Occlusal Changes Following Posterior Tooth Loss in Adults. Part 2. Clinical Parameters Associated with Movement of Teeth Adjacent to the Site of Posterior Tooth Loss

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Purpose: Much anecdotal evidence is available on tooth positional changes following loss of an adjacent tooth, but only a few studies are available. In Part 1 of this series, supraeruption was assessed and Generalized Linear Models were made to determine the clinical parameters associated with the supraeruptive process. The models demonstrated that clinical parameters were not only associated with the extent of supraeruption, but also with the type of eruption present. This investigation of tooth positional changes adjacent to sites of posterior tooth loss attempts to provide increased understanding of the magnitude, direction, and associated features that may be helpful in decision making and treatment planning in the clinical setting.

Materials and Methods: One hundred patients with an unopposed posterior tooth, with 100 age, sex, and bone level matched controls, were drawn from patients undergoing routine restorative care at Leeds Dental Institute. Study models were scanned, and the extent of eruption, type of eruption of the unopposed tooth, the overbite, overjet, buccal occlusion, and degree of crowding in the dentition, tipping, rotation, and buccal movement of the teeth associated with the edentulous site were recorded. Generalized Linear Models were developed to examine associations between each tooth movement and patient or dental factors.

Results: A statistical significance in the degree of tipping of teeth both mesial and distal to the extraction site was detected between the subject and control groups. There was also a significant difference in rotation of the tooth mesial to the site. Four Generalized Linear Models were produced of the types of non-vertical movements found in teeth associated with sites of tooth loss.

Conclusions: Teeth adjacent to the site of tooth loss may undergo non-vertical movements. Teeth mesial to the extraction site had a tendency to tip distally. The degree of tipping was increased in upper teeth and in subjects with a cusp-to-cusp buccal occlusion. Rotation of teeth mesial to the extraction site was more prevalent in the lower arch. Tipping of the tooth distal to the extraction site could be extreme and was found to be more prevalent in subjects with a reduced (Code 1) overbite and in the lower arch. Rotation of teeth distal to the extraction site was greater in the upper arch and was also associated with a reduced (Code 1) overbite. It also had an association with rotation of the tooth mesial to the extraction site. Models of non-vertical movement are likely to be of limited value due to overdispersion, indicating a high degree of variability within the model.

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INDEX WORDS: tipping, rotation, drifting, extraction site

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MUCH ANECDOTAL evidence is available on tooth positional changes following loss of an adjacent tooth, but only a few studies are available. These papers mainly concentrate on individual tooth movements in isolation from patient and other dental factors, and provide only a limited view of the overall clinical situation.

In Part 1 of this series, supraeruption was assessed, and Generalized Linear Models were made to determine the clinical parameters associated with the supraeruptive process. The models demonstrated that clinical parameters were not only associated with the extent of supraeruption, but also with the type of eruption present.

This investigation of tooth positional changes adjacent to sites of posterior tooth loss attempts to provide increased understanding of the magnitude, direction, and associated features that may be helpful in decision-making and treatment planning in the clinical setting.

Agerholm and Sidi[1] found that the teeth most commonly lost to caries were the lower first molars, and that those most commonly lost due to periodontal disease were the upper second molars and lower incisors. This distribution is similar to that reported by Vignarajah[2] who found that the upper third molars and the lower central incisors were most commonly lost due to periodontal disease.

Orthodontists have long been aware of the spontaneous movements made by teeth following the extraction of a neighboring tooth. As early as 1887, Davenport[3] studied in detail a wide range of possible tooth movements following the loss of an adjacent or opposing tooth. Although this article was essentially a description of the author's own observations, it was very much in agreement with the way post-extraction changes are perceived today. Natural spontaneous tooth movement has been used by orthodontists to relieve anterior and buccal crowding (Stephens[4]), although the outcome has been found to be unpredictable. Most of the studies available rely on subjects in their late childhood and teens. The effect of tooth extraction on crowding had been less well documented in adults. There will often be a need to counteract some of these spontaneous tooth movements in order to retain space at an extraction site to correct malocclusions. In other instances, orthodontic treatment has been used to counter undesirable movements prior to prosthetic replacement (Braun et al[5]).

Drifting and tipping of teeth adjacent to an extraction site are commonly reported phenomena. We may define drifting as the bodily horizontal movement of a tooth within the alveolar bone, which can be in a mesial, distal, lingual, or buccal direction, whereas tipping may be defined as the rotational movement of a tooth within bone about an axis located on its root length. Teeth commonly drift or tip unless restrained by contact with adjacent teeth or occlusal contacts in the opposing arch, and the direction of tip or drift will also be under these influences.

Kaplan[6] summarized these movements and acknowledged that tipping, drifting, supraeruption, and alveolar bone growth may take place simultaneously. Gragg et al[7] evaluated the rate of space reduction attributed to movement of teeth adjacent to extraction sites. The study involved the use of radiographs to determine space closure. The authors found that the rate of space closure was greatest during the 2 years following extraction, reducing to a less significant amount in the following years.

Love and Adams[8] investigated the incidence of tooth movement into edentulous areas. They reported distal and mesial movement into edentulous spaces, but did not differentiate between drifting and tipping.

From these reports it can be concluded that many factors determine the outcome of tooth loss in any individual. Teeth may move in several directions unless restrained by other tooth contacts, and the magnitude of these movements can be variable.

The purpose of this study was to determine the type and extent of non-vertical tooth movement of teeth adjacent to the site of tooth loss, and to examine associations between these movements and other clinical parameters.

Materials and Methods

In order to analyze the parameters associated with non-vertical tooth movement associated with posterior tooth loss, it was necessary to:

1. identify where non-vertical positional changes were occurring,
2. quantify the extent of these changes, and
3. explore patient and dental factors associated with non-vertical tooth movement.

Table 1. Tipping of the Tooth Anterior to the Extraction Site

Group	*Mean*	*Standard deviation*	*Range*
Subjects	0.25°	8.70	−19.4°–21.6°
Controls	2.74°	4.75	−6.16°–23.6°

95% confidence interval of the difference is −4.50, −0.41.
Mean of difference between groups: −2.49.

Table 2. Rotation of the Tooth Anterior to the Extraction Site

Group	*Mean*	*Standard deviation*	*Range*
Subjects	15.59°	11.53	0.01°–48.5°
Controls	7.97°	9.07	0.17°–47.47°

95% confidence interval of the difference is 4.70, 10.54.
Mean of difference between groups: 7.61.

The subject group for this study was the same group used to investigate supraeruption in Part 1 of this series. Briefly, there were 100 patients with an unopposed posterior tooth, with 100 age, sex, and bone level matched controls, drawn from patients undergoing routine restorative care at Leeds Dental Institute. Informed consent and Ethics Committee approval was obtained.

Diagnostic casts were scanned and analyzed using the methods previously described, thereby recording the extent of eruption, type of eruption of the unopposed tooth, the overbite, overjet, buccal occlusion, and degree of crowding of the dentition. Tipping, rotation, and buccal movement of the teeth associated with the edentulous sites were recorded.

Data analysis was divided into two parts:

1. *Basic data screening*
   Exploratory data analysis was undertaken using a number of statistical methods including examination of means and distributions, scatterplots, boxplots, and relative risk tables to examine trends and associations within the data set.
2. *Generalized Linear Modeling*
   Using Generalized Linear Modeling, models were developed to examine associations between each type of non-vertical tooth movement and patient or dental factors.

Results

Intra-examiner reliability was assessed using Bland–Altman plots and Kappa scores as appropriate. Reliability was found to be satisfactory.

A statistically significant difference in the degree of tipping of teeth anterior to the extraction site was detected between the subject and control groups (Table 1).

A statistically significant difference was detected in the degree of rotation of the tooth anterior to the extraction site between the subject and control groups (Table 2). The direction of rotation was also of interest, with the control groups more likely to display mesial rotation than the subject group, with 73% of control teeth having some degree of mesial rotation (Fig 1).

For buccolingual movement of the tooth anterior to the extraction site, no statistical difference could be detected between the subjects and controls (Table 3).

The extent of tipping of the tooth distal to the extraction site was statistically significant, with the subject group also having a wide range of values. All tipping in the subject group was in the mesial direction (Table 4).

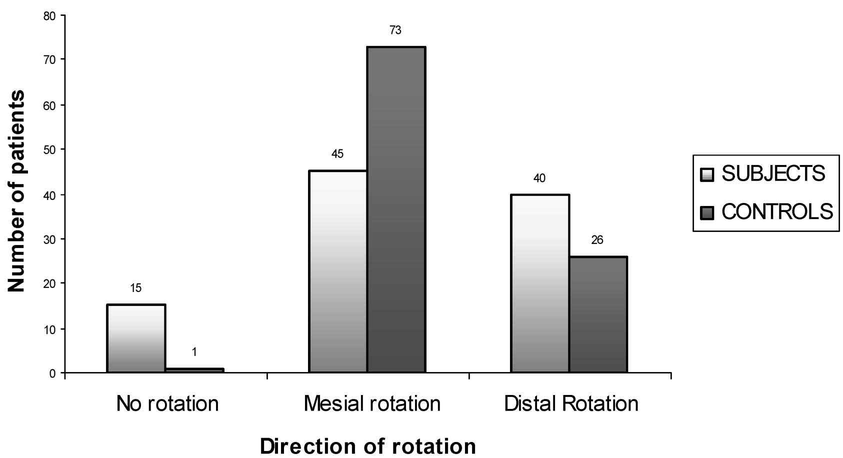

Figure 1. Direction of rotation of teeth anterior to the extraction site.

Table 3. Buccolingual Movement of Tooth Anterior to the Extraction Site

Group	*Mean*	*Standard deviation*	*Range*
Subjects	−0.09 mm	1.10	−6.4–2.7 mm
Controls	−0.05 mm	0.761	−3.2–3.4 mm

95% confidence interval of the difference is −0.21, 0.29.
Mean of difference between groups: 0.04

The means of the degree of tipping of upper and lower teeth distal to the extraction site are similar; however, the lower teeth have a greater likelihood of displaying extreme tipping (Table 5).

There was a statistically significant difference in rotation of the tooth distal to the extraction site between the subject and control groups (Table 6).

There was no statistically significant difference in buccal movement of the tooth distal to the extraction site between the subject and control groups (Table 7).

A Generalized Linear Model for tipping of the tooth anterior to the extraction site was produced and is shown in Table 8. Although in terms of standardized residuals and leverages the model would appear to be a good fit of the data, the residual deviance values appear to be inflated. This is likely due to overdispersion and is indicated by a high value for the dispersion parameter. Overdispersion indicates a high degree of variability in the model. On more detailed investigation of the raw residuals, these were found to have high values, indicating that although the model fits the data well, it is less useful due to the high degree of variability within the model.

A Generalized Linear Model for rotation of the tooth anterior to the extraction site was produced (Table 9). The fit of the model appears to be good when considering the standardized leverages and residuals. The residual deviance value was inflated and a high-dispersion parameter indicates that this model was also overdispersed.

A Generalized Linear Model for tipping of the tooth distal to the extraction site was produced (Table 10). As with the previous models of tooth movement associated with the teeth adjacent to the extraction site, this model fits well in terms of the standardized residuals and leverages, but has an inflated residual deviance and a high dispersion parameter indicating overdispersion.

A Generalized Linear Model for rotation of the tooth distal to the extraction site was produced (Table 11). Superficially the model may appear to fit the data well as the standardized residuals and leverages fit well; however, like the preceding models of this type of tooth movement, a high residual deviance and a high dispersion parameter indicate a poor fit of the data to the model.

Table 4. Tipping of Tooth Distal to the Extraction Site

Group	*Mean*	*Standard deviation*	*Range*
Subjects	18.45°	9.98	0–43.0°
Controls	2.77°	2.68	−2.3°–12.81°

95% confidence interval of the difference is 13.30, 18.05.
Mean of difference between groups: 15.67.

Table 5. Tipping of Upper and Lower Teeth Distal to the Extraction Site

Group	*Mean*	*Standard deviation*	*Range*
Upper	13.06°	1.37	0–23.8°
Lower	19.55°	10.75	0–43.1°

95% confidence interval in lower teeth is 16.9468, 22.1519.
95% confidence interval in upper teeth is 8.6117, 17.5114.

Discussion

An understanding of associated tooth movement following extraction should be appreciated by dentists practicing in all dental disciplines in order to provide the most appropriate care for both their adult and younger patients. Treatment planning should be carried out in the light of current evidence, and, should the treatment include extraction, the possible sequelae need to be appreciated by both the patient and the practitioner.

Table 6. Rotation of the Tooth Distal to the Extraction Site

Group	*Mean*	*Standard deviation*	*Range*
Subjects	10.91°	12.03	−30.20°–50.3°
Controls	4.78°	3.94	−11.92°–19.43°

Difference of means 6.13.
95% confidence interval of the difference is 3.22, 9.04.

Table 7. Buccal Movement of the Tooth Distal to the Extraction Site

Group	*Mean*	*Standard deviation*	*Range*
Subjects	0.35 mm	0.36	−2.37–3.18 mm
Controls	0.12 mm	0.12	−1.66–1.84 mm

95% confidence interval of the difference is −0.12, 0.49.
Mean of difference between groups: 0.19.

Loss of occlusal and interdental contact does not only occur in relation to complete tooth loss. It may also occur following caries, tooth fracture, loss of restorations, the wear of tooth tissue, and wear of restorations.

It has been advocated that a state of occlusal stability should be the goal of good treatment planning; however, Beyron[9] commented that occlusion is not a static concept but changes throughout life, due to disease, wear, tooth loss, and restoration, and therefore should be considered as an entity undergoing constant change.

Tooth positional changes, whether they are vertical, horizontal, rotational, or tipping, will affect the relative alignment of the crowns and roots of teeth, which may be involved in restoration or prosthodontic replacement. These positional changes may be of sufficient magnitude to complicate restorative treatment.

Obviously, change in the position of the tooth crown is clinically visible, but the changes in position of the root, and therefore the apex, may be of clinical relevance. Tilting may increase the proximity of roots of adjacent teeth and other anatomical structures, which may well create difficulties should surgical treatment become necessary. Changes in root position may also affect the interdental space available for implant placement.

While a few articles have reported on the movement of molars and premolars anterior to orthodontic extraction sites, it has been noted that distal drifting of canines can be responsible for a large degree of extraction space closure following orthodontic extraction to relieve crowding (Papandreas et al[10]). This investigation found that although in statistical and clinical terms there was only a small difference in the mean tip of teeth anterior to the extraction site (subjects: 0.2509, controls: 2.7740), the range of tipping (subjects: −19.4 to 21.6, controls: −3.16 to 23.3) does demonstrate a number of teeth had tilted distally

Table 8. Model and Estimates for Tipping of Tooth Anterior to Extraction Site

Model of Anterior Tooth Tip

$$TIPANT_i \sim N(u_i, \sigma)$$
$$\mu_i = 5.87_i - 7.04AR_i + 2.49BO2_i$$

Anterior tooth tip	*Value*	*95% CI*
Intercept	5.87	2.62, 9.12
Arch	−7.04	−10.78, −3.30
Buccal Occlusion Code 2	2.49	−0.25, 5.19

Residual Deviance: 5939 on 92 degrees of freedom

Where: $TIP\ ANT_i$ is the outcome for an individual, N is the normal distribution, AR_i is the arch in which the unopposed tooth lies, $BO2_i$ is the buccal relationship denoting cusp-to-cusp occlusion.

Table 9. Model and Estimates for Rotation of Tooth Anterior to Extraction Site

Model of Anterior Tooth Rotation

$$ROTANT_i \sim N(u_i, \sigma)$$
$$\mu_i = -2.43_i + 6.53AR_i + 8.50\ SIDE_i$$

Anterior tooth rotation	*Value*	*95% CI*
Intercept	−2.43	−9.82, 4.96
Arch	6.53	−1.88, 14.94
Side	8.50	1.21, 15.79

Residual Deviance: 29247 on 93 degrees of freedom

Where: $ROT\ ANT_i$ is the outcome for an individual, N is the normal distribution, AR_i is the arch in which the unopposed tooth lies, $SIDE_i$ is the side on which the unopposed tooth lies

Table 10. Model and Estimates for Tipping of Tooth Distal to Extraction Site

Model of Distal Tooth Tipping

$$TIPDIST_i \sim N(u_i, \sigma)$$
$$\mu_i = 8.24 + 3.36\,OB1_i - 4.12\,PRO_i + 7.14AR_i$$

Tip of distal tooth	*Value*	*95% CI*
Intercept	8.24	2.01, 14.47
Overbite	3.35	0.82, 5.88
Protrusive interference	−4.12	−8.77, 0.53
Arch	7.14	2.18, 12.10

Residual Deviance: 5503 on 69 degrees of freedom

Where: $TIPDIST_i$ is the outcome for an individual (extent of tip of tooth distal to extraction site), N is the normal distribution, $OB1_i$ is the presence of overbite Code 1, PRO_i is the presence of a protrusive interference, AR_i is the arch in which the unopposed tooth lies.

Table 11. Model and Estimates for Rotation of Tooth Distal to Extraction Site

Model of Distal Tooth Rotation

$$R.DIST_i \sim N(u_i\sigma)$$

$$\mu_i = 13.54 + 0.22ROT.A_i + 6.75OB1_i - 15.14AR_i$$

Rotation of distal tooth	*Value*	*95% CI*
Intercept	13.54	6.19, 20.89
Rotation of anterior tooth	0.22	0.06,0.38
Overbite Code 1	6.75	0.89,12.61
Arch	−15.14	−23.06,−7.22

Residual Deviance: 1533 on 65 degrees of freedom

Where: $R.DIST_i$ is the outcome for an individual (extent of rotation of tooth distal to extraction site), N is the normal distribution, $ROT.A_i$ is the rotation of the tooth anterior to the extraction site, $OB1_i$ is the presence of overbite Code 1, AR_i is the arch in which the unopposed tooth lies.

in the subject group. As no other studies quantifying tipping were available, comparisons with previous work were not possible.

In clinical terms, this distal tip alone may not create restorative difficulties; however, if combined with mesial tipping of an abutment tooth distal to the extraction site, path of insertion difficulties for prostheses may be encountered.

From the model produced, it might be deduced that mesial tipping of the tooth anterior to the extraction site will be less prevalent in the lower arch. More simply put, teeth anterior to lower extraction sites are likely to tip more distally than their matched controls. In a cusp tip-to-cusp tip buccal occlusion there is no cuspal interdigitation, and during functional movements the opposing cusp may exert forces that allow the tooth with no distal contact to alter position by tipping. Obviously, the direction of tip will be influenced by the presence of space distal to the tooth under investigation, but may also be influenced by the direction of force applied by functional occlusal movements against the opposing dentition.

A statistically significant difference in the extent of rotation was detected between the subject and control groups. Although functionally this may not be of clinical significance, extreme rotation of upper premolars may cause esthetic problems. What is also of interest is the wide degree of rotation of the teeth in this study, which were in the main premolars.

The arch in which the unopposed tooth lies, and the side of the arch, are the main explanatory covariates of the linear predictor of the outcome—rotation of the tooth anterior to the extraction site. The model produced demonstrates that mesial rotation of the tooth anterior to the extraction site is increased in the lower arch, on the left side.

It could be postulated that root form and/or area may influence a tooth's potential to rotate. It could be that the differences between upper and lower root forms have a role to play. The difference in the bony structure of the upper and lower alveolar bone may also be relevant. Kaplan[6] discussed segmental alveolar bone growth and bony remodeling in relation to drifting, tipping, and supraeruption. There is currently no quantitative evidence regarding the extent or etiology of rotation in healthy individuals. It is difficult to postulate why the side of the arch in which the unopposed tooth lies is significant in the model.

There was no statistically or clinically significant difference between the subject and control groups in the buccolingual position of the tooth adjacent to the extraction site. The reasons for this are likely to be similar to those for the maintenance of buccolingual position in unopposed teeth— that is the equilibrium theory (Weinstein,[11] Proffitt[12]).

Both research and anecdotal evidence exist to suggest that following tooth loss, in situations where mesial contact points are lost, teeth tend to undergo positional changes. Kaplan[6] suggested that the main force behind the production of tipping is the opposing occlusal contact. He presents no evidence for this assumption, and acknowledges that further research is needed in this area. The number of orthodontic papers demonstrating techniques for uprighting tipped molars suggests that this particular post-extraction movement has created a demand for correction.

The covariates that explain the outcome (tipping of the tooth distal to the extraction site) are overbite Code 1, presence or absence of a protrusive interference, and the arch in which the unopposed tooth lies. More simply put, tipping of the tooth distal to the extraction site will increase in patients with a reduced incisal overbite (1/3 or less overlap of the upper and lower incisors), with the absence of a protrusive interference and when the extraction site is in the lower arch.

There was a significant difference in the extent of rotation of teeth distal to the extraction site between the subject and control groups. Rotation was more prevalent in the upper arch and where rotation was also present in the tooth mesial to the extraction site. As with tipping, it also had an association with a Code 1 incisal overbite. This somewhat validated Davenport's[3] thoughts regarding upper molar rotation.

There were no significant differences in buccal displacement in the subject and control groups, probably for the same reasons as for lack of rotation of these teeth.

Overall, it can be seen from the models of tooth positional changes adjacent to the extraction site that the arch in which the tooth lies will affect the changes likely to occur. Lower teeth display a greater degree of tipping and rotation than upper teeth. The occlusion also appears to be important, in that tipping of the tooth distal to the extraction site is increased in patients with a reduced overbite, and that tipping of the tooth anterior to it is associated with a cusp-to-cusp buccal occlusion. There can be no demonstration of cause and effect in a cross-sectional study, and the change in buccal occlusion may have occurred as a result of the tipping of the tooth anterior to the extraction site, rather than the reverse.

Conclusions

Teeth adjacent to the site of tooth loss may undergo non-vertical movements.

Teeth mesial to the extraction site had a tendency to tip distally. The degree of tipping was increased in upper teeth and in subjects with a cusp-to-cusp buccal occlusion.

Rotation of teeth mesial to the extraction site was more prevalent in the lower arch.

Tipping of the tooth distal to the extraction site could be extreme and was found to be more prevalent in subjects with a reduced (Code 1) overbite and in the lower arch.

Rotation of teeth distal to the extraction site was greater in the upper arch and was also associated with a reduced (Code 1) overbite. It also had an association with rotation of the tooth mesial to the extraction site.

Models of non-vertical movement are likely to be of limited value due to overdispersion, indicating a high degree of variability within the model.

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