The relationship between occlusal and skeletal characteristics and lower incisor wear

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Dedication

To my parents,
for always supporting and believing in me.

Abstract

The aim of the present study was to investigate if a relationship exists between certain skeletal and dental characteristics and the amount of incisal wear of mandibular incisors. In this retrospective, cross-sectional study, an index specifically designed to measure incisal wear on dental study casts was used to examine mandibular incisal wear in 215 subjects using pre-treatment records from the University of Minnesota orthodontic clinic. Multiple linear regression analysis (R2 = 0.3886) resulted in a regression model with five independent variables. Age, gender, incisor irregularity, UI-SN and Sn-GoGn were all shown to be significantly associated with increased mandibular incisal wear. Based on these findings, a prudent clinician may be able to use dental and skeletal relationships to better predict patients who are at a risk for increased tooth wear.

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INTRODUCTION

Tooth wear is a physiologic process that occurs through a variety of mechanisms[1]. Erosion, abrasion and attrition all contribute to the wear of teeth. It has been shown that the amount of tooth wear increases with age[2] and several authors have reported a trend of increasing tooth wear in younger patients[3-6]. Loss of tooth substance due to attrition is a condition that can lead to significant long-term effect on one's dental health which includes loss of vertical dimension and can induce parafuction[7]. Due to its irreversible nature, early diagnosis of accelerated or pathological forms of attrition are of significant importance for researchers and clinicians.

The term "tooth wear" is defined as loss of dental hard tissue by a chemical or mechanical process not involving bacteria[1]. This overarching term includes three processes that are thought to contribute to tooth wear: erosion, abrasion and attrition [2,3]. Erosion is defined as the superficial loss of dental hard tissue as a result of a chemical process not involving bacteria[4]. This has been shown to occur in persons with alcoholism, bulimia, GERD, morning sickness, or high intake of acidic foods [5-7]. Abrasion is defined as the physical wear of the tooth surface by something other than another tooth[8]. Lastly, attrition refers to loss of tooth structure caused by tooth-to-tooth contact. This term includes both parafunctional contact *(i.e.*, bruxism), as well as functional contact (*i.e.*, mastication)[9,10]. Due to the difficulty in differentiating between these three conditions using only stone models, this study will use the term "incisal wear", to indicate general loss of tooth structure from the incisal edge of mandibular incisors.

The term occlusal wear is defined as the loss of tooth structure on opposing units or surfaces as a result of attrition or abrasion[11]. This term differs from "tooth wear" due to its exclusion of the process of erosion. It is recognized that occlusal wear is a universal process and when occurring in a mild form, is considered a physiologic process[12]. The majority of individuals fall into this category[13-15]. However, the prevalence of occlusal wear can vary greatly within a population[16], with some individuals demonstrating cases of severe wear [17]. Severe occlusal wear can have an impact on oral pain, dental appearance, masticatory function[10] and has been shown to induce parafuction[18]. Due to its irreversible nature, early detection and treatment has been the focus of previous research[19-24].

A number of previous studies have investigated the prevalence of tooth wear and examined various factors associated with different tooth wear patterns[2,9,10,23,25-28]. These studies have investigated the relationship between tooth wear and a number of variables including occlusal characteristics[9,23,25,26], age[9,25,26], TMJ symptomatology[25,23], orthodontic treatment[23] and gender[25]. Others studies have investigated a potential relationship between tooth wear and various cephalometric measures[6,22,2930], salivary characteristics[22,29,31], bite force[6,22,29,30], parafunctional habits [32,33] and diet[2,8,27]. The results of these studies, however, appear contradictory regarding the association between a number of factors and tooth wear and at this time, clear data describing general trends in tooth wear patterns is lacking[34]. This may be due to the multifactorial nature of tooth wear. However, if a better understanding of the factors associated with tooth wear can be achieved, it could help clinicians with more effective and timely interventions[27].

Therefore, the aim of the present study was to investigate if a relationship exists between certain skeletal and dental characteristics and the amount of incisal wear of mandibular incisors. It was designed to measure mandibular incisal wear on a variety of pre-treatment records of patients seeking orthodontic care at the University of Minnesota. If certain characteristics are found to lead to an accelerated tooth wear pattern, then practitioners may be better able to identify “at risk” patents and recommend 1) when to begin treatment and 2) the best course of treatment to minimize future tooth wear.

It was hypothesized that 1) specific dental and skeletal characteristics can predict an accelerated pattern of tooth wear and 2) patient age and gender will have a significant effect on the severity of mandibular incisal wear as measured by the Incisal Wear Index[26].

REVIEW OF THE LITERATURE

A review of current literature reveals several methods used to assess tooth wear. Authors have used clinical examination[35,36], photographs[19] and dental casts[9,23,25] to measure tooth wear. In addition, computer-aided methods have been used to score tooth wear[22]. Unfortunately, these methods have been reported to underestimate patterns of tooth wear[9]. Three-dimensional scanning systems, which promise to improve the accuracy of tooth wear measurements in both clinical and laboratory settings have been reported to be in development[37]. However, at the moment of this report, no research demonstrating the ability of these three-dimensional systems can be found in the literature.

The vast majority of authors investigating tooth wear have used dental casts to assign graded scores based on severity of wear[9,10,23,25,26,38]. One of the most commonly used tooth wear indices has been developed by Smith and Knight[39]. This index, the Tooth Wear Index (TWI), has been used repeatedly, with slight modifications, by many researchers[40-42]. The TWI uses stone casts and assigns a graded score (0-3) to each tooth based on the presence of specific wear characteristics, including presence of wear facets and depth of dentin exposure. A different index, which focuses on incisal wear, has been presented by Silness *et al*[26]. Their incisal wear index (iWi) uses a graded scale (0-3) based on incisal wear patterns observed on dental casts. Both, the TWI and iWi were designed to record levels of tooth wear regardless of the cause and have proved to be reliable as indicated by good to excellent kappa values[9,10,26,28]. An independent study by Wetselaar *et al*[43], determined that occlusal/incisal tooth wear could be scored using dental casts with a reliability between fair-to-good and excellent.

Numerous studies have investigated the relationship between tooth wear and a number of variables including, occlusal characteristic[9,23,25,26] , age[9,25,26], TMJ symptomatology[25], orthodontic treatment[23] and gender[25]. These studies have presented mixed results regarding the association between a number of occlusal factors and dental wear. Knight *et al.*[9] studied the relationship between various occlusal characteristics and tooth wear of the entire dentition in 223 subjects. The study included assessment of Angle class, overjet, overbite, posterior crossbite, anterior crossbite and open bite. Of all the occlusal parameters studied, only overbite and open bite were shown to have a significant association with tooth wear. Silness *et al.*[26] conducted a study, which focused on the relationship between incisal wear and the degree of vertical overbite and horizontal overjet. The results were in agreement with those of Knight *et al.* and the authors concluded that an increase in overbite is a clinical predictor of wear on maxillary and mandibular incisors. These results were confirmed by other clinical studies which have also shown that a deep overbite may induce pronounced attrition of anterior teeth[44]. In contrast, it has been shown that overjet alone is not significantly associated with tooth wear[9,26]. However, Silness *et al.*[26] found that when overjet (OJ) is considered in combination with overbite (OB) in an OB/OJ ratio, a statistically significant correlation exists with incisal wear.

The relationship between tooth wear and Angle classification has been suggested in various studies. For instance, Johansson *et al.*[45] and Cunha-Cruz *et al.*[27], both reported a significant relationship between Angle class and tooth wear. In addition, a study which investigated class I and class II division 2 patients using a modified version of the TWI, it was found that the two groups had significantly different tooth wear patterns[10]. The class I group had greater wear on the incisal surface of the maxillary incisors and canines, while the class II division 2 group showed significantly more wear on the labial surface of the mandibular incisors, the occlusal surfaces of the maxillary and mandibular premolars and the buccal surface of the mandibular premolars and first molars. The authors attributed their findings to differences observed in disclusion between various interocclusal arrangements. These findings were supported by Seligman *et al*.[25], who also reported distinct tooth wear patterns between the various Angle classes.

Other occlusal characteristics that have been investigated include anterior open bite and alignment of anterior teeth. A significant relationship between open bite and tooth wear has been reported in previous studies[9,27]. Subjects with anterior open bite have been shown to have an increase in posterior occlusal wear[9] and a decrease in incisal wear[27]. When investigating anterior alignment, Berge *et al.*[28] reported that participants with well-aligned teeth had more severe wear of the anterior teeth when compared to those with various degrees of non-alignment. This result was consistent with other findings[29] which suggest that less crowding is correlated with higher wear.

Another factor that seems to have an effect on tooth wear is age. Several studies have found that tooth wear increases with age[9,34,45-47]. For instance, Bernhardt *et al.*[2] conducted a tooth wear study which evaluated many occlusal and sociodemographic factors. They reported that age appears to be the most important in the progression of occlusal wear. A study by Hugoson *et al*.[46] evaluated the degree of occlusal or incisal wear in individuals of seven different age groups. When comparing the results from the different age groups, they not only found an increase in the severity of wear, but also an increase in the number of teeth with incisal or occlusal wear. The results of these studies were further substantiated in a systemic review, which determined that age and tooth wear are correlated significantly on both the subject and individual tooth level[34]. In contrast, Seligman *et al.*[25] were unable to demonstrate a significant relationship between age and tooth wear in a sample of 222 subjects. However, due to the narrow age range[48] of their subjects, the authors suggest the relationship between age and tooth wear would be more apparent had they included subjects with a broader age range.

Another factor which has received significant attention is the relationship between gender and tooth wear. Numerous studies have reported sex differences in tooth wear, with males having significantly greater wear than females[2,9,23,25,27,34]. In contrast, a study conducted by Johansson *et al*.[14] found little sexual dimorphism in the occlusal wear of Saudis. However, in a more recent study conducted on a western population[45], the same authors reported a significantly lower prevalence of severe wear in females when compared to males. These results may suggest a variation in wear patterns across diverse populations.

The relationship between cephalometric measurements and tooth wear has been addressed in a limited number of investigations. For instance, lateral cephalograms were used to study the relationship between craniofacial morphology and occlusal tooth wear in an adult population with advanced wear[6]. In this study, a reduced mandibular plane angle was found to be significantly related to increased occlusal wear. This finding is consistent with another study, which reported the mandibular plane angle in subjects with advanced attrition to be about 8^o smaller than the general population[49]. In contrast, two other studies were unable to demonstrate a significant relationship between increased wear and a reduced mandibular plane angle[6,22,29]. When evaluating gonial angle, a negative correlation with anterior tooth wear was found by Nystrom[22] and Kiliaridis[6]. These investigations also included an evaluation of bite force and both reported a higher biting force to be significantly associated to increased occlusal wear. Based on the combination of significant findings between tooth wear, cephalometric measures and bite force, both authors suggest that an interrelationship between muscle force, occlusal wear and dentofacial structure exists. Cephalometic measurements of incisor position and inclination have also received attention in previous studies. For instance, Johansson *et al*.[29] found that increased wear was correlated with retroclination and posterior position of maxillary incisors and a greater interincisal angle. An increased interincisal angle was also found in the severe attrition group studied by Krogstad and Dahl[49]. In contrast, other published reports found no significant relationship between incisal inclination or position[6,22].

The importance of recognizing and attempting to treat patients with accelerated tooth wear is evident. Occlusal wear can have an impact on oral pain, dental appearance, masticatory function[10] and has been shown to induce parafuction[18]. This, in turn, can lead to significant esthetic, functional and financial cost to those who experience severe tooth wear. In addition, it has been demonstrated that attrition is an ongoing process[9]. A child's predisposition to tooth wear represents a trait that can continue into adulthood[9], which demonstrates the clinical importance of predicting which patients are at risk for severe tooth wear at an early age in order to attempt to intervene and reduce the risk of further tooth wear in the permanent dentition.

From the current literature devoted to tooth wear, clear conclusions are difficult to obtain due to the variability in reported results. The present study will re-examine many of the relationships noted above in an effort to clarify the association between several occlusal and cephalometric characteristics and dental wear. In addition, the majority of previous studies have evaluated wear across the entire dental arch. This has led to conflicting results, as anterior and posterior wear patterns have been shown to be significantly different[23,46]. The current study will focus only on incisal wear of the mandibular incisor in order to describe more specific and consistent results.

*Due to the difficulty in differentiating between erosion, abrasion and attrition using only stone models, the present investigation will use the term “incisal wear”, to indicate general loss of tooth structure from the incisal edge of mandibular incisors.

AIMS

1) To grade the severity of mandibular incisal wear on study models using the Incisal Wear Index (iWi).
2) To measure specific dental characteristics using study models and lateral cephalometric radiographs.
3) To determine if specific dental and skeletal characteristics can predict an increase in mandibular incisal wear.
4) To determine any correlation between patient age and gender and the amount of mandibular incisal wear.
5) To identify a subgroup of subjects who experience an accelerated pattern of mandibular incisal wear.
6) To determine any correlation between subjects with an accelerated pattern of mandibular incisal wear and specific dental and skeletal characteristics.
7) To identify relationships between incisal wear and occlusal and skeletal characteristics that may become the focus of more specific and in-depth studies in the future.

HYPOTHESIS

1) Specific dental and skeletal characteristics can predict an increase in mandibular incisal wear. This hypothesis is derived from a thorough review of the literature.

2) A positive correlation exits between patient age and amount of incisal wear. This hypothesis is based on the assumption that tooth wear is a continuous process.

3) A significant correlation will be made between dental and skeletal characteristics and mandibular incisal wear in an “accelerated wear” subgroup.

MATERIAL AND METHODS

Subjects

The data was derived from a collection of pre-treatment orthodontic records of patients of all ages seeking orthodontic treatment at the University of Minnesota orthodontic clinic. Subjects (n=215) were selected for inclusion in the study based on the following criteria: (1) pre-treatment stone dental casts available with wax bite, free of any obvious distortion and accurately showing the incisal surface of the mandibular incisors, (2) pre-treatment lateral cephalometric radiograph available, and (3) complete eruption of maxillary and mandibular permanent anterior teeth. Subjects were excluded from the study based on the following criteria: (1) history of previous orthodontic treatment, (2) any missing permanent mandibular anterior tooth and (3) any restorative manipulation involving the incisal edge of a permanent mandibular incisor.

Records

Stone cast made from alginate impressions and a lateral cephalometric radiograph taken at the subject's initial orthodontic records appointment were used. Bite registration made from baseplate wax taken at the initial records appointment was used to confirm the subject's occlusion. All lateral cephalometric radiographs were digitized using Dolphin Imaging software version 11.0 (Dolphin Imaging & Management Systems, Chatsworth, Calif.).

Evaluation of mandibular incisal wear

Grading of casts was conducted according to the "incisal wear index" (iWi) presented by Silness *et al.*[26] (Table I). Photographs exemplifying each grade level are shown (Figures 1 to 8). Grading of all casts was completed by two investigators. When grading the dental casts using the iWi, the investigators had only the mandibular dental casts available. This was done in order to allow the investigators to complete the assessment of incisal wear blind to the occlusal relationships and cephalometric measurements of the subjects.

Table I. Graded scale for attrition assessment: incisal wear index (iWi)

0.	No detectable wear. Presence of mammelons (developmental incisal notches)
1.	Developmental incisal notches no longer visible
2.	Clearly outlined smooth incisal wear facets
3.	Loss of substance with excavation along the incisal edge ('ditching')

Figure 1. Grade 0 according to the iWi (occlusal view). No detectable wear. Presence of mammelons.

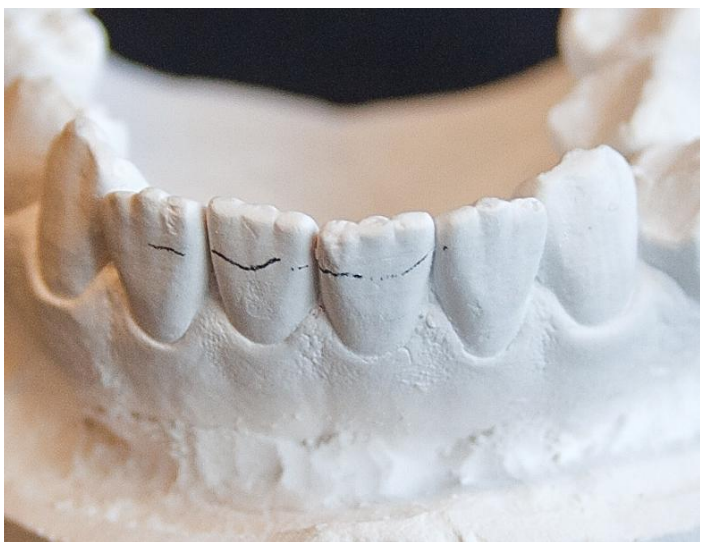

Figure 2. Grade 0 according to the iWi (buccal view). No detectable wear. Presence of mammelons.

Figure 3. Grade 1 according to iWi (occlusal view). Developmental incisal notches (mammelons) no longer visible.

Figure 4. Grade 1 according to iWi (buccal view). Developmental incisal notches (mammelons) no longer visible.

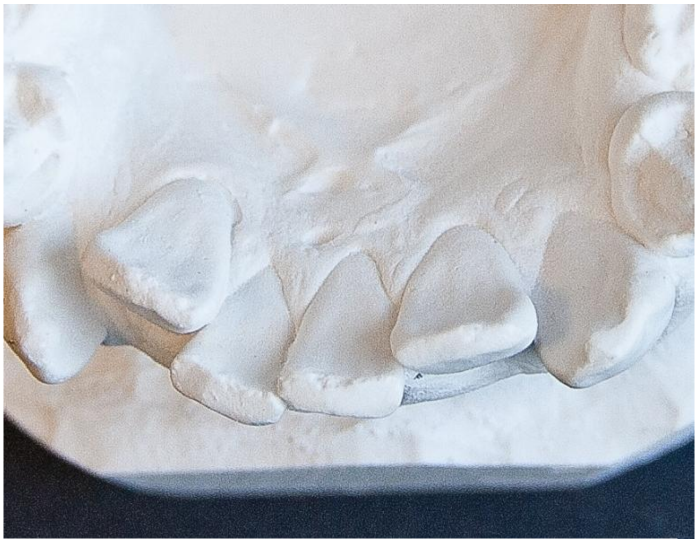

Figure 5. Grade 2 according to iWi (occlusal view).
Clearly outlined smooth incisal wear facets.

Figure 6. Grade 2 according to iWi (buccal view).
Clearly outlined smooth incisal wear facets.

Figure 7. Grade 3 according to iWi (occlusal view).
Loss of substance with excavation along the incisal edge ('ditching').

Figure 8. Grade 3 according to iWi (occlusal view).
Loss of substance with excavation along the incisal edge ('ditching').

Dental Measurement

i) Canine Angle Class: Class I was defined as the position where the cusp of the maxillary canine fits in the embrasure formed by the mandibular canine and 1^{st} premolar. Class II was scored when the cusp tip of the maxillary canine was located towards the mesial, greater than ½ the distance from the embrasure formed by the mandibular canine and 1^{st} premolar and the cusp tip of the mandibular canine. Class II was divided into division 1 and 2. The division was based on UI-SN measurements. Measurement $\geq 95^{o}$ were classified as division 1, while those measuring $< 95^{o}$ were classified as division 2. An angle of 95^{o} was selected as the dividing value between division 1 and 2 as this value is two standard deviations from the UI-SN norm. Class III was scored when the cusp tip of the maxillary canine was located towards the distal, greater than ½ the distance from the embrasure formed by the mandibular canine and 1^{st} premolar and the cusp tip of the mandibular 1^{st} premolar.

ii) Overbite: Overbite was defined as the amount of vertical overlap of the upper central incisors and lower incisors. Measurements were made perpendicular to the occlusal plane, taken from incisal edge of the maxillary central incisor to incisal edge of the mandibular incisor. The point of maximum overbite measured at the central incisors was recorded. The measurement was completed by placing the opposing casts in occlusion and using a pencil to mark the point of maximum vertical overlap of the maxillary central incisor on the mandibular cast. The overbite measurement was then made from this pencil mark to the incisal edge of the mandibular incisor. Positive values indicate the presence of overbite. In cases with anterior open bite, the measurement was made from the shortest distance between the incisal edges of the maxillary and mandibular central incisors. Negative values indicate the presence of anterior open bite. Measurements were made using a hand held digital caliper to the nearest 0.01 mm.

iii) Overjet: Overjet was measured in millimeters from the labial surface of the mandibular incisor to the incisal tip of the central maxillary incisor. Measurements were made parallel to the occlusal plane, at the point of maximum overjet with a digital caliper to the nearest 0.01 mm. Positive values were used to indicate positive overjet, while negative values indicate presence of an anterior crossbite.

iv) Incisor alignment: Little's irregularity index was used[50]. Irregularity was measured as the total sum, in millimeters, of the displacement of the 5 anatomic contact points from mandibular canine to canine. Measurements were made with a digital caliper to the nearest 0.01 mm.

Cephalometric Measurements

The following measurements were recorded from each subject's lateral cephalometric radiograph:

i) SN-GoGn
Measured as the internal angle between sella-nasion and gonion-gnathion.

ii) LFH:TFH
Measured as a percentage of total anterior face height. Lower face height is defined as the linear measurement from anterior nasal spine to menton and total anterior face height is defined as the linear measurement from nasion to menton.

i) UI-SN:
The internal angle formed between the long axis of the upper incisors and the sella-nasion line.

ii) IMPA:
The internal angle formed between the long axis of the lower incisors and the mandibular plane.

All cephalometric radiographs were digitally traced and measured using Dolphin imaging software version 11.0 (Dolphin Imaging & Management Systems, Chatsworth, Calif.). Angular measurements were recorded to the nearest 0.1^{o}, linear measurement to the nearest 0.1 mm.

Accelerated wear group

The accelerated wear group was composed of those subjects with a cumulative iWi score ≥ 6 and under 30 years of age.

Reproducibility

To determine intraexaminer reliability, the primary and secondary investigators each scored 20 randomly selected dental casts on two separate occasions, two weeks apart. In order to determine inter-examiner reliability, all casts were graded by the primary investigator as well as a secondary investigator. Prior to data collection, both investigators spent three sessions together grading dental casts of subjects not included in the study in order to calibrate their scoring technique. Intraexaminer reliability was measured using the intraclass correlation coefficient (ICC).

Statistics

The subjects' occlusal and skeletal characteristics were examined using descriptive statistics. A multiple linear regression was used to determine the association of the potential risk factors with attrition. In order to analyze the relationship of the risk factors with the accelerated wear group, a multiple logistic regression was used. P-values of less than 0.05 were considered statistically significant. A multiple logistics regression was used after dichotomizing the subjects into the "accelerated wear" group and "non-acclerated wear" group. Again, P-values of less than 0.05 were considered statistically significant. Statistical analysis were performed using SAS for Windows software (SAS institute Inc., Cary, NC, USA).

Results

Intraclass correlation coefficient results for intraexaminer reliability for iWi ranged from 0.864-0.977 (Table II).

Table II. ICC results for intraexaminer reliability.
LL2 = lower left lateral, LL1=lower left central
LR1= lower right central, LR2= lower right lateral
PI= primary investigator, SI= secondary investigator

	PI	SI
LL2	0.936	0.958
LL1	0.977	0.864
LR1	0.971	0.916
LR2	0.971	0.933

The interexaminer reliability results (weighted kappa) ranged from 0.821-0.914 (Table III). Due to the good kappa values, the iWi scores as measured by both investigators were averaged together. An overall iWi score for each subject was determined by adding together the individual score of each lower incisor, leading to an overall score ranging from 0-12.

Table III. Interexaminer Reliability Results (Weighted Kappa)

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	Kappa
LL2	0.821
LL1	0.914
LR1	0.904
LR2	0.843

In total, 215 subjects (137 females, 78 males) were examined with an average age of 18.8 years and a mean attrition score of 5.021 ± 3.16. Demographic, occlusal and cephalometric characteristics of the sample are shown in Table IV.

Table IV. Description of the sample and mean attrition score

Variable	**Mean (N)**	**Std. Dev.**
Attrition	5.021	3.16
Age	18.814	10.133
OB	2.572	2.033
OJ	4.089	2.244
Incisor Irreg.	4.782	3.752
SN_GoGn	31.858	6.485
LFH:TFH	55.948	2.517
UI_SN	103.612	9.054
LI_MP	93.657	7.752
Gender		**%**
Female	137	63.72%
Male	78	36.28%
Angle Class		**%**
Class I	72	33.80%
Class II, Div 1	97	45.54%
Class II, Div 2	26	12.21%
Class III	18	8.45%

For the main study, all subjects were included in a multiple linear regression (Table V). With the complete data set, the first stepwise selection resulted in a regression model with 5 independent variables and an R^2 of 0.3886. The individual results of each variable are displayed graphically in Appendix I. The results of the multiple linear regression indicate that age, gender, incisor irregularity, UI-SN angle and SN-GoGn angle are significantly associated with attrition. Specifically, the results indicate that increases in age, being male and increased incisor irregularity tend to increase attrition while increases in UI-SN angle and SN-GoGn angle lead to decreases in attrition, on average.

Table V. Associations with attrition using multiple linear regression

Variable	Estimate	P-value
Age	0.141	<.0001*
Gender	1.961	<.0001*
OB	-0.204	0.189
OJ	0.054	0.661
Incisor irreg.	0.113	0.020*
UI_SN	-0.089	0.002*
LI_MP	0.004	0.874
SN_GoGn	-0.185	<.0001*
LFH:TFH	-0.081	0.288
Class I	0.110	0.352
Class II, div 1	0.664	
Class II, div 2	-0.239	
Class III	0.000	

The original subject pool was divided into those subjects with “accelerated wear” (n= 67) and those without accelerated wear (n=148). Subjects with accelerated wear were defined as those with a cumulative iWi score ≥ 6 and under 30 years of age. The mean attrition score of the accelerated group was 7.91 ± 1.86, compared to 3.71 ± 2.73 in the non-accelerated group. Of the 67 subjects in the accelerated group, 61.2% were males, whereas, 25% of the 148 subjects in the non-accelerated group were males. Demographic, occlusal and cephalometric characteristics of both groups are shown in Table VI.

Table VI. Description of the “accelerated” and “non-accelerated” groups

	Non-Accelerated		**Accelerated**	
Variable	**Mean (N)**	**Std. Dev.**	**Mean (N)**	**Std. Dev.**
Attrition	3.713	2.732	7.91	1.856
Age	19.845	11.671	16.537	4.679
OB	2.249	1.976	3.287	1.988
OJ	4.042	2.218	4.193	2.312
Incisor Irreg.	4.273	2.84	5.909	5.081
SN_GoGn	33.492	6.069	28.248	5.925
LFH:TFH	56.132	2.237	55.542	3.024
UI_SN	104.051	9.33	102.642	8.397
LI_MP	93.326	8.098	94.388	6.926
Gender		**%**		**%**
Female	111	75.00%	26	38.81%
Male	37	25.00%	41	61.19%
Angle Class		**%**		**%**
Class I	53	36.30%	19	28.36%
Class II, Div 1	63	43.15%	34	50.75%
Class II, Div 2	16	10.96%	10	14.93%
Class III	14	9.59%	4	5.97%

A multiple logistic regression analysis was completed using this dichotomized date set. This analysis showed that males, increased incisor irregularity and decreased UI-SN angle and SN-GoGn angle were associated with accelerated wear (Table VII).

Table VII. Associations with "Accelerated Wear" group using multiple logistic regression

Variable	Odds Ratio	P-value
Gender	5.314	<.0001*
OB	0.005	0.968
OJ	-0.055	0.616
Incisor Irreg.	1.171	0.004*
UI_SN	0.909	0.004*
LI_MP	1.022	0.469
SN_GoGn	0.818	<.0001*
LFH:TFH	0.922	0.280
Class I	1.201	0.670
Class II, div 1	1.937	
Class II, div 2	1.371	
Class III	1.000	

DISCUSSION

Although a number of studies have previously investigated the relationship between tooth wear and occlusal and cephalometric factors, none to date have analyzed as many factors while focusing on mandibular incisal wear as this current study. In this cross-sectional study, a number of significant relationships were found between occlusal and skeletal measurement and extent of mandibular incisal wear. The current study was also able to identify a group of individuals who experience "accelerated wear" and compare them to a "non-accelerated" group.

Sample

The sample was taken from the patients who had undergone an orthodontic records appointment at the University of Minnesota. Although the study had a large age range (10-65), it was significantly skewed towards younger patients due to the population which generally seeks orthodontic care. In the current study, the mean age was 18.8 years of age and 70.2% of all subjects were 18 years or younger. This number is consistent with Guay *et al.*[51], who reported results of a national surveyed showed 76.9% of patients seeking orthodontic treatment are under the age of 19.

Experimental design

Several methods to assess tooth wear have previously been utilized by investigators, including clinical examination[35,36], evaluation of photographs[19] and dental casts[9,23,25] to measure tooth wear. The current study used only stone models of patient's dentition to assess tooth wear. The primary reason plaster models were chosen was due to their availability. A major goal of this investigation was to gain a broad overview of relationships between various skeletal and occlusal characteristics and the severity of lower incisor wear. In order to analyze such a large number of variables, a large sample size was needed. Since specifics of tooth wear are not documented during a standard orthodontic examination, a new clinical exam would have been required from each subject in order to focus on lower incisor attrition. It is thought that this requirement would have significantly decreased the sample size given the timeframe of the study. Additionally, the use of photographs has been used in conjunction with clinical exams and plaster models to determine tooth wear scores. Photographs were not included in the current study due to the lack of availability of clear photographs of the mandibular incisal edge. In past studies, photographs have been used to determine if dentinal exposure has occurred[52]. This requires clear, sharp images, in order to differentiate between enamel and dentin on a photograph. Given that the current study is retrospective in nature, the records taken at the time of initial exam were used. In reviewing the mandibular occlusal photographs which were available, it was determined that an accurate assessment of dentinal exposure could not consistently be made. Although the use of photographs and clinical examination cannot be underestimated, dental casts do represent a stable replica of the dentition and previous retrospective studies have shown that tooth wear can be scored using only dental casts with good to excellent reliability[9,10,26,28,43].

The present study was cross-sectional in nature and was intended to assess incisal wear levels at one time point. Several longitudinal studies have shown that wear patterns observed in a child are significantly associated with the amount of tooth wear observed in that same individual as an adult[9,22].

In the current study overbite was measured as the amount of vertical overlap of the upper central incisors and lower incisors. This measurement may be viewed as controversial due to the nature of incisal wear. As mandibular incisal wear progresses, there is a loss of tooth structure from the incisal edge of the lower incisors. This in turn, would lead to less vertical overlap between the maxillary and mandibular incisors and would result in decreased overbite values, which could significantly influence the resulting relationship between lower incisor wear and amount of overbite. However, this measurement was included in the analysis due to previous findings that continued vertical growth of the face and attrition of a tooth are compensated by slight tooth eruption for occlusal maintenance[57,58]. On the basis of these findings, the assumption was made that although incisal wear was occurring, the overbite relationship of the subject was being maintained.

Analysis of complete data set

When analyzing the complete data set, a regression with stepwise variable selection was performed. This resulted in a regression model which included five independent variables which were significantly associated with attrition scores. This study determined that attrition scores tend to increase with an increase in age. This finding is consistent with previous published studies[9,34,45-47], which have also reported an increase in tooth wear with increasing age. In the current study, the ages of the subjects ranged from 10-65 years of age, which appears broad enough to demonstrate a significant relationship between age and wear. The increase in tooth wear that is apparent with increased age may be explained by several factors. Some degree of tooth wear is considered a normal physiologic process[27,53] and since tooth wear is an irreversible process, the additive effects of tooth wear will lead to an expected increase in total wear in an older population. In addition, an increase in age also provides more time for pathologic patterns to express themselves. Changes in occlusal and cephalometric relationships that occur with age may play a role in the increased tooth wear observed with increased age as well. Changes in occlusal relationships with age have been reported in studies by Bjork[54]. Bjork has reported changes in overbite, overjet, forward and backward rotation of the lower jaw and changes in inclination of the incisors occurring with age. These changes could lead to possible effects on the amount of dental wear observed in a patient.

Another variable which was included in the current regression model was gender. In this study, males had significantly more wear than females. This finding is consistent with most reports in the current literature[2,9,23,25,27,34]. It has been demonstrated that men have stronger maximal masseter biting forces, greater muscle fiber mass and stronger ligaments than women[55], possibly leading to an overall increase in tooth wear observed in males. Thus, sexual dimorphism may be explained by variation in muscle strength between genders as previous studies have found a correlation between high bite force and the severity of tooth wear[6,56].

In the current regression model incisor irregularity was shown to be significantly related to incisal wear. An increase in incisor irregularity as determined by Little's index[50], was found to be associated with a higher incisal wear score. This finding is in contrast to reports by Berge *et al*.[28] and Johansson *et al.*[29], who investigated the relationship between anterior alignment and incisal wear. These authors reported that participants with well-aligned teeth had more severe wear of the anterior teeth when compared to those with various degrees of non-alignment. The conflicting results obtained in this current study may be due to differences in subject selection. The study by Berge was conducted on a 50 subject sample with a narrow age range (16-19 years of age). In contrast, this study had a sample of 215 subjects with an age range of 10-65 years. The age range used may have a significant effect on the results obtained, as wear patterns in younger patients may not be sufficiently expressed to be detectable until later in life. In addition to the age difference, the study by Berge *et al.* did not use Little's index to account for incisor irregularity. Instead, it used a non-aligned tooth index (NONAT) which includes only 2 possible scores; NONAT=1 when teeth are not aligned and NONAT=0 when teeth are aligned. This index is significantly different from Little's index which assigns a millimetric measurement to that amount of proximal contact displacement from canine to canine. A major difference in methods was also present between the current study and Johansson's study. Johansson studied occlusal wear of the entire dentition in a selected high-wear sample, whereas this current study focused solely on mandibular incisal wear on a general sample of patients seeking orthodontic treatment.

The angular measurement of U1-SN is one of two cephalometric variables included in the regression model. U1-SN is a measurement of maxillary incisor inclination and in the current study, as the inclination increased, a decrease in incisal wear score was observed. This observation was also reported by Johansson *et al.*[29], who found maxillary incisors to be significantly more retroclined in a selected "high-wear" sample. This also agrees with findings in anthropologic material, which has described a relationship between attrition and lingual tilting of human teeth[60]. Anthropometric studies have reported that excessive function and wear frequently leads to the development of an "edge-to-edge" bite with retroclined incisors[60,61]. It has been reported that this occurs as a result of anterior rotation of the mandible in response to dental wear[49]. This does not appear to be a satisfactory explanation for the results observed in this current study. If the incisor inclination were significantly influenced by an anterior rotation of the mandible in response to wear, it would be expected that the mandibular incisors would appear more retroclined with advanced wear and the inclination of the maxillary incisors would be affected to a lesser degree. However, the results obtained in this study are opposite, with the maxillary incisors showing a significant increase in retroclination with increased wear, an observation that did not produce significant levels in the mandibular arch. One possible explanation is that age-dependent changes in buccal and lingual musculature and in remodeling of the cortical plate[60] may contribute to the increased UI-SN values associated with increased wear. The natural eruptive path of teeth may be altered due to these age-dependent changes and as incisors wear over time, the compensatory eruption may follow a more retroclined path. Thus, it may be true that wear causes the incisors to retrocline, rather than retroclined incisors being at a greater risk for wear. The finding of decreased mandibular incisal wear with increased U1-SN values may also be explained by a decrease in incisal contact that occurs as the maxillary incisor proclination increases.

The Sn-GoGn is the second cephalometric measurement included in the current regression model. The results suggest that a decreased mandibular plane angle is significantly associated with increased lower incisor wear. This result is consistent with findings from Kiliaridid *et al*.[6] and Krogstad[49] who both reported advanced attrition in subjects with reduced mandibular plane angles. It has been demonstrated that extensive wear can be positively correlated to increased bite force[6,56]. In addition, previous studies have reported significantly higher bite forces in subjects with lower mandibular plane angles[62,63]. Thus, an interrelationship between muscle force, occlusal wear and dentofacial structure, specifically mandibular plane angle may exist. Another potential explanation of this significant finding is that the reduced mandibular plane angle may be the result of increased occlusal wear rather than a potential etiologic factor. This is possible if the rate of dental wear exceeds the rate of compensatory tooth eruption, leading to a forward rotation of the mandible. However, this explanation contradicts the theory that loss of vertical dimension after tooth wear is compensated for by tooth eruption, as is reported by several authors[57,58].

The findings of this study, along with previous reports, suggest that certain occlusal and skeletal patterns show an association with increased tooth wear beyond the likelihood of random occurrence.

Analysis of "accelerated wear" group

A secondary analysis was completed in order to investigate a group of subjects who demonstrated "accelerated wear" (table 5). The group with advanced wear (n=67) was compared to the remainder of the subjects (n=148). The results were consistent with those obtained when all subjects were pooled together in the initial analysis. Once again the variable which were found to have a significant correlation with incisal wear were; gender, incisor irregularity, U1-SN angle and Sn-GoGn.

Cause of tooth wear

The multifactorial nature of tooth wear must be taken into careful consideration when reviewing the results of this study. Although this study analyzed a number of occlusal and cephalometric values as well as age and gender, there still are a number of variables which have previously been shown to have a significant relationship with the severity of tooth wear which were not included in the present study. Other etiologic factors, such as saliva[6,17], diet[23], parafunction[64,65], temporomandibular joint disorders[25], and periodontal condition[27] have all previously been shown to be correlated with wear. Due to the number of factors which have shown significant correlations with tooth wear, cause and effect relationships are difficult to demonstrate and it appears that severity of tooth wear is affected by a complex interdependence of factors.

Clinical Application

A goal of the study was to indentify characteristics which were associated with increased wear. Through the use of a regression model, a number of characteristics which were significantly associated with increased wear were identified. Although a cause and effect relationship cannot be determined from correlations alone, an informed clinician may be able to use these characteristics to identify those patients who may have an increased risk of accelerated tooth wear. Should a clinician be able to identify these "at-risk" individuals, the next question to ask is "will orthodontic treatment have a protective effect on tooth wear?". After an extensive literature search, only one study was found which investigated the relationship between malocclusion, orthodontic treatment and tooth wear[23], however, it is difficult to draw any conclusion based on this one study due to several limitations in the design. Further studies are needed to determine if orthodontic treatment can alter the progression of tooth wear.

Future Studies

Tooth wear, being a continual process, can lead to significant long-term effect on one's dental health[18]. Previous authors have investigated various relationships between a number of possible etiologic factors and tooth wear. The focus of the current study was limited to mandibular incisal wear. This study detected a number of skeletal and occlusal characteristics associated with an increase in mandibular incisal wear. In general, this study supports the conclusions of a number of previous studies, while also clarifying conflicting results that had been reported in studies evaluating whole-mouth tooth wear. The results of this study can help clinicians identify patients who are at risk for "accelerated wear".

It appears the question, "does orthodontic treatment have a protective effect on tooth wear?" remains to be answered. The importance of this question is significant to a treating clinician who is able to identify the characteristics associated with increased tooth wear reported in this study. Further studies could investigate the effect of orthodontic treatment on the progression of tooth wear. If future studies are able to show that orthodontic treatment does have a protective effect on tooth wear, then alert clinicians will be able to inform patients and parents of the benefit of timely orthodontic treatment in reducing the progression of incisal wear.

Conclusions

i) Increase in age is significantly associated with an increase in mandibular incisal wear.

ii) Males demonstrated significantly more mandibular incisal wear than females.

iii) An increase in incisor irregularity is significantly associated with an increase in mandibular incisal wear.

iv) A decrease in UI-SN angle is associated with an increase in mandibular incisal wear.

v) A decrease in Sn-GoGn angle is associated with an increase in the mandibular incisal wear.

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APPENDIX I

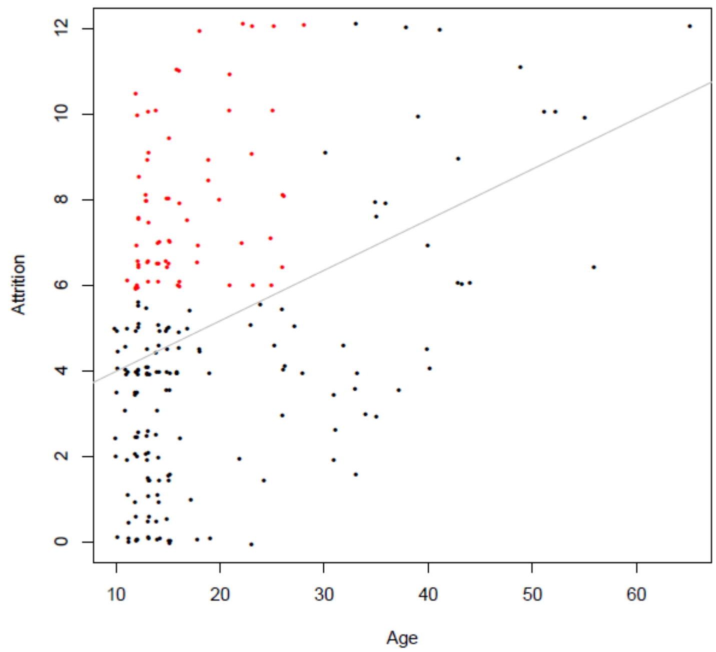

Figure A1 - iWi score (attrition) as a function of age

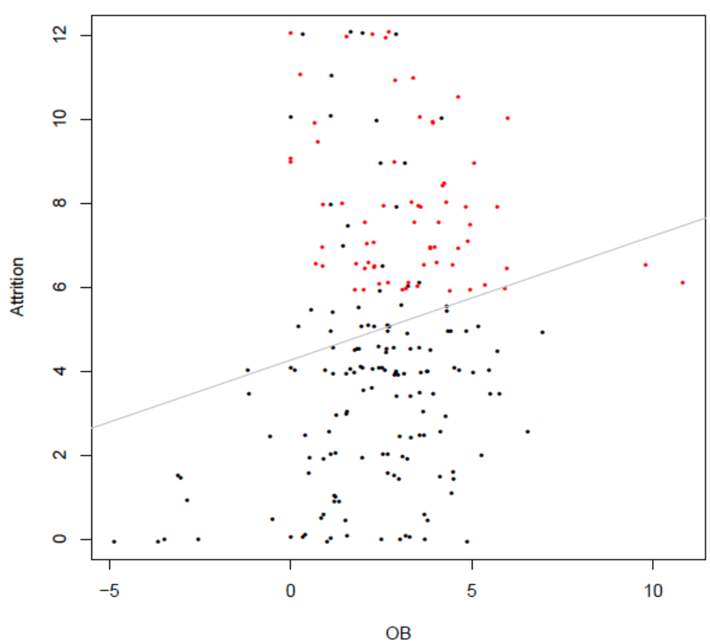

Figure A2 : iWi score (attrition) as a function of overbite (OB)

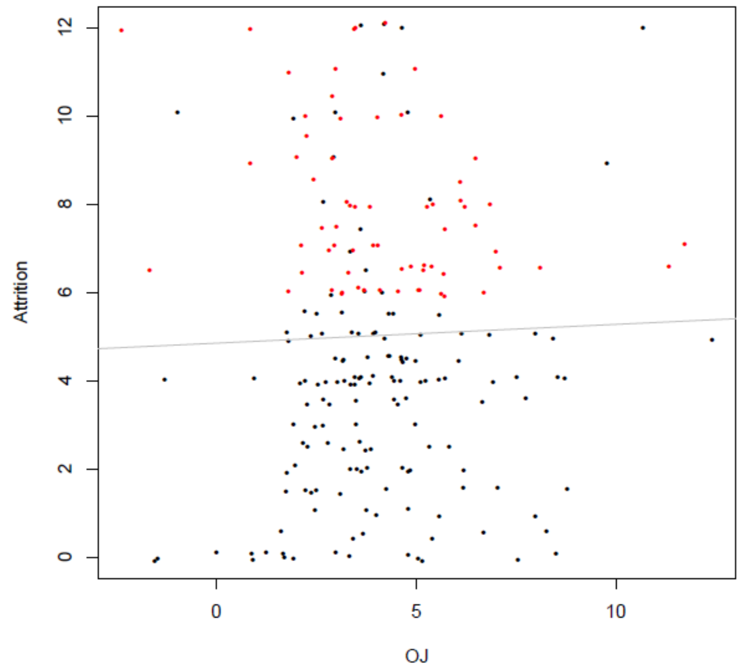

Figure A3 - iWi score (attrition) as a function of overjet (OJ)

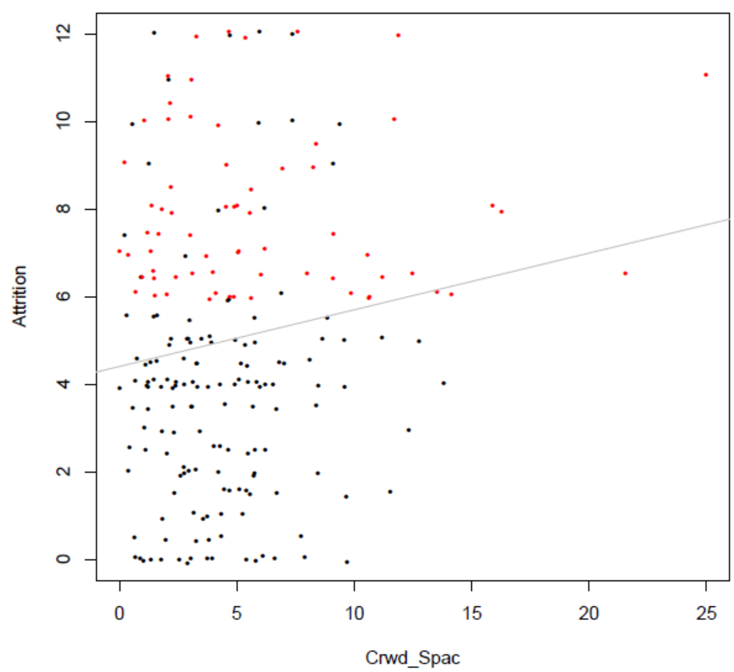

Figure A4 : iWi score (attrition) as a function of incisor irregularity (Crwd_Spac)

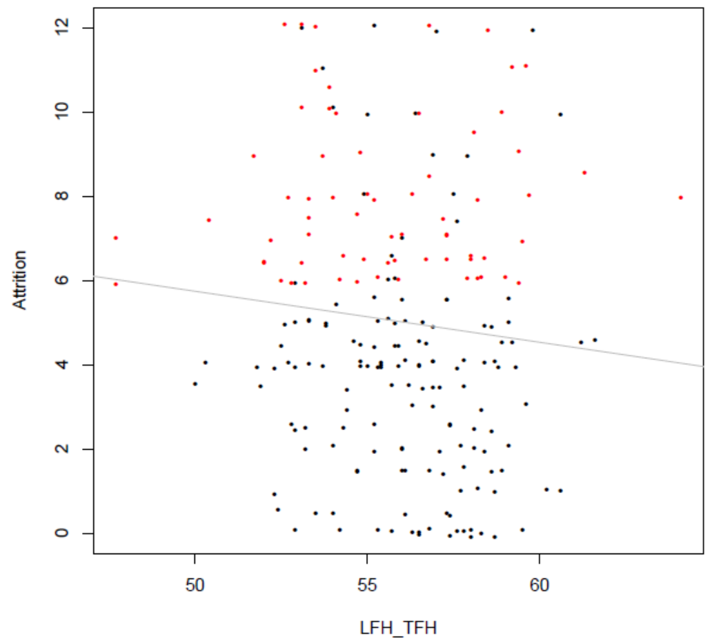

Figure A5 - iWi score (attrition) as a function of incisor lower face height : total face height (LFH:TFH)

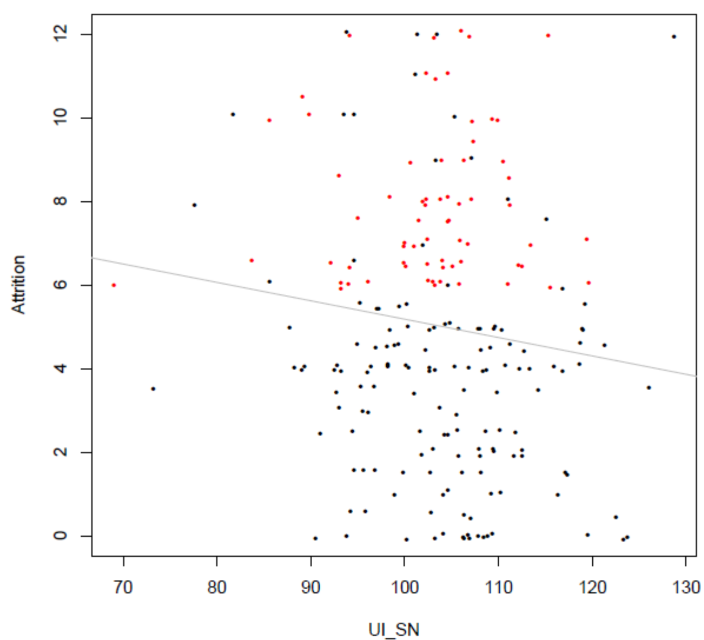

Figure A6 - iWi score (attrition) as a function of upper incisor to sella-nasion angle (UI_SN)

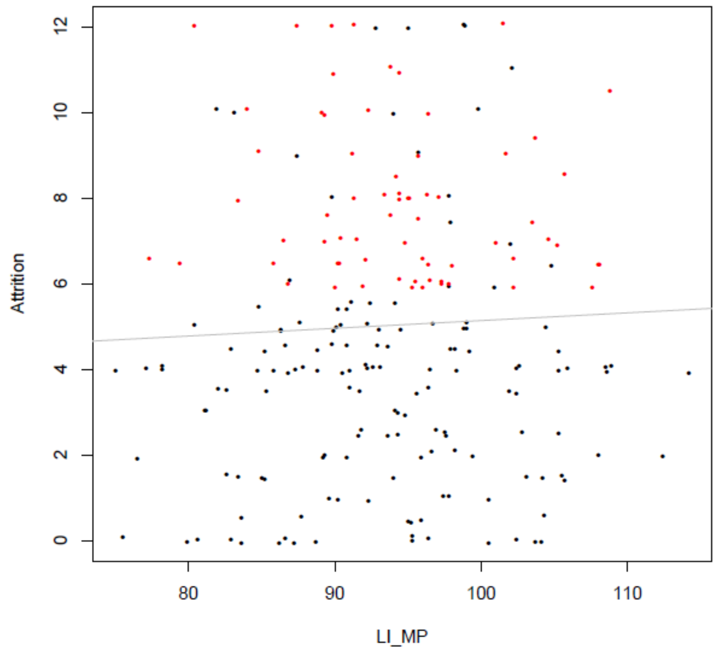

Figure A7 - iWi score (attrition) as a function of lower incisor to mandibular plane angle (LI_MP)

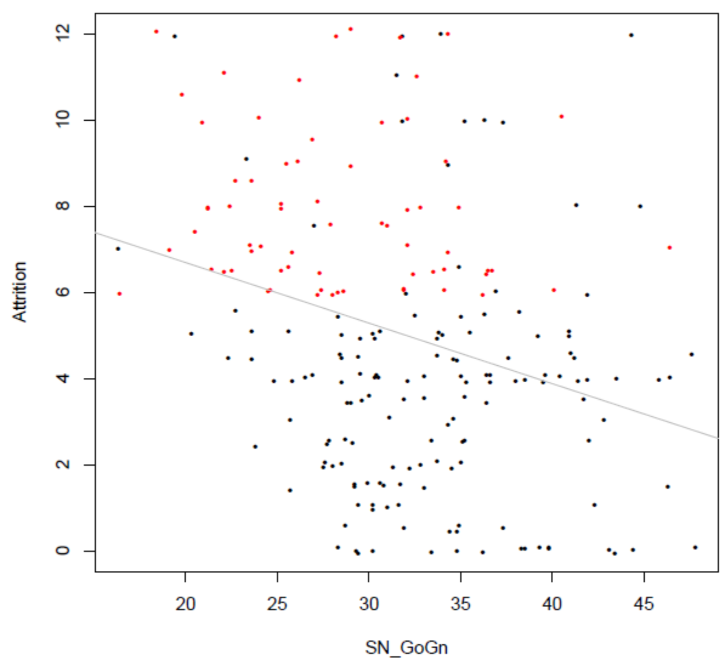

Figure A8 - iWi score (attrition) as a function of sella-nasion to gonion-gnathion angle (SN_GoGn)