Genetic and environmental influences on variation in overbite, overjet and tooth wear

A thesis submitted to The University of Adelaide in partial fulfilment of the requirement for the Degree of Doctor of Clinical Dentistry (Prosthodontics)

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May 2011

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SUMMARY

Introduction

Tooth wear is clinical problem that has been attracting the attention of dental professionals in recent times. Although tooth wear might be considered an age-related, physiological process its incidence has been increasing in younger individuals. The effect of tooth wear can be minimal, but it can have serious negative effects on both oral function and aesthetics.

In the past occlusal variations and interferences were believed to be causative factors for tooth wear, however there is little compelling evidence of such an effect. Genetic factors have been shown to contribute significantly to the observed variation in dento-facial growth and development, but to the best of our knowledge the contribution of genetic factors to the aetiology of tooth wear has not been investigated in detail.

The aim of this study was to determine the relationship between two significant occlusal variables (overbite and overjet) and tooth wear, and to determine the relative contribution of genetic and environmental factors to the observed variation in these measures.

Material and Methods

Twins' models, which have been collected as part of an ongoing craniofacial study at The University of Adelaide, were used. In total 128 twins pairs were included.

Selection was based on age (14-20 years old) and the eruption of all the permanent teeth apart from the third molars. Information such as age, gender and zygosity were all available.

Tooth wear was scored according to the following scale:

(0) No wear facet detected

(1) Wear facet that involved enamel only, flat facet without cupping

(2) Wear facet that involved enamel and dentine, detected by the extent of tooth structure loss and/or the presence of cupping.

(m) Tooth not present, primary tooth retained, or if stone model distorted in any way preventing adequate scoring.

Overjet and overbite were measured using digital callipers.

Statistical analysis

All data were analysed using Microsoft Excel spreadsheets (Microsoft Office Excel 2010). For the descriptive statistics one member of each twin pair was randomly selected to avoid the possible bias that may arise from the shared environment of twin pairs.

To determine the heritability of overjet, overbite and tooth wear, structural equation modelling was undertaken with software package Mx: Statistic modelling (Neale 1992, 2003).

Results

Tooth wear prevalence was high with no apparent effect of gender, zygosity or tooth position.

No statistically significant relationship was found between either overjet or and tooth wear.

Heritability values for overjet, overbite and tooth wear low with no detected genetic contribution; however there was evidence that the shared environment had an effect on the heritability of these occlusal variables.

The findings of this study indicate that genetic factors do not consistently influence wear scores for the first molar teeth but that the combined effect of all possible genetic factors account for between 46% and 63% of the observed variation in wear scores for canines and central incisors.

DECLARATION

This work contains no material which has been accepted for the award of any other degree or diploma in any other university or other tertiary institution to and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

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ZAINAB HAMUDI

Dated this 16th day of February 2011

ACKNOWLEDGEMENTS

I would like to take this opportunity to express my thanks and gratitude to my research and clinical supervisor Professor Lindsay Richards whose wisdom, endless help, support and encouragement have made the three years of my doctorate degree possible and indeed enjoyable.

I wish to thank my clinical supervisors Dr Thomas Berekally, Associate Prof John Abbott, and Dr James Dudley for sharing their knowledge and for their appreciated guidance.

Many thank to Dr Thomas Wilkinson and Dr Cosimo Maiolo for the time and efforts they spent to pass their knowledge and wisdom to all of the Doctor of Clinical Dentistry students.

My thanks and appreciation to Prof Viv Burgess for his encouragement and kindness.

Thanks to all the staff members in clinic 1.4 and Colgate Centre in the Adelaide Dental Hospital for their help and hard work. It was my pleasure to know them.

I wish to acknowledge Dr Toby Hughes for his help with the statistical analysis.

I wish to thank my parents, Wisam and Abdulmahdi, and my mother in law, Dr Suha Alfarhan, for their encouragement and support at all times.

My great thanks to my husband Dr Ahmad Abdulkarim for his love, support, encouragement and patience.

1. LITERATURE REVIEW

1.1 INTRODUCTION

Severe tooth wear is a clinical problem that represents a frequent challenge to dental professionals and has attracted increasing attention in recent time due to its high incidence in all age groups (Smith and Robb 1996). As with all variation in biological systems, the observed variation in tooth wear between individuals and populations depends on both genetic and environmental factors. An understanding of the relative significance of these factors is central to understanding and managing clinical problems.

1.2 Tooth wear

1.2.1 Past and present views

Many studies have been conducted to determine tooth wear prevalence in both modern and ancient societies. In addition the pattern, aetiology and severity of the wear has also attracted the attention of researchers. In the past, severe and advanced tooth wear was the norm. In fact it might be considered a physiological phenomenon associated with coarse diet and the use of teeth as tools, as a third hand or as a weapon, all of which required constant sharpening (Molnar 2008, Djurić-Srejić 1998, Deter 2009). At the present time, and due to changes in dietary habits and the consumption of softer food, the presence of severe or early tooth wear might no longer be considered as physiological (Hinton 1982). Although the presence of tooth wear in modern societies might be considered pathological, some suggest that the absence of tooth wear is indeed what should be considered a pathological phenomenon and believe that it is actually needed for proper function of the masticatory system. For example, Berry and Poole (1974, 1976) considered the unworn cusp as a disease of civilization that prevents the dentition from reaching a stage of optimal efficacy as a chewing apparatus. In fact, tooth wear has been considered as a protective mechanism against teeth mal-alignment, a condition that has shown increasing prevalence in modern societies.

1.2.2 Effects of tooth wear

A proposed beneficial effect of tooth wear (especially proximal tooth wear) was proposed by Begg (1935) who explained its effect on providing adequate space for the eruption of a full dentition with the avoidance of crowding or impactions. This was part of the basis of Begg's orthodontic technique for treatment that involved minimizing overjet and overbite resulting in a dentition that is more vulnerable to tooth wear rate and therefore less susceptible to pathology that may result from the lack of tooth wear.

Despite some authors considering tooth wear as a normal physiological phenomenon, it might be considered pathological when it is so extensive and advanced in relation to age that it affects function and aesthetics and is of concern to the patient. Oral function may be affected by tooth wear due to pulpal exposure that leads to constant hypersensitivity and pain or even loss of tooth vitality, tooth drifting and reduced masticatory efficiency. The same degree of tooth wear that may be considered pathological in people who are in their 20's may be considered normal in people in their 70's. A younger individual may have a problem associated with aesthetics as well as function related to hypersensitivity and pain especially when tooth wear advances quickly giving no chance for the development of secondary dentine to compensate for tooth structure loss.

In addition to the reduction in tooth dimensions that result from tooth wear, alteration of arch shape and dimensions as well as inter-arch relationships that results from the reduced vertical dimension are further consequences of the tooth wear process (Fishman 1976). Due to these effects of tooth wear, a change in facial morphology (including gradual facial lengthening and lateral narrowing) may be the result of tooth wear processes rather than evolution (Begg 1935). Although tooth wear was at a time considered pathological because it simply meant alteration of the original tooth form, dental opinion has changed and it is no longer considered pathological when the oro-facial complex is capable of adapting to the changes and the oral function is maintained.

1.2.3 Prevalence of tooth wear

Van't Spijker et al. (2009) showed that prevalence of tooth wear was significantly higher in older age groups. The percentage of adults presenting with severe tooth wear varied from 3% at age 20 years to 17% at 70 years of age. This has been supported by anthropological studies suggesting a significant correlation between tooth wear and age (Molnar 2008, Richards and Miller 1991, Bernhardt 2004). Combining this with the fact that more people are retaining their teeth to an older age due to increasing dental health awareness (Micheelis et al 1996 , Nunn et al 2000), severe tooth wear continues to be a condition with a high incidence despite the consumption of a softer non-abrasive diet. By way of contrast, Seligman in (1988) found that attrition was not related to age, indicating that severe attrition can occur early in life. He also found that tooth wear was not related to any studied local factor such as occlusion and concluded that bruxism, which is the main aetiological factor for attrition, is a centrally mediated phenomenon. Severity of tooth wear has been found to be higher in males than females with this being attributed to the higher biting forces demonstrated by males (Bernhardt et al 2004). Also in pre-contemporary groups this difference in wear severity was assumed to be due to differences in physical and work-related activities between genders that was reflected in the way the teeth were used as tools or as a third hand (Molnar 2008).

Dahl et al (1985) disagreed with the above idea indicating that bite force is not an important factor in developing attrition and that there is great individual variation in the value of the bite force between individuals and that this was true for both bruxers and non-bruxers with the no statistical difference in the mean biting force for those two groups.

The aetiology of tooth wear is usually multi-factorial and has been related to different local and systemic factors. Although many local factors can show a direct effect on the presentation and form of wear, several other systemic factors can contribute either directly or indirectly to cause tooth wear.

1.2.4 Tooth wear terminology

Depending on the causative factor, tooth wear has been described using many terms including attrition, erosion and abrasion where each of these terms have been specifically defined. Unfortunately, for many years the terms have been used interchangeably to describe tooth wear in general. Clearly defining and understanding each of the terms is important as they involve different mechanisms and aetiologies.

Attrition occurs as the result of tooth-to-tooth contact without the presence of food (Kaidonis 2008, Grippo et al 2004, Hugoson 1988. Pindborg 1970). It is usually characterized by well defined facets with matching facets on the opposing teeth. It involves flattening of cusp tips, incisal edges, palatal surfaces of the upper anterior teeth and even the interproximal surfaces. Depending on the severity, tooth wear may affect enamel only or may extend further affecting the dentine. However, the affected surfaces are expected to be flat without scooping or cupping. Close examination of the worn surfaces reveals parallel striations that typically occur within the borders of the wear facet (Kaidonis 2008). Active attrition can be diagnosed from a patient's history of on-going bruxism or from a close clinical examination that shows shiny wear facets.

Tooth-to-tooth contact that causes attrition has always been referred to as a parafunctional oral activity (such as bruxism) rather than as a functional activity. Functional tooth contact in general does not occur without food, except when swallowing, which involves a very short time period and normally does not involve enough forces to cause tooth wear. (Bernhardt et al 2004, Grippo 2004).

It has been claimed that bruxism and parafunction are triggered by malocclusion and that occlusal interferences are the main factor that lead to grinding and tooth wear as well as many of the signs and symptoms of temporomandibular joint dysfunction (TMD). For a long time the management of TMD as well as the prevention and control of bruxism, and in turn tooth wear, was planned with an emphasis on the correction of occlusion and the achieving of ideal occlusal relations. This led to the provision of extensive, sometimes unnecessary, irreversible and expensive restorative procedures that in many cases failed to achieve the required aim and ended with even more complex and frustrating situations. There is a growing body of evidence that supports the idea of nocturnal bruxism being a sleep disorder that is related to waking emotional status and that attrition is not related to occlusal factors. This has reinforced the view that bruxism, which is the main cause of attrition, is a centrally induced phenomenon and is not triggered by local factors (Rugh et al. 1984, Seligman 1988).

In addition to the above, Lazic et al (2006) studied the relation between bruxism and occlusal factors by performing computerized occlusal analysis of two groups: an experimental group included individuals with signs and symptoms of nocturnal parafuctional activity; and a control group with no such signs and symptoms. They concluded that there was no evidence of a direct correlation between occlusal factors and bruxism. In a review by Van't Spijker et al (2007) the loss of posterior teeth did not appear to be an aetiological factor in the development of tooth wear, however they pointed out that it is a very complicated issue and that drawing such a conclusion might be difficult.

It has been shown, however, that in individuals with bruxism the morphology of the mandibular condyle may change as a result of remodeling, and it has been suggested that flattening of the condylar head is strongly associated with tooth wear (Staz 1951, Scott 1957, Brown 1965, Owen 1991). This association might be a reflection of the shared aetiological influence of parafunction.

Abrasion occurs as a result of friction between the teeth surfaces and exogenous material. In contrast to attrition, abrasion lesions tend to involve a wide area and, when dentine is exposed, differential wear becomes evident with “cupping” resulting from faster dentinal wear (Pindborg 1970, Grippo 2004, Kaidonis 2008, Hugoson 1988). A magnified view of an abrasive lesion reveals haphazard scratch marks, a reflection of food particles or other extrinsic materials being forced against the tooth surface (Kaidonis 2008). The most common abrasive material that causes dental abrasion in most populations is food and the intentional ingestion of a diet which is highly fibrous, and the non-intentional ingestion of abrasive particles (like sand, ash or grit) that can contaminate food during preparation (Grippo 2004, Deter 2009). Abrasion can be caused by occupational activities, habitual or compulsive behavior like using the teeth as manipulate objects (pipe, pin) or as tools (cutting), all of which result in an irregular form and distribution of wear. Abrasion has attracted anthropologists’ attention as an activity-induced marker helping in the understanding of various behavioral activities of prehistoric man (Hinton 1982, Lukacs and Pastor 1988, Deter 2009).

Dental erosion refers to the dissolution of tooth substance due to chemical action without the presence of plaque (Kaidonis 2008, Eccles 1982). Sources of acids in the oral cavity can be endogenous or exogenous resulting in different tooth wear patterns. Intrinsic acid originates in the stomach and is due to either a medical condition such as acid reflux or regurgitation, or a psychological condition that is associated with selfinduced vomiting such as bulimia nervosa or anorexia (Grippo 2004, Eccles 1982). When dentine is exposed the worn surface shows differential wear that manifests as cupping or scooping of the wear lesion. Occlusal erosion might look like abrasion, however the difference between the two is that abrasion leaves the dentine surface with a smear layer that blocks the dentinal tubules and is not usually associated with sensitivity. On the other hand erosion, when it is active, leaves the dentinal tubules open and the tooth sensitive (Kaidonis 2008).

The commonly used term “dental erosion” has been questioned in a review by Michael et al (2009). They suggested use of the term “corrosion” to describe loss of tooth structure by acidic elements with “erosion” used more correctly to describe a chemo-mechanical tooth wear combining corrosion with abrasion or attrition.

A more controversial term is **abfraction** referring to cervical tooth surface loss that is induced by concentrated stresses at the cervical area due to excessive, cyclic, eccentric occlusal forces. Theoretically these stresses could be high enough to overcome the boundary between hydroxyapatite crystal and cause micro-cracks between the crystals making the area more prone to erosion and abrasion (Grippo 1991). The theory of abfraction has not been proven and has been challenged in a number of papers (eg Michael et al 2009).

Non-carious cervical lesions present in a variety of forms. It has been suggested that the shape of these lesions is an indication of their aetiology, with a lesion with well defined and sharp margins probably caused by abrasion while one which broader, dish-shaped and shallower more likely to result from erosion (Bartlett 2006).

Many different classifications have been used to describe tooth wear, most of which are based on the aetiological factors and wear mechanisms. Classifying tooth wear according to its cause is very beneficial clinically as the first stage of management which usually involves defining and eliminating or at least controlling and minimizing the impact of the causative factors whenever possible. The aetiology of tooth wear is usually multi-factorial and has been related to different local and systemic factors. Although many local factors can show a direct effect on the presentation and form of wear, other contributing factors can have direct or indirect effects.

1.2.5 Salivary effect on tooth wear

Although attrition and abrasion are both caused by mechanical friction of at least two surfaces, in a moist environment like the oral cavity the presence of saliva is an important modifying factor that should not be ignored when identifying aetiological factors and managing tooth wear. Salivary flow and its buffering capacity are important to neutralize the intraoral pH after an acid attack. It also acts as a reservoir of important minerals (calcium, phosphate and fluoride) that play a critical role in the remineralization process after an acid attack. Salivary acquired pellicle is helpful to protect enamel from transient acid attack (Smith 2003, Piangprach 2009). Dehydration has been found to be related to decreased salivary flow that is in turn associated with dental diseases including erosion (Smith 2003). Dehydration is a frequently overlooked but critical contributing factor for tooth wear. The low pH in the oral cavity whether it is externally or internally sourced can normally be neutralized by the effect of normal salivary flow. However, in cases where the salivary flow rate is reduced the low pH takes longer to be neutralized and may actually not achieve the required pH (which is higher than the critical value of 5.5). This will prolong the effect of the acid and in turn extends the time where the tooth surface is softened and vulnerable to wear.

1.2.6 Effect of occlusion on tooth wear

As defined by the Glossary of Prosthodontic Terms (2005), “Occlusion is the static relationship between the incising or masticating surfaces of the maxillary or mandibular teeth or tooth analogues”. Previous studies have shown that the relationship between attrition and occlusal factors is weak and may not be clinically significant (Seligman, Pullinger et al. 1988). Cunha-Cruz did not find a significant relation between tooth wear and orthodontic treatment, missing teeth and race/ethnicity. However, in this study a relationship was found between some occlusal factors and tooth wear. For example, Angle Class II Div.2 malocclusion was associated with more wear and an open bite was related to less wear (Cunha-Cruz, Pashova et al. 2010). Similarly Bernhardt et al. (2004) demonstrated a correlation between occlusal wear and several factors including: male gender, bruxism, loss of posterior contact, edge to edge incisal relationship, unilateral cusp-to-cusp occlusion as well as unemployment.

1.3 Genetic considerations

Genetics factors have been related to the susceptibility of subjects to different diseases. Factors that may be associated with the prevalence of tooth wear such as occlusion have been shown to be influenced by genetic factors; however environmental determinants of occlusal variation are also significant (Bernhadt et al 2004, Corruccini and Potter 1980, Boaas et al 1988, Hughes et al 2001). In fact, some authors have found that the genetic contribution to occlusal variation to be low and have emphasized the environmental influence (Harris and Smith 1980). An example of the environmental effect is the noticeable increase in occlusal variation in non-industrialized populations after their transition to a western diet (Corruccini 1984).

To determine the genetic effects on dental variables such as occlusion and tooth wear twins studies have proved to be a valuable tool to complement molecular approaches in unraveling the aetiology of diseases and disorders with a multifactorial aetiology

(Townsend et al 1988). With twin studies it is possible to determine the relative role of genetic and environmental factors by comparing the similarities in monozygotic (MZ) twins and dizygotic (DZ) twins. The main principle in twin studies is that MZ twin pairs share all of their genes and so any morphological variation reflects an environmental effect rather than a genetic effect. Generally it is assumed that these environmental variables are exogenous. A limitation of classical twins studies is the bias that may result from a shared environment can result in a phenotype being attributed to genetic similarity when in fact it is environmentally controlled (Townsend et al 2003). Bouchard (1997) dealt with this limitation by conducting a twin study in which the twins were reared apart and lived in different environments. This overcomes the possible environmental effect that may skew the results and has allowed the confirmation of the genetic role in certain dental characteristics and conditions.

To summarize, tooth wear and occlusal variation are both associated with clinical problems of multifactorial aetiology. While many studies have identified locally-acting factors, other aetiological factors may have not yet been identified and may have an underlying genetic basis worthy of investigation.

2. Aims

The general aim of this study was to consider the relationship between two common occlusal variables (overbite and overjet) and tooth wear and to assess the relative significance of environmental and genetic factors to the observed variation in each of these dental variables.

In particular the study aimed:

- To determine the prevalence of tooth wear in selected teeth (16,13,11,21,23, and 26) and describe the overbite and overjet in Australian twins aged 14-20 years.
- To determine whether there is any significant relationship between overjet, overbite and tooth wear.
- To determine the significance of the contribution of genetic factors to the observed variation in overbite, overjet and tooth wear.

3. MATERIALS AND METHODS

3.1 Study sample

The study sample consisted of a total of 128 twins' models collected as part of ongoing study of dento-facial structures of Australia twins at The University of Adelaide (Townsend 1988, 2003).

Only the models of twins with completely erupted permanent dentition (excluding third molars) with an age range from 14 to 20 years were included. When, in some cases, the permanent teeth are not present (eg. due to retention of a primary tooth, congenitally missing permanent teeth or permanent teeth lost for other reasons) the tooth was scored as missing. Similarly some models were damaged in a way that prevented adequate scoring of the tooth in question (eg. stone rough, broken or scratched), and the teeth were scored as missing.

In addition to dental casts, the collection included information about gender, age, zygosity (determined by blood or DNA markers) and additional information about maternal and twin health, perinatal events, handedness, and fingerprints.

3.2 Scoring tooth wear

Six teeth were scored in each arch; those were all first molars (16, 26, 36, and 46) all canines (13, 23, 33, and 43) and all central incisors (11, 21, 31, and 41).

Scores were assigned according to the following scale:

(0) No wear facet detected

(1) Wear facet that involved enamel only, flat facet without cupping

(2) Wear facet the involved enamel and dentine, detected by the extent of tooth structure loss and/or the presence of cupping.

(m) Tooth not present, primary tooth retained, or if stone model distorted in a way preventing adequate scoring.

Tooth wear scoring was done under magnification (4x) and standardized lighting. In the case of multi-cusped molars the cusp showing the most advanced wear was scored.

Because the reproducibility of tooth wear scoring index used in this study had not previously been assessed, scoring was repeated by the same examiner with a second scoring performed three months after the initial scoring for 30 randomly selected twin pairs.

All the scores were regarded as reproducible with concordant scores assigned in more than 85% of cases for all teeth. The reproducibility of scores for each of the teeth is shown in Table 1.

Table 1: Reproducibility of the tooth wear scores (%)

	Left	Right
Incisor	86.8	92.5
Canine	90.0	86.0
Molar	90.0	90.0

3.3 Measuring overjet and overbite

Overjet and overbite were both measured using modified digital calipers (Figure 1). The casts were hand articulated to maximum intercuspation with meticulous care to avoid damaging the occlusal surfaces that could result from stone-to-stone contact.

All of the models used had a stable occlusion defined by the presence of all the teeth from second molar to second molar.

NOTE:
This figure is included on page 18 of the print copy of the thesis held in the University of Adelaide Library.

Figure 1: Modified digital caliper (Mitutoyo Corporation, Kanagawa, Japan)

Overbite was defined as the vertical distance between the incisal edges of the upper and lower central incisors measured perpendicular to the occlusal plane (Harris 2008). Overbite measurement was performed by hand articulating the upper and the lower casts to the maximum intercuspation and drawing a fine line on the labial surface of the lower central incisor at the level of the incisal edge of the upper central incisors, then separating the casts and using the depth gauge of the modified digital caliper to measure the distance between the drawn line and the incisor edge of the lower central incisor (Figure 2).

In cases of edge-to-edge incisal relationships, overbite measurement was zero. In cases with anterior open-bite, the distance between the upper and lower incisal edges was measured and the derived measurement was given a negative value. When the left and right side measurements were different, the side with the higher value was chosen to be measure and considered as the overbite value for that individual.

Overjet was defined as the horizontal distance between the labial surfaces of the upper and the lower central incisors (Harris 2008). Again the depth gauge of the modified digital caliper is used for this measurement by placing the caliper touching the labial surface of the upper central incisor and the depth gauge touching the labial surface of the lower central incisor (Figure 3).

When the upper and lower incisors were in an edge-to-edge relationship the overjet had zero value. When the lower central incisor was positioned in front of the upper central incisor the measured distance was given a negative value (described as reverse overjet or anterior crossbite) and this was considered the case even when one of the central incisors had this relation.

When the left and right incisors had different values of overjet, the side with the higher value measured was considered as the overjet for that individual.

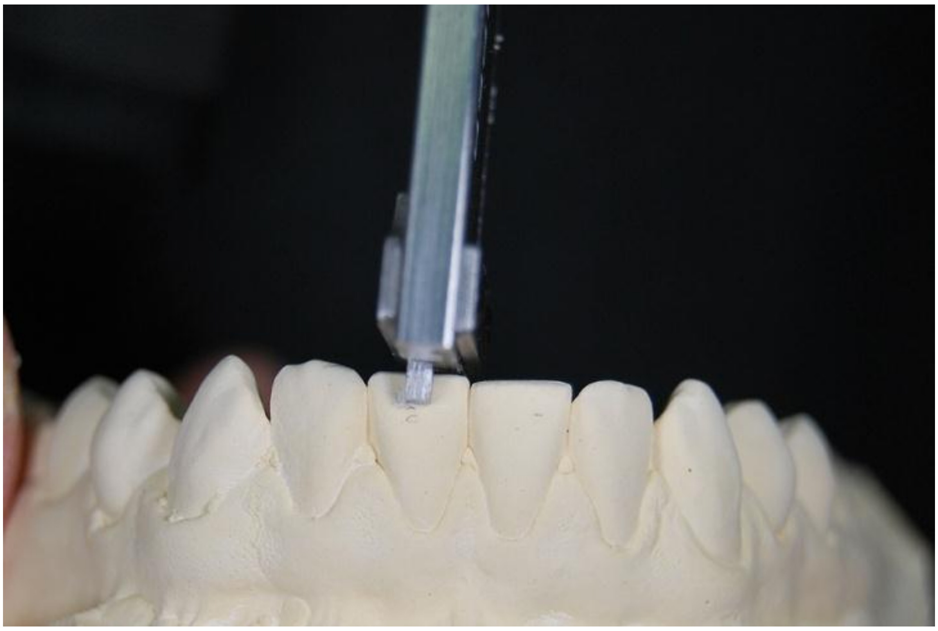

Figure 2: Overbite measurement

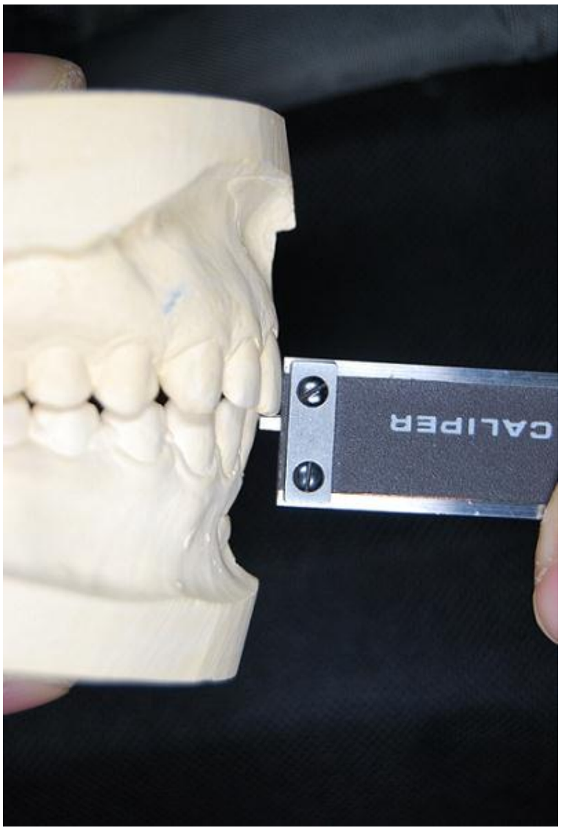

Figure 3: Overjet measurement

3.4 Statistical methods

All data were entered into Microsoft Excel spreadsheets (Microsoft Office Excel 2010). In addition to the tooth wear scorings and overjet and overbite measurements, twins' zygosity, age, and gender were included as variables.

For the part of the study involving descriptive statistics for the population, one twin member was randomly selected to be included in the statistical analysis to avoid any potential bias that may be caused by the expected similarity between the twin pair members potentiated by genetic influence as well as the shared environments between the twin members. Chi-square tests were used to determine the significance of the differences in tooth wear scoring in relation to different variables (males versus females, upper teeth versus lower teeth, MZ versus DZ twins). This test was also used to determine the significance of differences in the occlusal variables difference in MZ and DZ twins.

Structural equation modeling was undertaken with software package Mx Statistical modeling (Neale 1992, 2003). Four sources of variation (A, additive genetic variance; C, non-additive genetic variance; D, common [shared] environment; D, non-additive genetic variance; and E, unique [non-shared] environment variance) can be modeled for a pair of twins.

The process in explained in detail by Hughes et al (2001) and involves the initial decomposition of the data to produce a ‘super-model’ against which goodness-of-fit of nested sub-models is tested (Figure 4). A model incorporating decompositions of additive genetic, unique environmental and common environmental variances was then fitted.

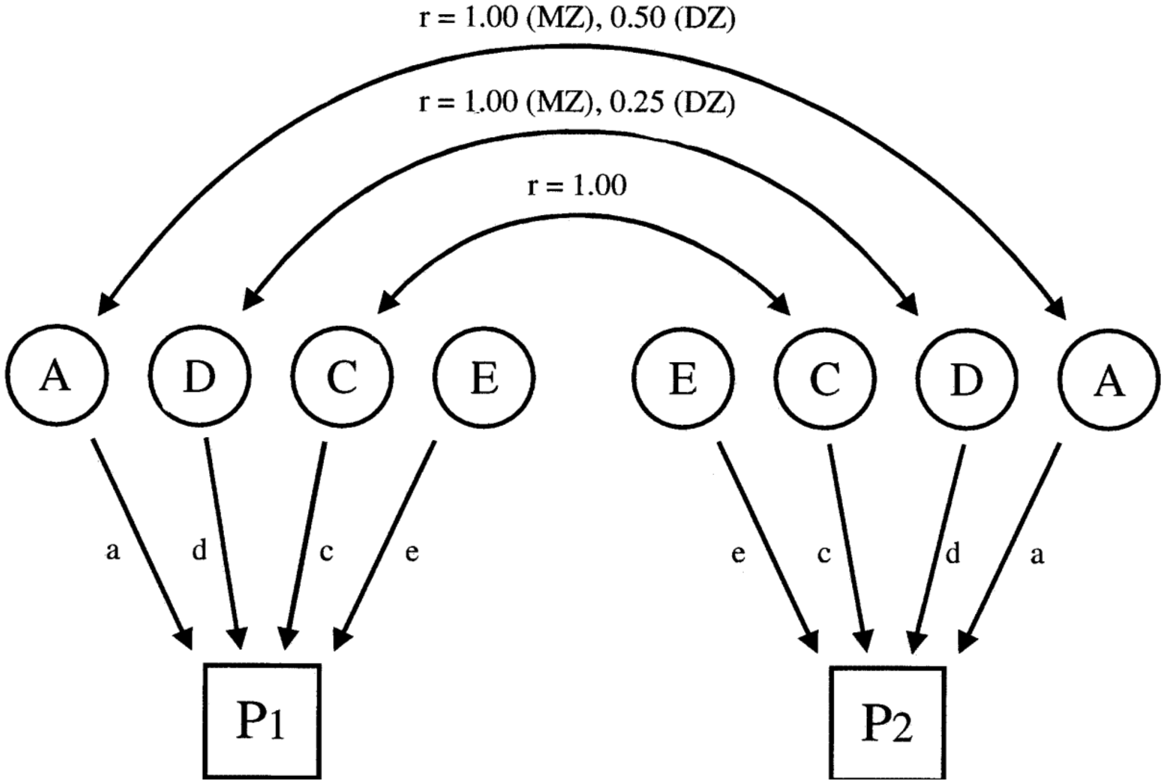

Figure 4. Structural equation modeling
” Univariate path diagram showing four potential influences affecting the phenotypes of MZ and DZ twin pairs. P1 and P2 represent the phenotypes of the first and second twin pair members, respectively. The latent factors A, D, C and E denote the additive genetic variation, non-additive genetic variation, common environmental variation, and unique environmental variation, respectively, for each twin. The double-headed arrows indicate the correlations between latent factors in co-twins. The path coefficients a, d, c and e indicate the relative importance of each of the contributing influences A, D, C and E.” (Adopted from Hughes 2001)

As part of the model-fitting approach path coefficients (a, c and e) were estimated and chi-squared statistics for goodness-of-fit of the models were calculated. The general approach adopted was to accept a more complex model only if a simpler one had failed.

Narrow-sense heritability estimates (h^2) ranging from 0 to 100% were calculated as the ratio of additive genetic variance to total phenotypic variance in the best-fitting model. Values of heritability estimates near 100% indicated that most of the phenotypic variation could be explained by additive genetic effects whereas values near zero indicated that environmental effects accounted for most of the variation in the phenotype.

4. RESULTS

4.1 Tooth wear

Tooth wear was found to be a very common occurrence in the selected twin sample. (Table 2, Figures 5 and 6)

Table 2: Tooth wear prevalence (%)

		Upper		Lower	
		Left	Right	Left	Right
Incisor	No wear	20	25	16	17
	Enamel	34	36	51	51
	Dentine	46	39	33	32
	Enamel & dentine	80	75	84	83
Canine	No wear	26	28	36	30
	Enamel	67	68	60	65
	Dentine	7	4	4	5
	Enamel & dentine	74	72	64	70
Molar	No wear	17	13	11	10
	Enamel	81	84	83	84
	Dentine	2	3	6	6
	Enamel & dentine	83	87	89	90
All	Enamel & dentine	79	78	79	81

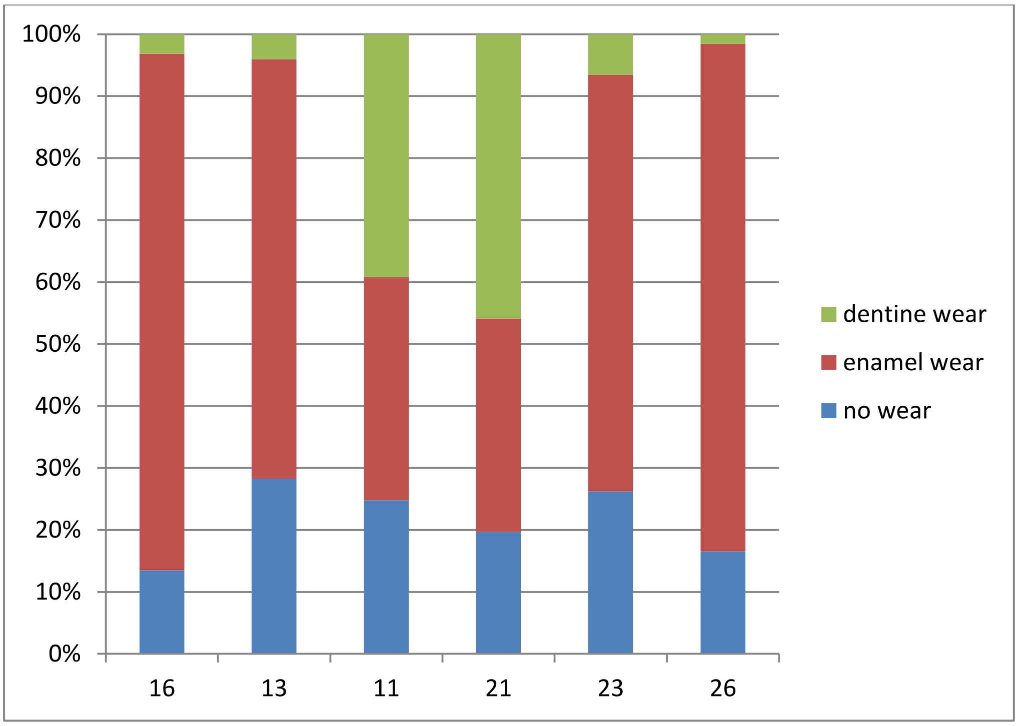

Figure 5: Tooth wear prevalence of the upper teeth (16, 13,11,21,23 and 26)

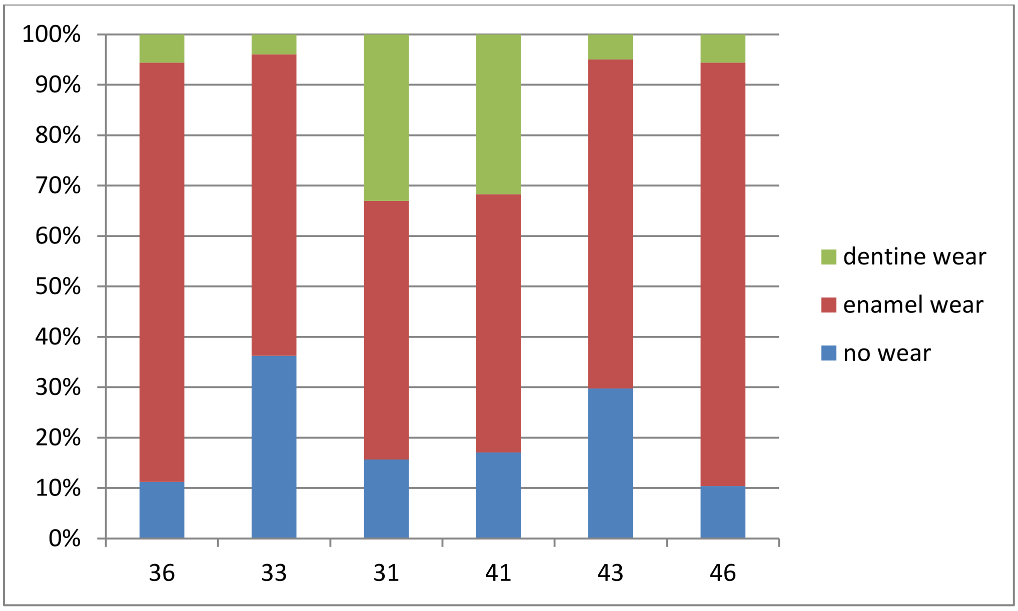

Figure 6: Tooth wear prevalence of the lower teeth (36, 33,31,41,43 and 46)

In general, molar teeth showed the highest overall prevalence of tooth wear (ie, wear in either enamel or dentine) in the range 83% for 26 to 90% for the 46.

Although the first molar teeth had the highest tooth wear scores they had the lowest dentine wear scores with a maximum of 6% both lower molars, 3% for tooth 16 and 2% for tooth 26 (average of 4.25%).

Canines showed the lowest tooth wear prevalence with a range from 64% for tooth 33 to 74% for tooth 23 and 72% and 70% respectively for the 13 and 43. The average wear prevalence for the canine was 70%.

Central incisors tooth wear prevalence ranged from 75% for tooth 11 to 84% for tooth 31. Teeth 21 and 41 had tooth wear prevalence of 81% and 83% respectively. The average wear prevalence for the central incisors was 80.75%.

Unlike the first molars and canines for which enamel wear scores were higher than scores for dentine wear, dentine wear scores were higher than enamel wear scores for the central incisor teeth.

Tooth wear prevalence was separately determined for males and female (Figures 7, 8, 9 and 10), it is clear that the same trend of wear distribution is seen in males and females. For females the average tooth wear prevalence was 85.25%, 65.75%, and 78.5% for the first molars, canines and central incisors respectively.

For males the average tooth wear prevalence was 86%, 75.75%, and 80.5% for the first molars, canines and central incisors respectively.

A comparison between the numbers of wear facets found in males and in females found no significant of the difference between the males and females groups (p=0.17).

Table 3: Number of wear facets in males versus females

Wear Score	M	F
0	166	224
E	533	581
D	130	153

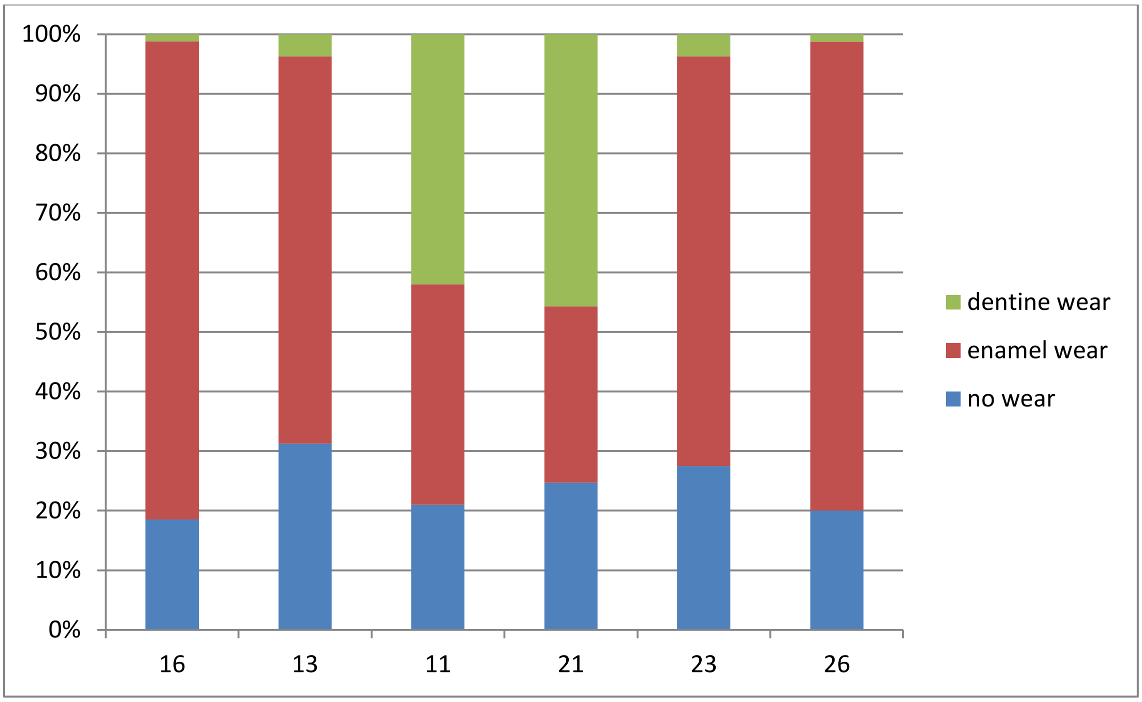

Figure 7: Tooth wear prevalence of upper teeth in females

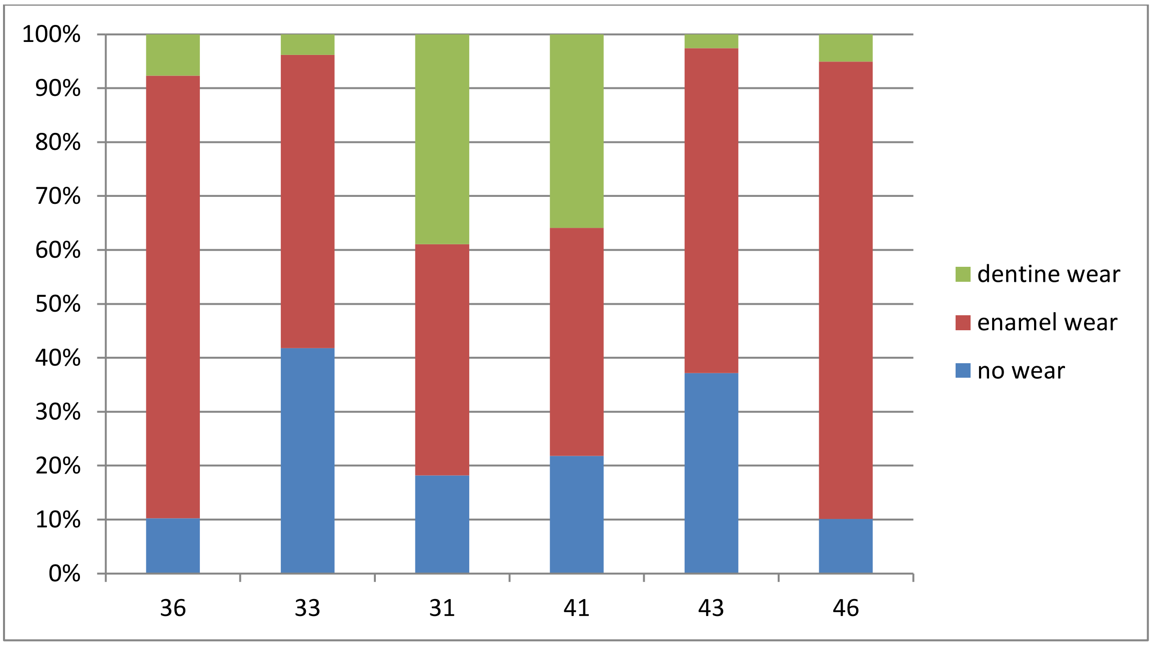

Figure 8: Tooth wear prevalence of lower teeth in females

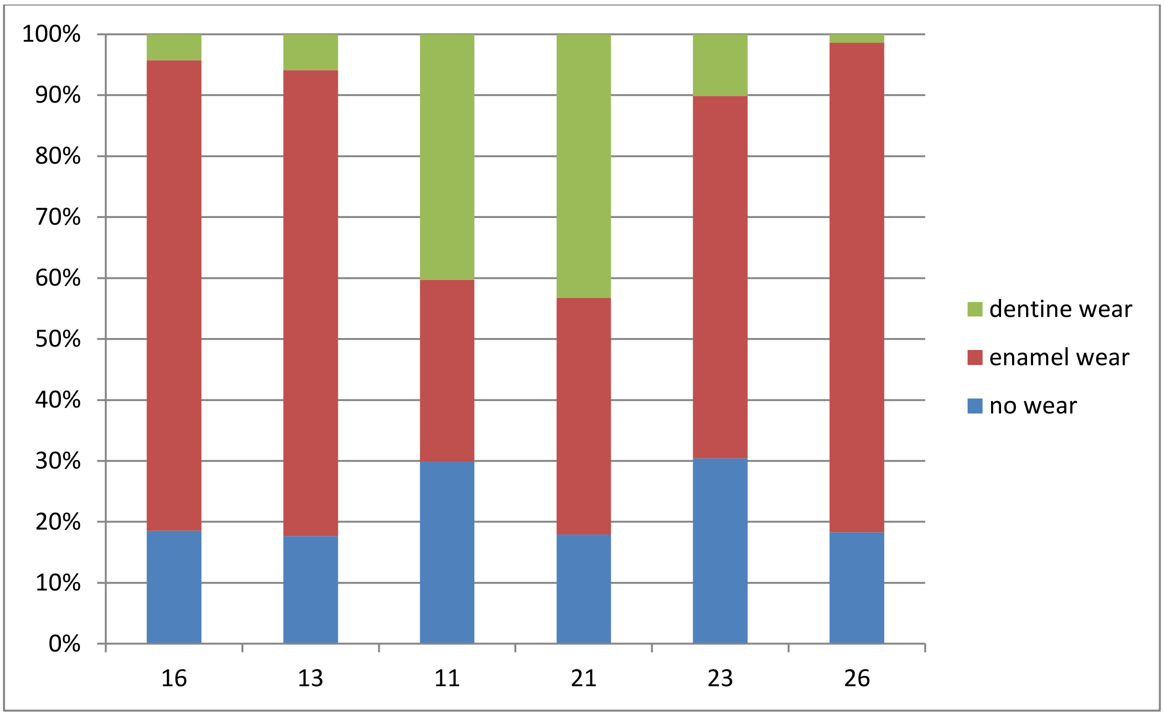

Figure 9: Tooth wear prevalence of upper teeth in males

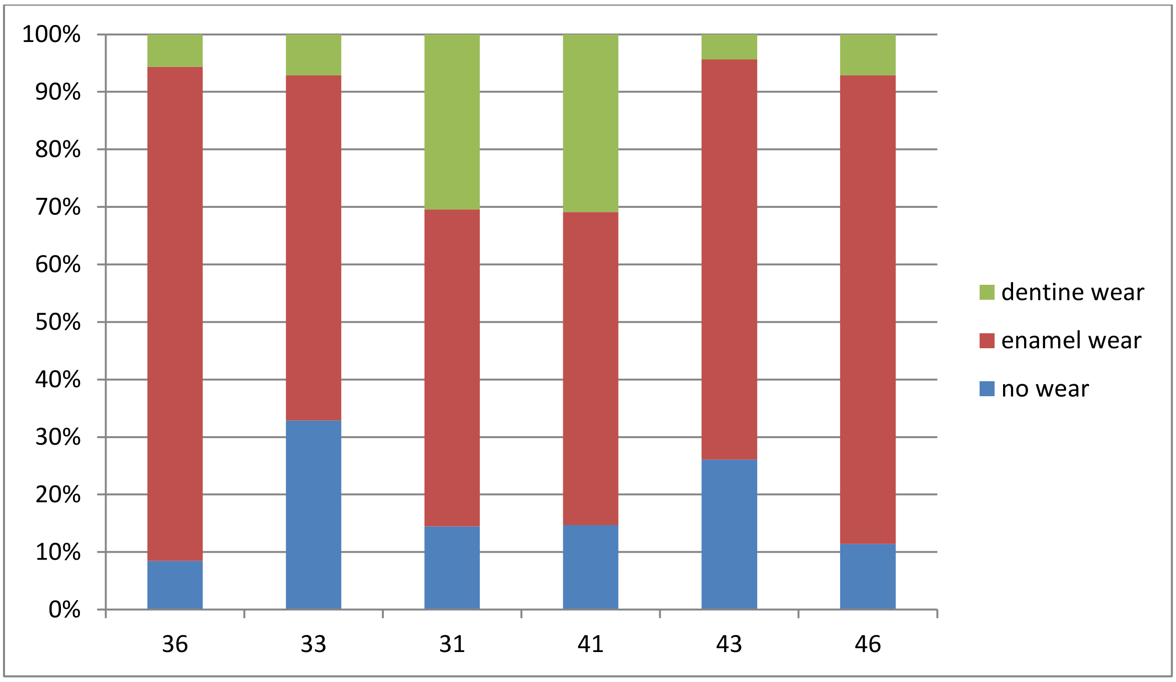

Figure 10: Tooth wear prevalence of lower teeth in males

To facilitate subsequent genetic analysis tooth wear scores for MZ and DZ twins were compared. These data showed a trend similar to the overall tooth wear scores (Figures 11, 12, 13 and 14).

For MZ twins the average tooth wear prevalence was 82%, 68.25%, and 76.25% for the first molars, canines and central incisors respectively. For DZ twins the average tooth wear prevalence was 92%, 68%, and 85.25% for the first molars, canines and central incisors respectively.

Table 4 shows data comparing the number of wear facet found in MZ and DZ twins suggesting that there is no significant difference between the groups ($p>0.05$).

Table 4: Number of wear facets in MZ versus DZ twins

	MZ	DZ
0	187	136
E	456	486
D	122	113

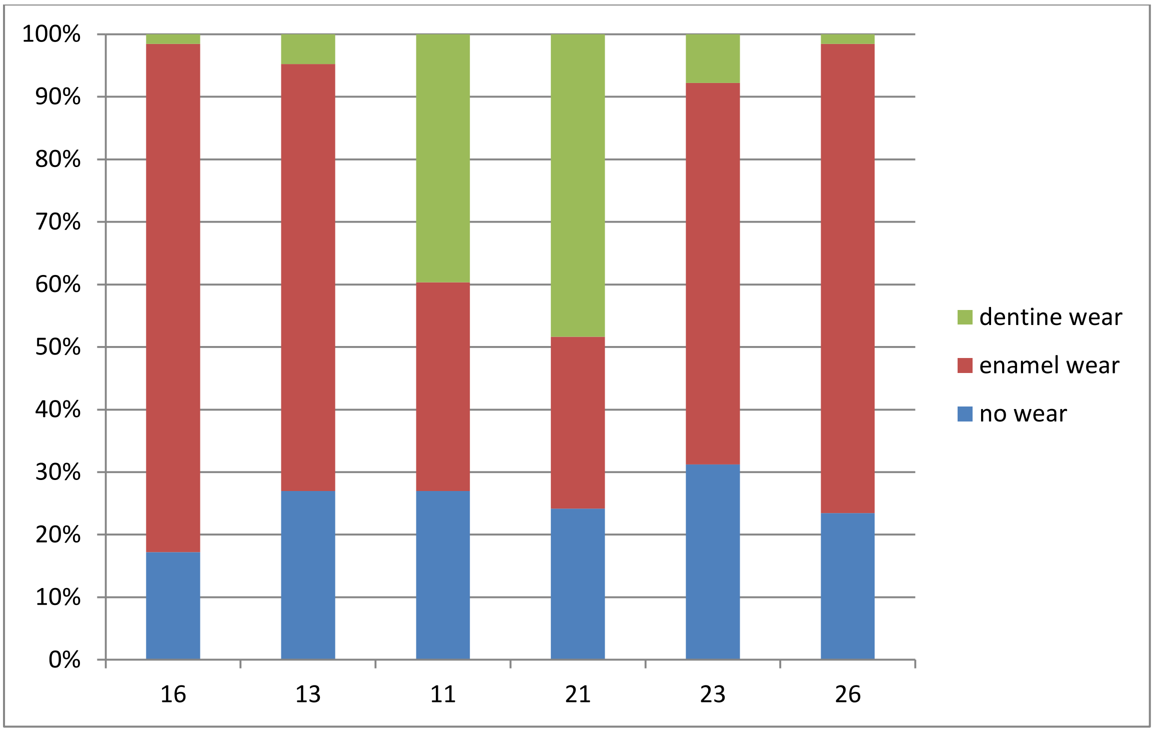

Figure 11: Tooth wear prevalence of upper teeth in MZ twins

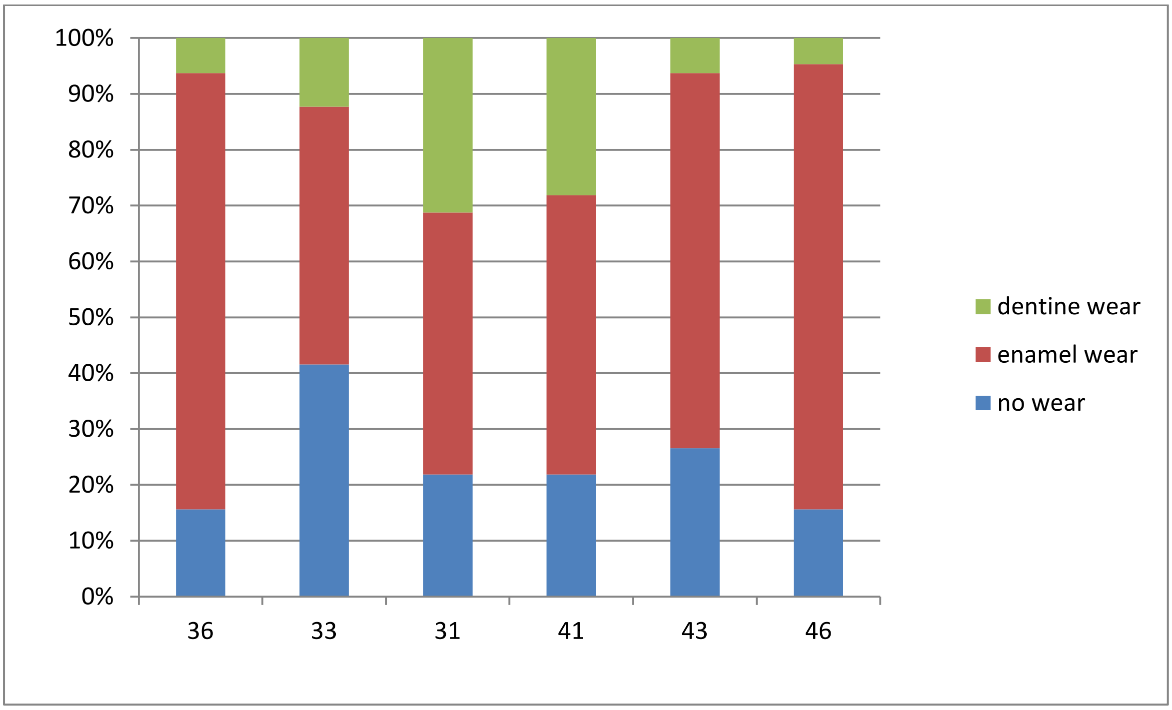

Figure 12: Tooth wear prevalence of lower teeth in MZ twins

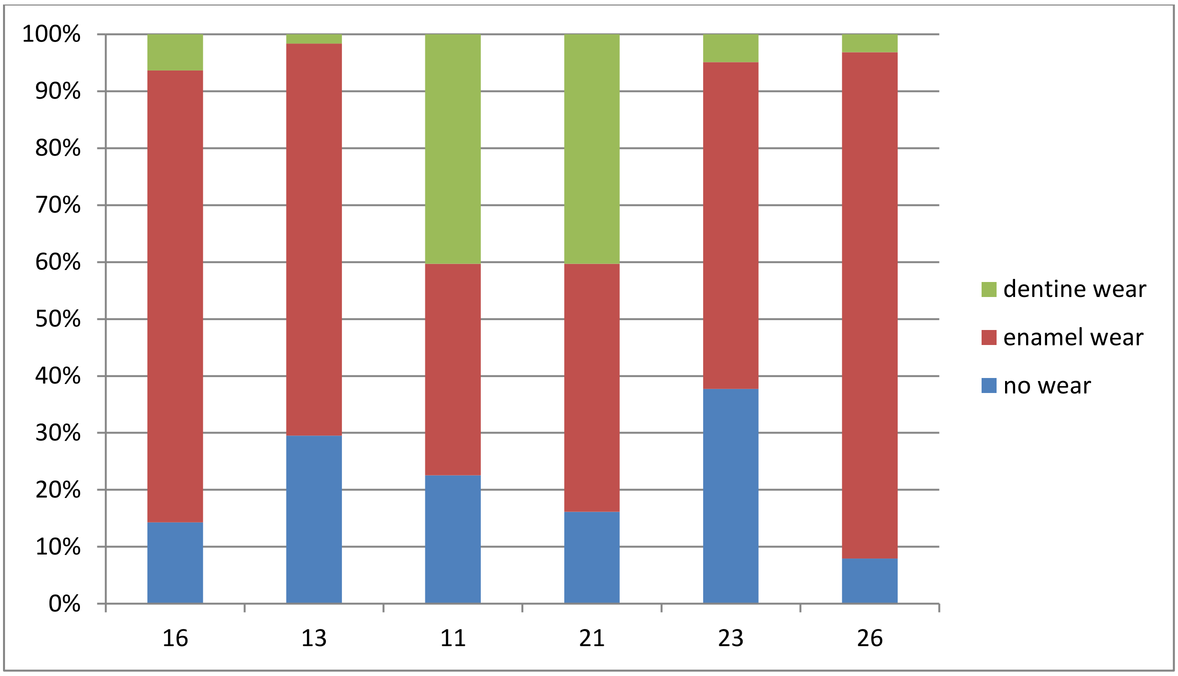

Figure 13: upper tooth wear score in DZ twins

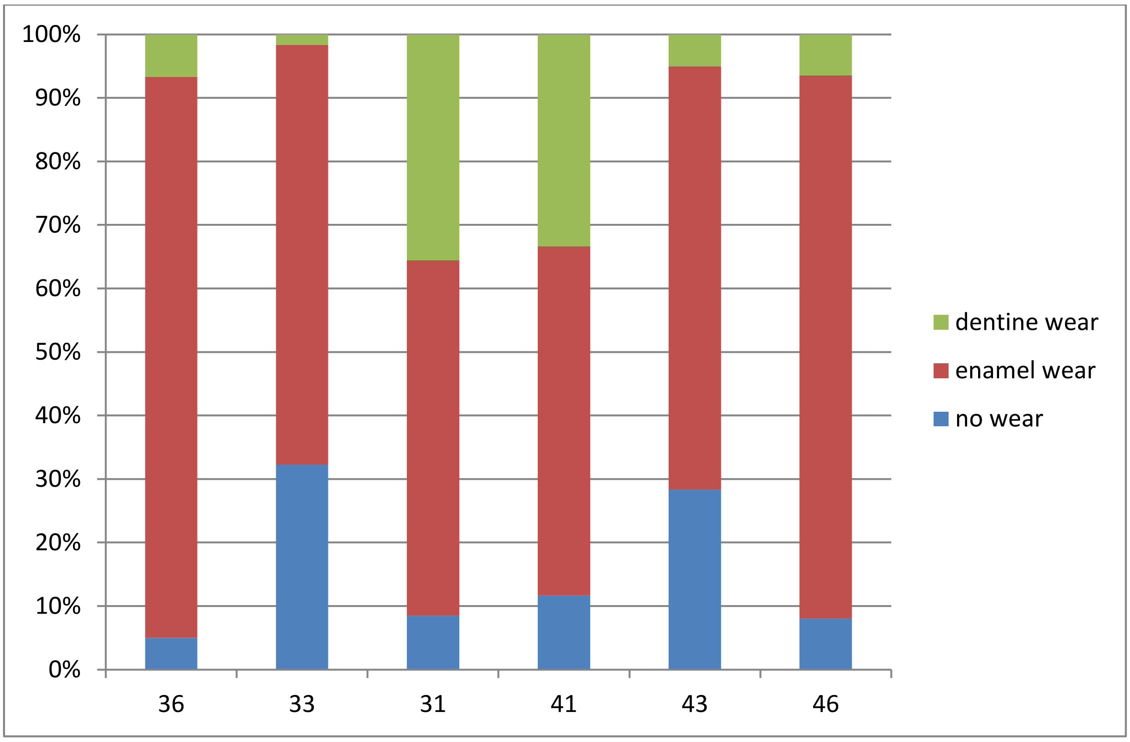

Figure 14: Tooth wear prevalence of lower teeth in DZ twins

4.2 Overjet and overbite

Data describing overjet and overbite are presented in Tables 5 and 6. Mean overjet and overbite for the selected sample was within the normal limits (2-4 mm) (Hirsch et al 2005, Kinaan 1986).

Table 5: Overjet and overbite values

	N	mean	SD
Overjet	128	3.62	1.66
Overbite	128	3.31	2.29

Table 6 shows the comparable overjet and overbite values between males and females.

Table 6: Overjet and overbite values in males and females.

		N	Mean	SD
Overbite	Male	71	3.61	1.54
	Female	81	3.38	1.26
Overjet	Male	71	3.52	1.45
	Female	81	3.17	2.69

As part of the genetic analysis, overjet and overbite scores were compared between MZ and DZ twins members (Figures 15, 16, 17, and 18)

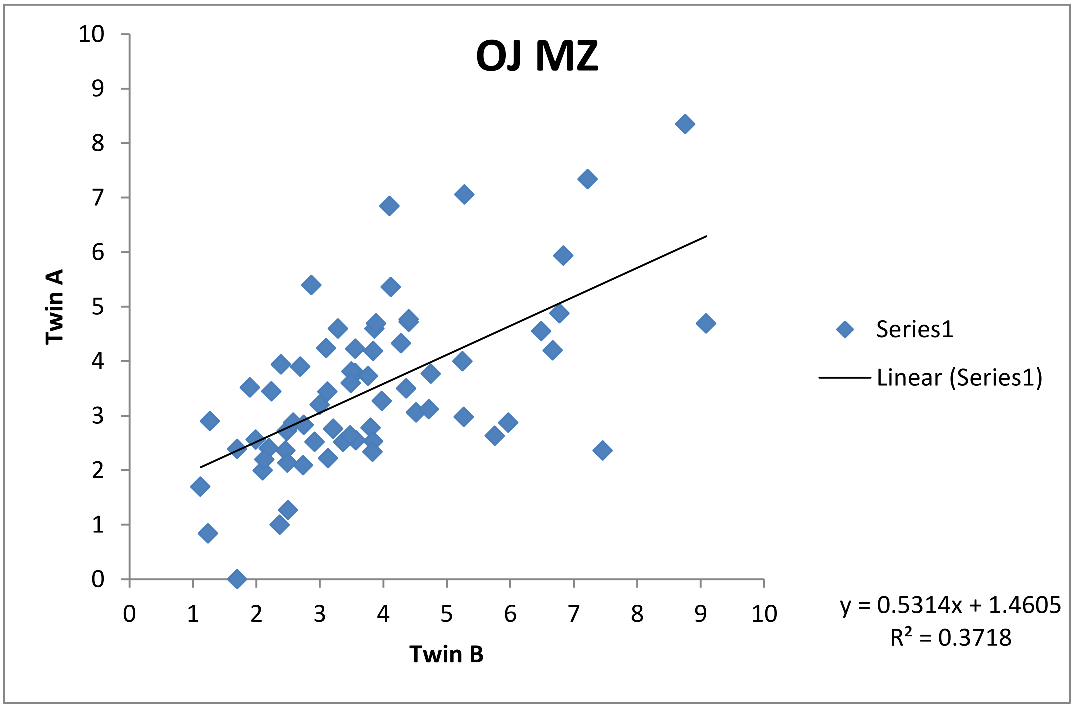

Figure 15: Overjet values in MZ twins (twins A versus twin B)

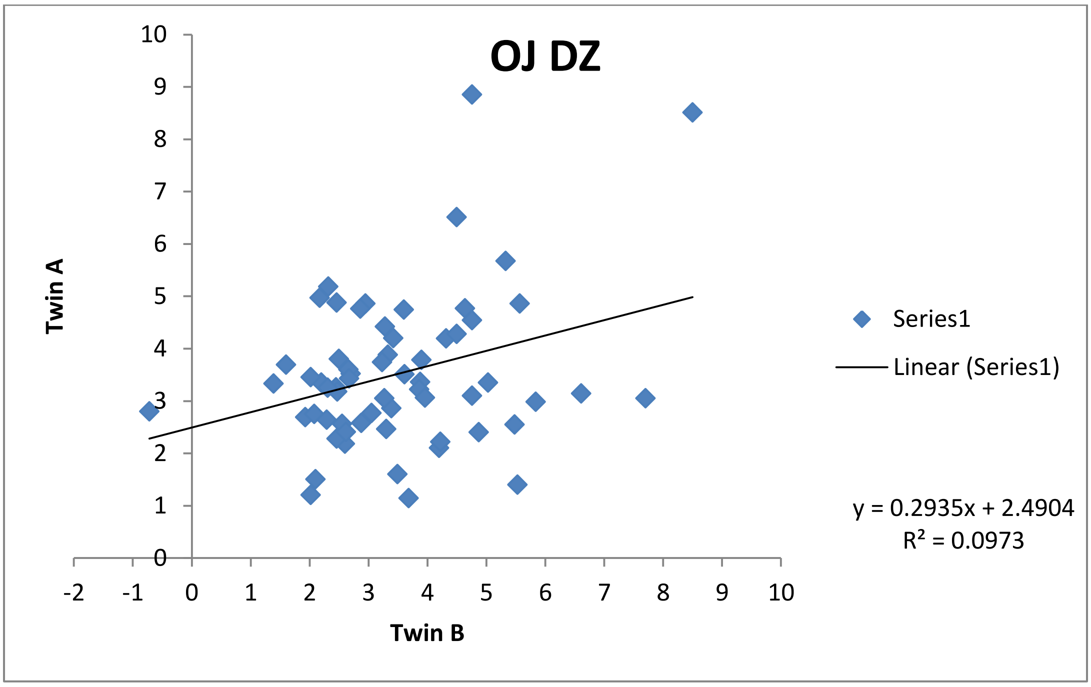

Figure 16: Overjet values in DZ twins (twin A versus twin B)

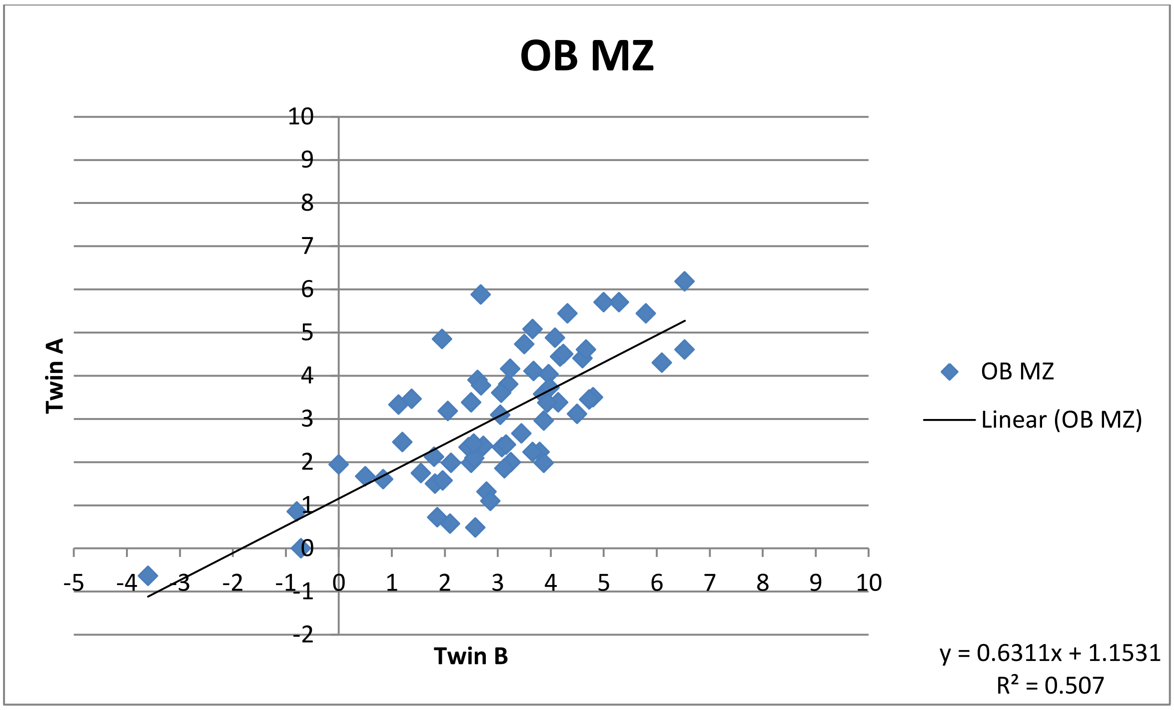

Figure 17: Overbite values in MZ twins (twin A versus twin B)

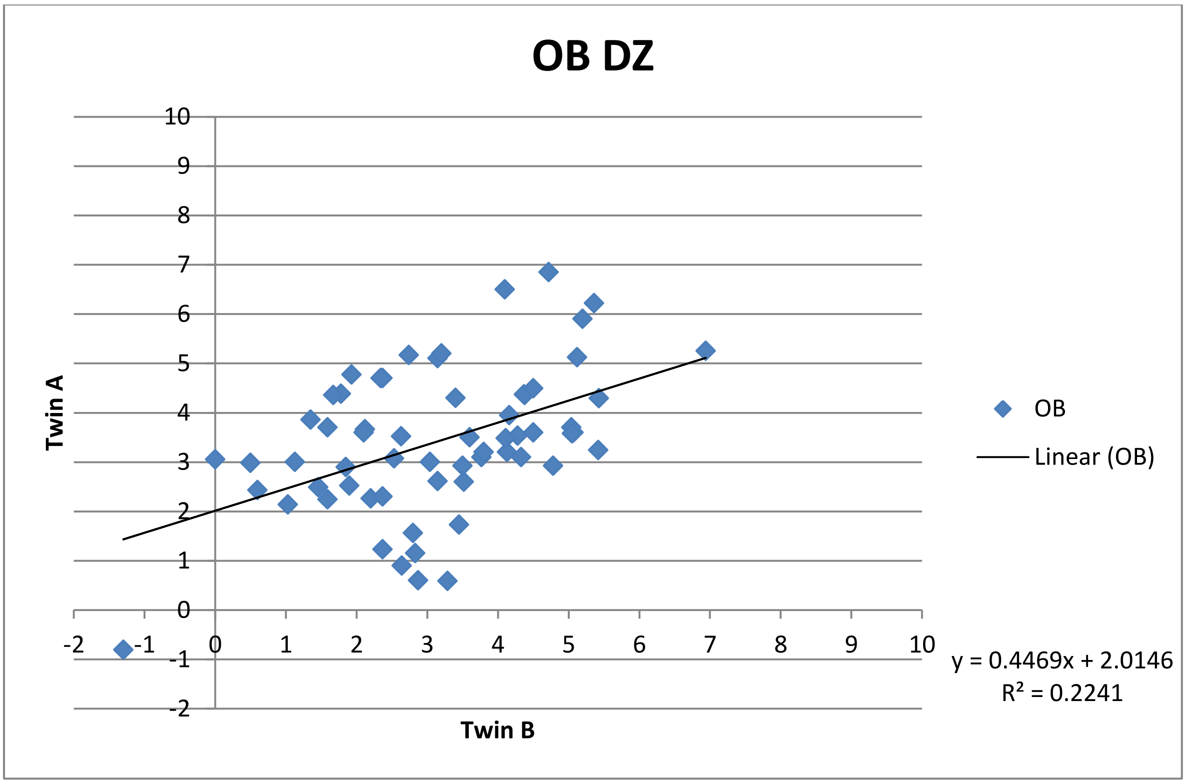

Figure 18: Overbite values in DZ twins (twin A versus twin B)

Overjet and overbite values were compared to tooth wear in all individuals (one randomly selected member of each twin pair) and the analysis was repeated separately for MZ twins and DZ twins to facilitate the subsequent genetic analysis. This was done by comparing OJ and OB to tooth wear prevalence of each scored tooth separately (this included all the first molar teeth, all the canine teeth and all the central incisors teeth). No significant relationship between the overjet and overbite values and the tooth wear prevalence was evident for any of the teeth considered. ($p>0.05$). The outcome of this analysis is presented in Appendix 1.

The relationship between overbite and overjet was also investigated in the MZ and DZ twin samples and among unrelated individuals. The correlation coefficients were positive but did not differ significantly from zero (Figures 19, 20, and 21)

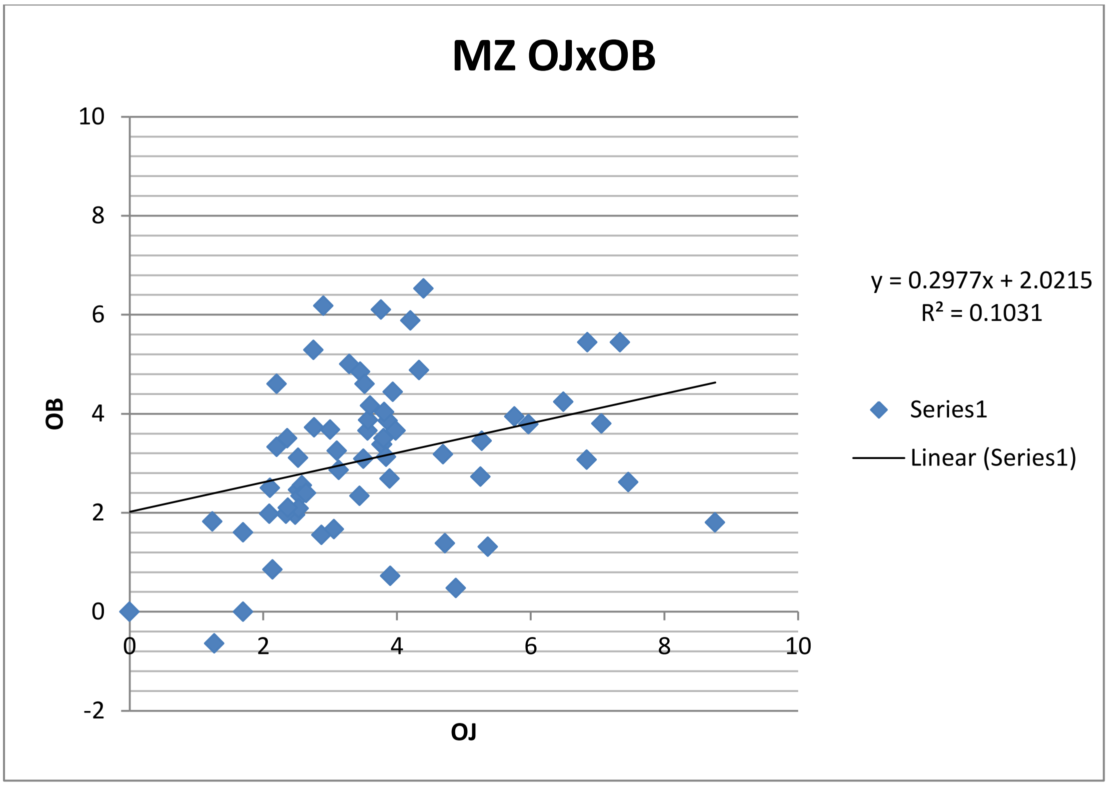

Figure 19: The relation between overjet and overbite values in MZ twins

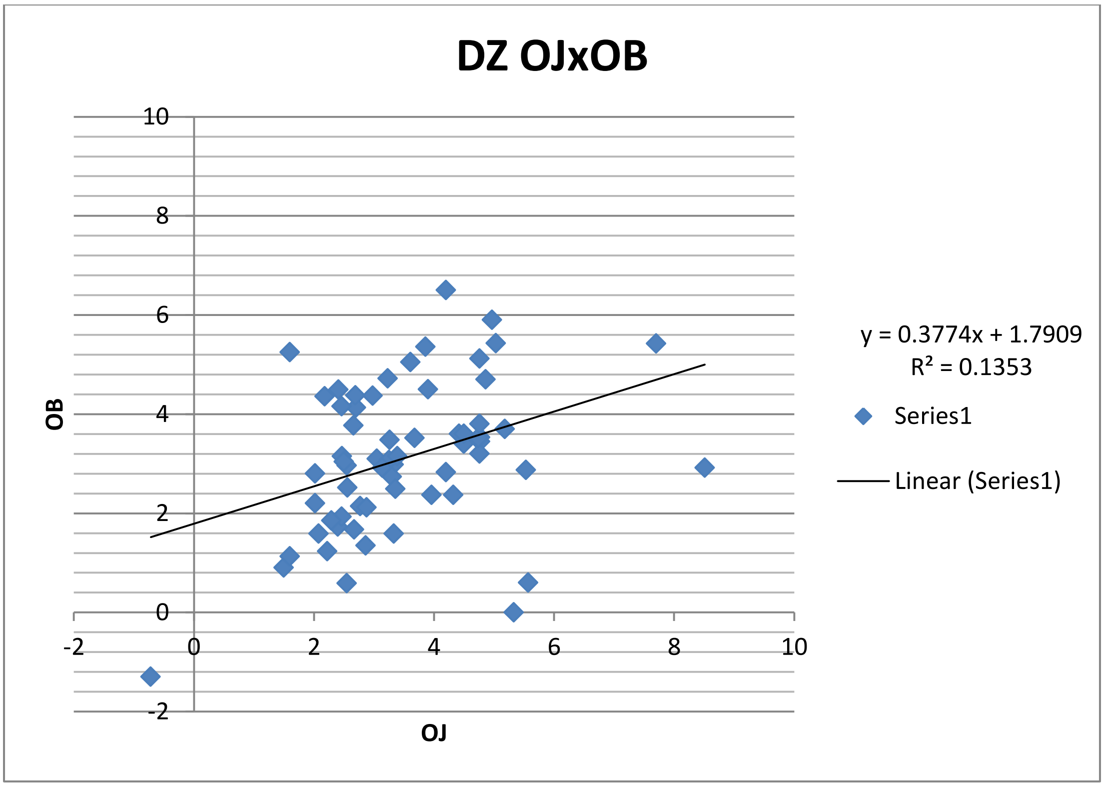

Figure 20: The relation between overjet and overbite values in DZ twins

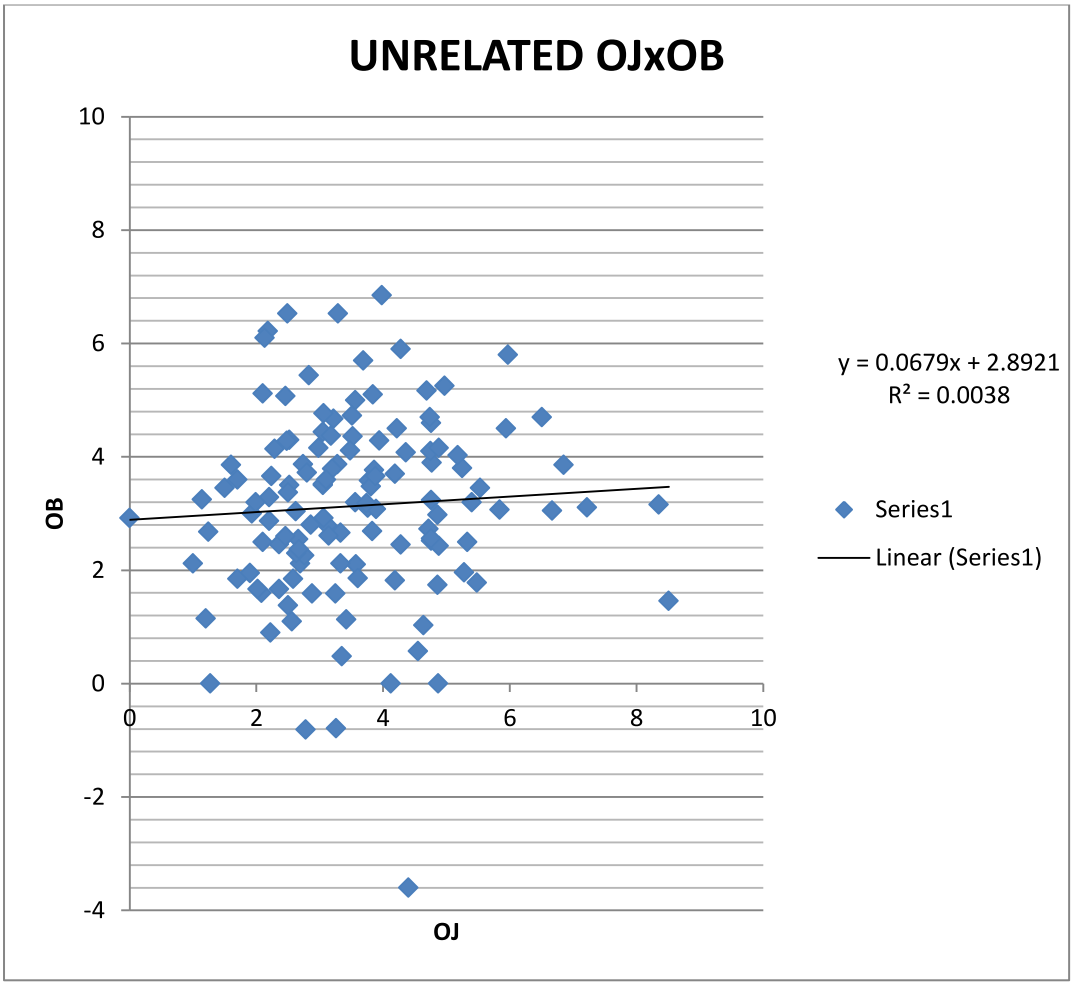

Figure 21: The relationship between overjet and overbite values in unrelated individuals

4.3 Genetic analysis

The structural equation modeling suggested that there was no evidence of a significant genetic contribution to the variation in overbite or overjet (h^2 not significantly different to zero) but there was evidence (data not included) of an influence of shared twin environment on the variation in overjet (30%) and overbite (50%) .

The heritabilities for each of the tooth wear scores are presented in Table 7. For the molars (except for 46 where the h^2 was unexpectedly high - range 0.36-0.87) estimates were generally not significantly different from zero (or as low as 0.02 for the 16) indicating a very low or undetectable genetic input to the observed variation. For the incisors heritabilities were in the range 0.51-0.63 indicating that 51-63% of the observed variation in wear scores could be attributed to underlying genetic factors while canine score heritabilities ranged from 0.46 to 0.57 but was not different from zero for tooth 13.

Table 7: Heritability estimates

	Heritability (h^2)	Upper 95% confidence limit	Lower 95% confidence limit
Tooth 16	0.44	0.02	0.76
Tooth 13	ns		
Tooth 11	0.63	0.41	0.78
Tooth 21	0.58	0.3	0.78
Tooth 23	0.57	0.26	0.77
Tooth 26	ns		
Tooth 36	ns		
Tooth 33	0.46	0.22	0.66
Tooth 31	0.51	0.25	0.71
Tooth 41	0.57	0.3	0.77
Tooth 43	0.51	0.23	0.72
Tooth 46	0.67	0.36	0.87

5. DISCUSSION

Many studies have considered the aetiology of tooth wear leading to the general view that it has a multifactorial origin and that in the majority of cases more than one causative factor is involved. In many tooth wear cases it is difficult to detect the main aetiological factor and it may be even more difficult to control or eliminate the cause even though this is a very important step in management of tooth wear. Many of these studies concentrate on the local and environmental factors, but not much is known about the underlying genetic effect on the factors that influence the prevalence of tooth wear.

This study considered the prevalence of tooth wear in selected, fully erupted permanent teeth including all the first permanent molars, all the permanent canines and all the central incisor teeth.

The data revealed that tooth wear was a very a common phenomenon in the current selected sample with no obvious effect of the gender, the zygosity or even the tooth position in the arch on the prevalence or pattern of tooth wear. These results are in agreement with Seligman's (1988) finding that tooth wear is a centrally induced phenomenon.

In general, canines may have been expected to show the highest wear scores due to their involvement in providing guidance for lateral excursions, but in this study canines were the least affected and also had the least dentine wear. This might be explained by the fact that of the scored teeth the canines were the last to erupt and therefore had the least exposure to any environmental factor (local or systemic) that may cause tooth wear.

Dentine wear scores were highest for the central incisor teeth. This may be the result of parafunction occurring in a more anterior jaw position, but could also arise because of the eruption times for these teeth resulting in them being exposed to the causative factors for a longer period. In addition, the role of the incisors in the provision of anterior occlusal guidance could also result in more wear.

The high prevalence of tooth wear in our study sample may support the statement by Seligman et al (1988) who concluded that " individuals in modern society who show notable attrition often demonstrate this occlusal feature (which is the tooth wear) at least by the time they are young adults".(Seligman 1988)

Occlusal variables studied including overjet and overbite did not show high heritability which supports the findings of Corruccini and Potter (1980) who studies multiple occlusal variables in twins to determine the genetic basis for dental variation and also found their data difficult to interpret because of the confounding effect of common environment.

The cause and effect relationship between occlusal factors and tooth wear is a continued debate and a question that still needs to be investigated and hopefully answered.

In a study by Wang (1992) investigating the effect of occlusal factors on bruxism (one of the major causes of tooth wear) by clinical examination and photo-occlusal analysis it was concluded that "*occlusal factors are not a major causative factor in bruxism occurrence*" This conclusion agreed with what Vanderas and Manetas (1995) concluded in a review of literature regarding the relationship between malocclusion and bruxism. They stated that "malocclusion does not increase the possibility of bruxism" and therefore early treatment of malocclusion to prevent bruxism has no scientific justification. A similar conclusion was reached by Cheng et al. (2004) who explored the influence of occlusion on the incidence of bruxism in children in Shanghai. They found that "occlusion does not affect the incidence of bruxism in children".

In the current study, the occlusal factors considered (over bite and overjet) did *not* seem to be related significantly to tooth wear prevalence. This conclusion supports a previous study which found that parafuctional habits (such as bruxism and clinching) are responsible for excessive occlusal wear, fractured teeth, tooth mobility, the effect of traumatic occlusion on periodontium, fractured restorations, myofascial pain involving muscles of mastication, and TMJ pain (Denbo, 1990). Correction of malocclusion with orthodontic procedure, restorative procedure, or occlusal adjustment by selective grinding will not control parafuctional habits.

The findings of this study suggest that genetic factors do not consistently influence wear scores for the first molar teeth but that the combined effect of all possible genetic factors account for between 46% and 63% of the observed variation in wear scores for canines and central incisors.

Apart from Taji et al (2010) no previously reported studies have considered the contribution of genetic factors to variation in tooth wear scores. In their study they found no differences between dental erosion of primary teeth in MZ and DZ twins age 2-4 years and concluded that the contribution of genetic factors to dental erosion was negligible. The present study suggest that in older subjects and when all forms of permanent tooth wear are considered (ie attrition, erosion and abrasion), there is some evidence of the influence of genetic factors.

The observed difference in the influence of genetic factors between anterior teeth and first molars remains unexplained. It could be speculated that this involves factors such as the greater protection of posterior teeth by saliva, or the protection of molars from parafunctional wear by excursive anterior contacts, but it might also arise as a result of differences in eruption times between molars and canines and overall differences in scores between incisors and molars.

Further study involving larger sample sizes, more complex analytical methods and the longitudinal analysis of twin pairs will be required to determine the exact nature of the genetic factors influencing tooth wear and the causes of the differences in these patterns between anterior teeth and first molars.

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Appendix 1

Overbite and Tooth wear

To determine a possible relationship between tooth wear and on one hand and overjet and overbite on the other hand, the values of overjet and overbite were divided into 3 groups (small, medium, and large) with even number of individuals in each group.

The tables bellow show the prevalence of tooth wear in relation to the overjet and overbite levels (left hand side). On the right hand side, the probability with values indicating the lack of statistically significant relationship between tooth wear and overbite or overjet.

OB x 16tw			16		
		0	1	2	
	small	3	37	3	
OB	mid	5	34	1	P=0.997172
	large	9	34	0	

OB x 13tw			13		
		0	1	2	
	small	13	26	3	
OB	mid	13	25	1	P=0.977163
	large	9	33	1	

OB x 11tw			11	
		0	1	2
	small	11	12	20
OB	mid	11	17	12
	large	9	16	17

P=0.969215

OB x 21tw			21	
		0	1	2
	small	10	11	21
OB	mid	7	17	15
	large	7	14	20

P=0.968383

OB x 23tw			23	
		0	1	2
	small	11	26	5
OB	mid	12	24	1
	large	9	32	2

P=0.98647

OB x 26tw			26	
		0	1	2
	small	4	38	1
OB	mid	9	30	1
	large	8	36	0

P=0.979746

OB x 36tw			36	
		0	1	2
	small	6	34	2
OB	mid	2	36	2
	large	6	35	3

P=0.957803

OB x 33tw			33	
		0	1	2
	small	14	29	0
OB	mid	18	18	5
	large	14	30	0

P=0.999995

OB x 31tw			31	
		0	1	2
	small	9	20	12
OB	mid	6	19	14
	large	4	24	14

P=0.962194

OB x 41tw			41	
		0	1	2
	small	10	18	15
OB	mid	6	20	13
	large	5	25	12

P=0.972428

OB x 43tw			43	
		0	1	2
	small	9	33	1
OB	mid	11	23	4
	large	16	24	1

P=0.998017

OB x 46tw			46	
		0	1	2
	small	6	31	5
OB	mid	1	39	0
	large	6	36	2

P=0.999835

Overjet xTooth wear

OJ x 16tw			16		
		0	1	2	
	small	5	33	2	
OJ	mid	6	35	1	P=0.916575
	large	6	37	1	

OJ x 13tw			13		
		0	1	2	
	small	11	25	3	
OJ	mid	9	30	1	P=0.971583
	large	15	29	1	

OJ x 11tw			11		
		0	1	2	
	small	5	15	19	
OJ	mid	9	14	19	P=0.999708
	large	17	16	11	

OJ x 21tw			21		
		0	1	2	
	small	6	12	21	
OJ	mid	9	10	20	P=0.992409
	large	9	20	15	

OJ x 23tw			23		
		0	1	2	
	small	8	27	3	
OJ	mid	9	28	4	P=0.982376
	large	15	27	1	

OJ x 26tw			26		
		0	1	2	
	small	2	36	2	
OJ	mid	6	35	0	P=0.999974
	large	13	33	0	

OJ x 36tw			36		
		0	1	2	
	small	4	32	3	
OJ	mid	3	37	2	P=0.9485
	large	7	36	2	

OJ x 33tw			33		
		0	1	2	
	small	17	23	0	
OJ	mid	15	25	2	P=0.974568
	large	14	29	3	

OJ x 31tw			31		
		0	1	2	
	small	5	18	15	
OJ	mid	7	17	16	P=0.993091
	large	7	28	9	

OJ x 41tw			41	
		0	1	2
	small	6	19	14
OJ	mid	7	18	16
	large	8	26	10

P=0.969191

OJ x 43tw			43	
		0	1	2
	small	10	26	2
OJ	mid	13	26	2
	large	13	28	2

P=0.911328

OJ x 46tw			46	
		0	1	2
	small	3	31	5
OJ	mid	1	41	0
	large	9	34	2

P=0.999996