of forces within the oral cavity, and the loss of attachment makes teeth more vulnerable to extrinsic forces such as bruxism, tongue thrust, lip habits, sucking habits, and playing of wind instruments (Towfighi et al., 1997). Intrinsic factors include pressure from inflamed tissue and periodontal pockets and loss of opposing or adjacent teeth without replacement (Brunsvold, 2005). Hence, the prevalence of pathologic migration of teeth increases with the severity of the periodontal disease. PTM can be an esthetic concern or the first change that the patient notices and is a common complaint that motivates the patient to seek dental care (Khorshidi et al., 2016). According to Khorshidi et al, PTM is relatively common among patients with moderate (stage II) to severe (stage III) periodontitis. The prevalence of PTM is significantly associated with bone loss and gingival inflammation, based on a cross-sectional epidemiological study (Martinez-Canut et al., 1997). Brunsvold also corroborates that while the etiology of PTM is multifactorial, bone loss appears to be the major feature (Brunsvold, 2005).

PTM can be exhibited in multiple forms including but not limited to mesial or distal shift, flaring facially or lingually, extrusion, and intrusion. Yet, there is a paucity of research on PTM as it is difficult to compare before and after PTM and the etiology can be complex. Existing research to determine PTM mostly relies on patient's subjective evaluation that can include recall bias.

1.3 Relationship between Orthodontic Proclination and Attachment Loss

In non-extraction orthodontic treatments, leveling and aligning tend to increase the IMPA as it levels the curve of Spee and alleviates crowding, leading to an increase in arch circumference aided by proclination of teeth. There have been several studies that evaluate whether the orthodontic movement of teeth is associated with clinical attachment loss, mainly gingival recession. Yet, the results seem controversial.

In a systematic review that comprised of two case-control trials, there was no evidence of an association between proclination of incisors and gingival recession (Tepedino et al., 2018). Of the two studies, Allais and Melson claimed that the occurrence of a recession was higher in the orthodontic treatment group compared to the untreated group, but the difference was not clinically significant (Allais D and Melsen, 2003). The other study looked at the difference in gingival recession in an extraction treatment group and non-extraction treatment group and found no difference (Villard and Patcas, 2015). Both studies relied on cast measurements of clinical crown length before and after treatment to assess gingival recession; an increase in clinical crown length measurement signifying an increase in gingival recession. A follow-up study observed the treated group five years after the treatment and claimed that the mandibular incisor proclination did not increase the risk of gingival recession (Renkema and Navratilova, 2015).

On the other hand, Vassalli claimed that the more proclined teeth and teeth with movements out of the osseous envelope have a more severe gingival recession in a systematic review, in which 17 articles were included in the analysis (Joss-Vassalli et al., 2010.). In an animal study with adult monkeys, where the investigator could control the facial movement of the incisors, the gingival margin was significantly displaced apically and connective tissue was lost (Wennström et al., 1987). Yet, in a study with multiple variables that contribute to gingival recession, notable significance was found between the width and biotype of keratinized gingiva and gingival recession, further complicating the relationship between proclination and attachment loss (Melsen B and Allais, 2005).

Furthermore, another systematic review suggested orthodontic treatment may not only affect the soft tissue but also the hard tissue periodontium. It identified weak evidence that the orthodontic treatment was associated with 0.03mm of gingival recession, 0.13mm of alveolar bone loss, and 0.23mm of increased pocket depth compared to the control that did not receive orthodontic treatment, thereby asserting small detrimental effects on the periodontal health (Bollen et al., 2008). It is unclear whether the orthodontic treatment caused inflammatory reactions enhanced by poor oral hygiene that led to attachment loss, causing proclination or the actual process of proclining teeth prompted attachment loss.

2.0 Purpose of Present Study

As orthodontic treatment tends to increase the mandibular incisor inclination (IMPA), there have been multiple studies that examine post-orthodontic IMPA and periodontal involvement mostly limited to gingival recession via cast or clinical examination. However, there has not been a study where the mandibular incisor inclination is evaluated regarding the periodontal status that includes not only the gingival recession but also the loss of clinical attachment level (CAL), which is defined as the distance from cemento-enamel junction to the probe tip, giving more objective evaluations than pocket probing depth.

In this study, the periodontally unhealthy group is compared with the periodontally healthy group to investigate whether the clinical attachment loss (CAL) in mandibular incisors is associated with pathologic tooth migration, specifically labial flaring, as noted by the incisor to mandibular plane angle (IMPA) in cephalometric analysis.

3.0 Methods

3.1 Overview

This was a single-visit study. All patients were recruited from the University of Pittsburgh School of Dental Medicine, specifically the orthodontics and periodontics departments during the regular clinical hours during the week. The investigator reviewed the electronic health records (Axium) as part of clinical care and for the eligibility of patients to be enrolled in the study. The periodontally healthy group, defined as patients without periodontal diagnosis and without visible gingival recession in the mandibular anterior region, was retrieved from the orthodontic patient pool and the periodontally unhealthy group, defined as patients with various active periodontal diagnoses and visible gingival recession in the mandibular anterior region, was retrieved from the periodontal patient pool. Data from both groups were extracted prior to any active orthodontic or periodontal treatment that may affect the mandibular incisor inclination.

3.2 Sampling

The intended statistical test was the 2-sample t-test. Sample size calculation was performed using the IMPA norm of 90 with a standard deviation of 5 from the literature. A meaningful difference of two standard deviations (90-100) yielded 6 patients in each group and a meaningful difference of 1.5 standard deviations (90-97.5) yielded 9 patients in each group. However, this calculation is not including confounding factors such as age, sex, etc. As the patients are enrolled in a consecutive manner to minimize selection bias, confounding factors were analyzed via regression after data collection. The alpha level was set at 5% and the power was set at 80%.

3.3 Inclusion and Exclusion Criteria

Inclusion criteria were adult (21+ years old) Caucasians as the study was using the Caucasian norm for the IMPA, all four mandibular incisors present, and mostly dentate from the right first molar to the left first molar on the mandible (1-2 teeth missing in the mandible). For patients recruited from the orthodontics department, they did not have underlying active periodontitis nor visible clinical attachment loss. For patients recruited from the periodontics department, they were diagnosed with active periodontitis with varying severity with visible clinical attachment loss. Exclusion criteria include systemic diseases, craniofacial involvements or syndromes, pregnancy, and skeletal Class III that may have compensatory effects on dentitions.

3.4 Data Gathering

Once potential subjects were identified, the investigators approached the individuals at their next clinical appointment and introduced the study. The potential subjects were asked to self-identify their ethnicity as the IMPA is a measurement based on Caucasian standards. When the potential subjects are women of childbearing age, they were asked to self-identify whether they are or think they may be pregnant. Patient consent to be a part of the study was obtained.

For the periodontally healthy group, recruited from the orthodontics department, cephalometric radiographs were retrieved from the electronic health records as they are routinely taken for orthodontic diagnosis and treatment planning. After the consent, the mandibular incisors were periodontally probed for the calculation of clinical attachment loss (CAL) prior to any active orthodontic treatment. Periodontal probing was done according to the University standards by the primary investigator using the Williams marking probe.

For the periodontally unhealthy group, recruited from the periodontics department, periodontal charts were retrieved from electronic health records. After the consent, a cephalometric radiograph was taken at the Department of Radiology by licensed and qualified personnel according to the University standards.

3.5 Outcome Measures

Clinical attachment loss was calculated via the sum of probing depth and the distance from the gingival margin to cemento-enamel junction (CEJ). Six sites were measured per tooth, and they were mesio-facial, middle-facial, disto-facial, mesio-lingual, middle-lingual, and disto-lingual as shown in *Figure 5*. All measurements were rounded to the nearest whole number. Then, the average of mesio-facial, middle-facial, and disto-facial was calculated to yield the average facial measurement and the average of mesio-lingual, middle-lingual, and disto-lingual was calculated to yield the average lingual measurement. The IMPA was defined as the angle formed by the long axis of the mandibular incisor and mandibular plane, defined as Gonion (Go) to Menton (Me). Two lines were drawn to represent the long axis of the mandibular incisor and the mandibular plane respectively on MIPACs electronic cephalometric radiograph. Then, the angle formed by the two lines was measured using a digital protractor on MIPACs for the IMPA value as shown in *Figure 6* below.

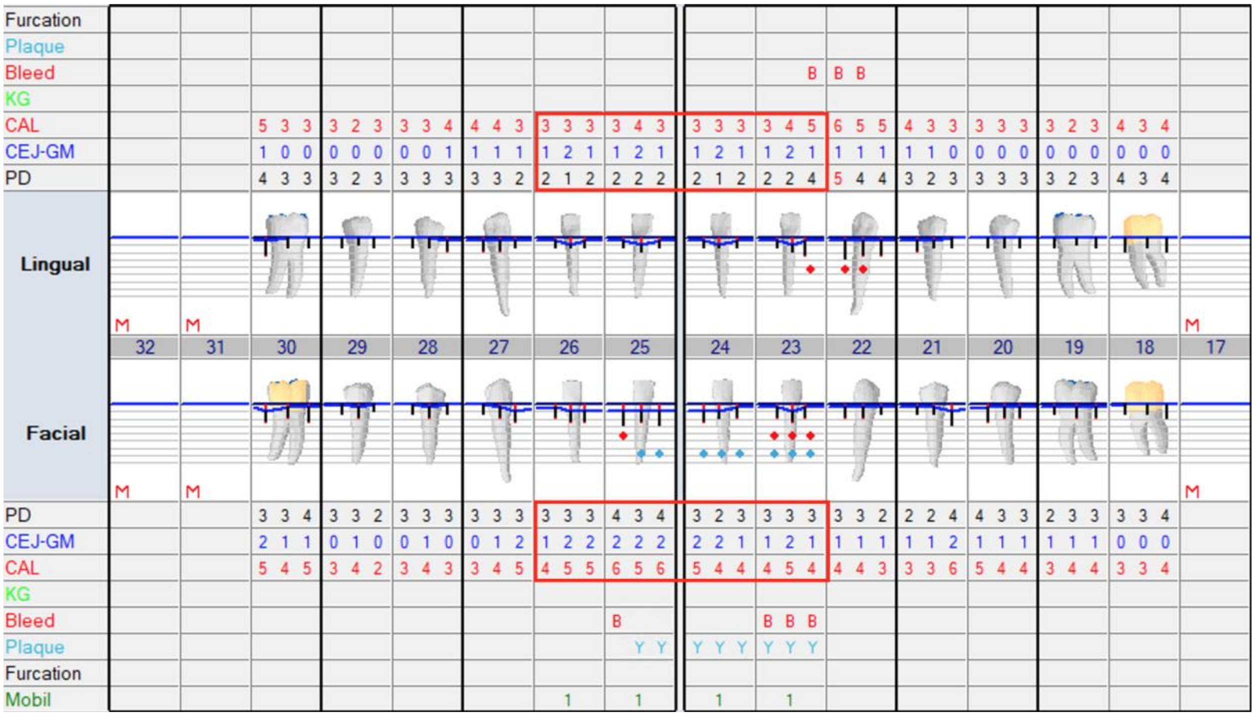

Figure 5 Example of Obtained Data (Red Box) from Perio Chart

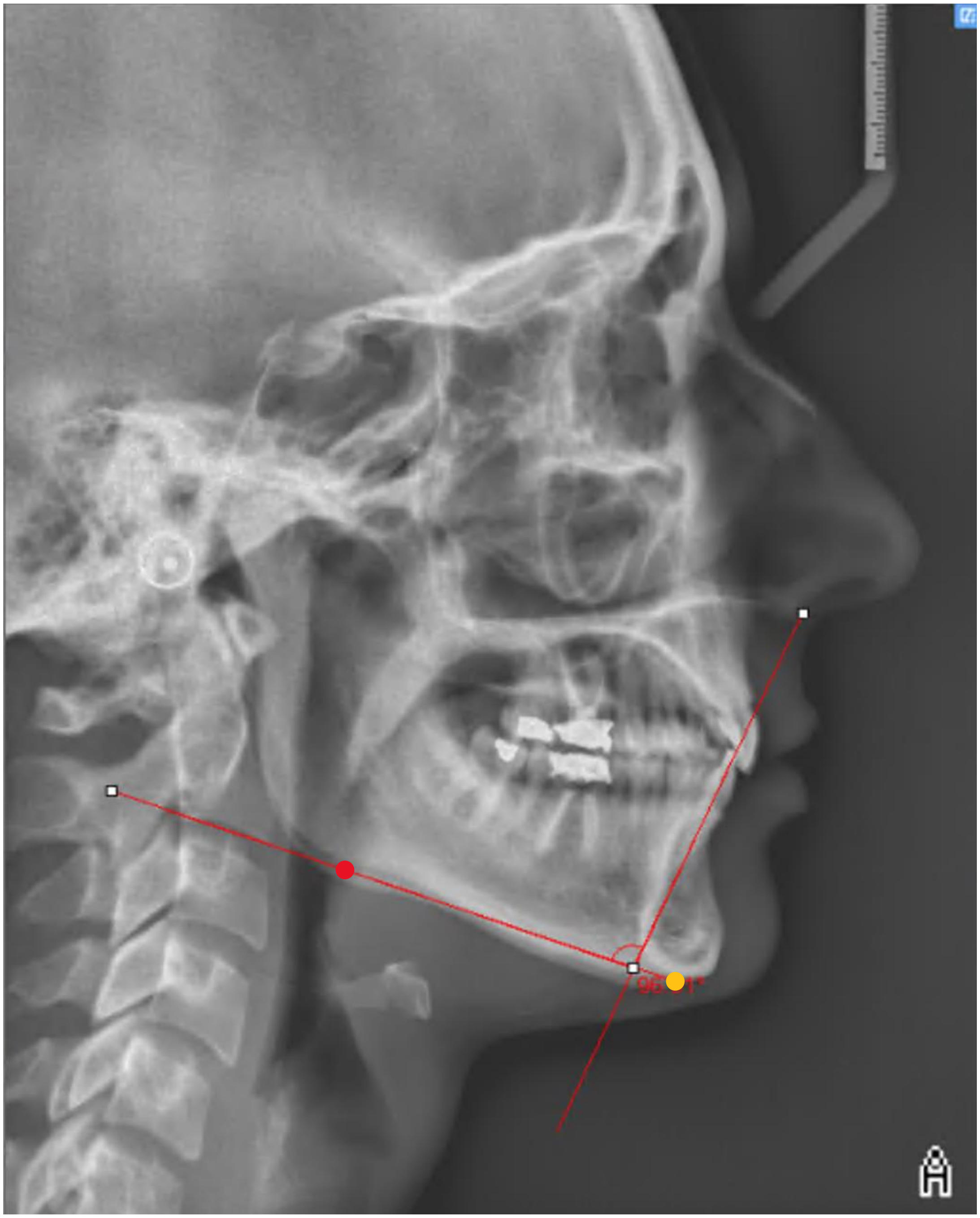

Figure 6 Example of IMPA measurement using MIPACs
Red point: Gonion, Yellow point: Menton

3.6 Statistical Analysis

All statistical analyses were performed using the Stata software. Two sample t-test was performed between the two groups to compare the average CAL and IMPA. Regression was performed to adjust for age and sex as confounding factors. The significance value of $p<0.05$ was applied for all comparisons.

4.0 Results

A total of 20 consecutive patients were enrolled in this cross-sectional study. The patient demographics are listed in *Table 2.* In the periodontally healthy group, recruited from the orthodontics department, there were 4 male and 6 female patients with a mean age of 37.7 years. In the periodontally unhealthy group, recruited from the periodontics department, there were 5 male and 5 female patients with a mean age of 54.4 years. Both groups had a wide range in age, 24 to 60 years old in the periodontally healthy group and 22 to 70 years old in the periodontally unhealthy group. Periodontal diagnoses of all enrolled subjects were identified and listed in *Table 3.* The results of probing depth (PD), clinical attachment loss (CAL), and incisor to mandibular plane angle (IMPA) are listed in *Table 4.*

Group	Periodontally Healthy	Periodontally Unhealthy
Number of patients	10	10
Age, years (mean ± standard deviation)	37.7 ± 14.2	54.4 ± 17.2
Age, range (min, max)	(24, 60)	(22, 70)
Sex distribution: Male/ female	4/6	5/5

Table 2 Patient demographics for the periodontally healthy and the periodontally unhealthy groups

Group	Patient #	Periodontal Diagnoses		
		Sites	Stages	Grades
Periodontally Healthy	1-10	No periodontal diagnoses (Patients were evaluated and cleared periodontally to receive orthodontic treatments)		
Periodontally Unhealthy	1	Generalized	III	B
	2	Generalized	II	C
	3	Localized	II	A
	4	Generalized	II	B
	5	Localized	II	A
	6	Generalized	III	B
	7	Generalized	III	B
	8	Generalized	II	B
	9	Generalized	IV	B
	10	Generalized	III	B

Table 3 Periodontal Diagnoses of Study Subjects

Classification	Patient #	Age, years	Sex	L2-2*, mm				L1-1*, mm				IMPA, degrees
				Facial		Lingual		Facial		Lingual		
				PD	CAL	PD	CAL	PD	CAL	PD	CAL	
Periodontally Healthy	1	34	M	1.67	0	2	0	1.67	0	2	0	84.3
	2	31	F	2	0	1.67	0	2	0	1.67	0	103.25
	3	60	F	2.08	0.42	1.83	0.5	2	0.33	1.67	0.67	97.77
	4	59	M	2.08	0.42	2.25	1	1.83	0.17	2	0.67	96.3
	5	28	M	2	1.17	2.08	0	1.83	1	2.17	0	91.42
	6	24	F	1.92	0	1.75	0	1.83	0	1.67	0	91.43
	7	54	M	1.92	0.42	2.16	0.33	1.83	0	2.17	0.5	99.36
	8	28	F	2	0.33	2	0.33	2.33	0.67	2.33	0.67	96.91
	9	25	F	1.83	0.17	1.83	0.5	1.67	0.83	1.67	0.17	94.61
	10	34	F	1.75	0.5	1.83	0.5	1.67	0.83	1.67	0.17	90.92
Average		37.7		1.925	0.343	1.940	0.234	1.882	0.317	1.902	0.268	94.627

Periodontally Unhealthy	1	59	F	2.25	3.93	2.17	3.25	2.16	3.75	2.33	3	87.17
	2	67	M	2.41	5.17	2.83	4.17	2.5	4.33	2.83	4.17	95.88
	3	22	F	1.67	3.17	1.67	1.89	1.67	3	1.67	2	99.41
	4	61	M	1.67	3	1.67	4.08	1.67	3	1.67	4.67	81.54
	5	26	M	1.67	3.33	1.67	0.67	1	3	1.67	0.67	106.21
	6	61	F	2.25	3.33	2.5	3.25	2.16	3.67	2.16	3.17	89.6
	7	70	M	2.33	4.5	2.33	5.5	3.17	4.33	1.83	3.17	107.04
	8	70	F	1.25	3.17	1.5	2.33	1.33	3.83	1.5	2.67	98.25
	9	45	F	3	3.5	2.5	2.67	3.67	4.17	2.67	2.83	108.53
	10	59	M	2.75	4.67	1.83	3.42	3	5.5	1.83	3.83	93.7
Average		54.4		2.125	3.777	2.067	3.123	2.233	3.858	2.016	3.018	96.733

Table 4 Probing depth (PD), clinical attachment loss (CAL), and incisor to mandibular plane angle (IMPA) for both the periodontally healthy and the periodontally unhealthy groups

***L2-2: mandibular central and lateral incisors, L1-1: mandibular central incisors**

		Periodontally Healthy	Periodontally Unhealthy	T-test (p)
Age, years (SD)		37.7 (14.2)	54.4 (17.2)	0.0294*
Average PD, mm (SD)	L2-2 Facial	1.925 (0.137)	2.125 (0.547)	0.2772
	L2-2 Lingual	1.940 (0.188)	2.067 (0.458)	0.4276
	L1-1 Facial	1.882 (0.192)	2.233 (0.855)	0.2215
	L1-1 Lingual	1.902 (0.261)	2.016 (0.469)	0.5043
Average CAL, mm (SD)	L2-2 Facial	0.343 (0.351)	3.777 (0.753)	0.0000*
	L2-2 Lingual	0.234 (0.325)	3.123 (1.340)	0.0000*
	L1-1 Facial	0.317 (0.380)	3.858 (0.781)	0.0000*
	L1-1 Lingual	0.268 (0.318)	3.018 (1.129)	0.0000*
IMPA, degrees (SD)		94.627 (5.329)	96.733 (8.992)	0.5321

Table 5 Comparison of average values between the two groups

*** denotes statistical significance (p<0.05)**

Although the periodontally unhealthy group had greater average probing depths on all incisors facially and lingually, the difference was not statistically significant as shown in *Table 5*. The two groups were significantly different regarding CAL on the facial and lingual of the mandibular central incisors (p=0.0000). The periodontally unhealthy group had an average IMPA that was 2.106 degrees greater than the periodontally healthy group, yet the difference was not statistically significant (p=0.5321). The correlation between IMPA and facial CAL of the mandibular central incisors, as defined as L1-1 facial, was adjusted for age and sex, as the two groups had significantly different mean age and the sex ratio was not matched. Following the age and sex adjustment, the correlation stayed statistically not significant (p=0.422) and concluded that age (p=0.668) and sex (p=0.768) was not confounding factors.

When the CAL and age were regressed for all 20 subjects, there was a significant association (p=0.013), and this is corroborated by basic literature as age is a risk factor for developing periodontal disease. Sex was regressed in the same manner, but it was not related to increased CAL (p=0.564).

5.0 Discussion

Previous systematic reviews suggested that the photos and dental casts from retrospective studies are not the ideal methods to measure gingival recession (Tepedino et al., 2018). Ideal measurement for bone loss would incorporate a three-dimensional imaging technique such as cone beam computerized tomography. However, to minimize radiographic exposure, a chair-side probing for CAL was chosen. Participating patients had all four mandibular incisors and maxillary central incisors present to rule out any pathologic tooth migration of the mandibular central incisors due to missing adjacent or opposing teeth and to demonstrate that the clinical attachment loss was mostly generalized in the anterior mandible. None of the patients had greater than two mandibular posterior teeth missing from the left first molar to the right first molar to ensure stable occlusion with no vertical collapse.

The periodontally unhealthy group had an average CAL of 3.858mm on the mandibular central incisors facially and 3.018mm lingually, whereas the periodontally healthy group had an average CAL of 0.317mm on the mandibular central incisors facially and 0.268mm lingually. The two groups had significantly different CAL measurements as intended as part of patient recruitment. The periodontally unhealthy group had slightly higher average probing depths compared to the periodontally healthy group, but the difference was not statistically significant. Hence, the greater average CAL in the periodontally unhealthy group can be attributed to gingival recession rather than deep pockets. The facial CAL of the mandibular central incisors (L1-1 facial) was chosen as the independent variable as the IMPA traces mandibular central incisors and the facial attachment loss tends to be greater and more common than the lingual loss, as corroborated by the data in *Table 4*. The average IMPA, the dependent variable, for the periodontally unhealthy group was 96.733 degrees, whereas for the periodontally healthy group was 94.627 degrees and they were not significantly different. Therefore, based on the current data, there was no association between CAL and IMPA.

Age was a risk factor for the CAL but not for the IMPA and sex was not a risk factor for either of the variables. As the literature corroborates, gingival recession is a cumulative result of trauma and periodontitis and thus, the prevalence and severity increase with age (Newman et al., 2019). There are multiple etiologies for gingival recession. The junctional epithelium may have migrated apically following trauma or periodontal disease or the tooth may have supra-erupted following attrition without the gingival margin following the eruption, exposing the root surface. Since the clinical attachment loss was measured at a single point in time, the etiology of the recession could not be identified and standardized.

Further limitations of the study include that the patient groups could not be demographically matched. The samples were collected in a consecutive manner to avoid selection bias. In the periodontally unhealthy group, the enrolled subjects had varying severity and duration of periodontitis and the patients' inflammatory level at the time of data collection is unknown as this was a cross-sectional study. Additionally, although the patients with systemic disease, craniofacial involvements or syndromes, and pregnancy were excluded, other periodontal risk factors were not recorded such as patients' oral hygiene and plaque index, brushing habits, smoking, and others that could have affected attachment level and dental proclination.

The study has limited generalizability as the study groups only included adult Caucasian patients to eliminate confounding factors such as dentoalveolar growth, passive eruption, and different ethnic norms for cephalometric measurements.

Although based on the collected data, the association between CAL and IMPA is minimal to nonexistent, it is important to note that CAL only measures the vertical bone and attachment loss. Recent research alludes that the labial plate thickness of the alveolar bone and gingival biotype that measure the horizontal hard and soft tissue may play a more significant role in CAL than IMPA (Gorbunkova et al., 2016). Similarly, in a retrospective cross-sectional study, there was a marked cortical bone loss after the mandibular incisor proclination, especially in patients with a low bone thickness or density (Filipova et al., 2019). Patients with low labial plate thickness and minimal keratinized gingiva may be more prone to pathologic migration as there is less resistance in the direction of tooth movement. Therefore, while the null hypothesis was accepted for the current study, new hypotheses may be revised as follows: (1) Increased CAL (vertical attachment loss) *with decreased labial plate thickness and thin gingival biotype* is associated with increased IMPA, (2) Increased IMPA *with decreased labial plate thickness and thin gingival* biotype is associated with increased CAL. Further research is needed to clarify the relationship between susceptibilities of alveolar bone loss and incisor proclination.

6.0 Conclusion

(1) No significant association was found between CAL and IMPA. Age and sex were not confounding factors.

(2) Age was a risk factor for CAL but not for IMPA and sex was not a risk factor for either of the variables.

(3) Further research is needed to clarify the relationship between susceptibilities of alveolar bone loss and incisor proclination.

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