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# Periodontal status following surgical–orthodontic alignment of impacted central incisors with an open-eruption technique

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SUMMARY Several factors may affect the outcome of the orthodontic/surgical modality for the resolution of impacted central incisors, but particularly the manner in which the impacted tooth is exposed. The present study aimed to evaluate the post-retention clinical appearance and periodontal status of impacted maxillary central incisors which were exposed and aligned with an open-eruption surgical–orthodontic technique. Twelve subjects (four males, eight females), aged 22 years (range 15–38 years), previously treated for a unilateral impacted central incisor (ICI), were examined 10 years (range 3–25 years) post-retention. A split-mouth method was used for the comparison with the unaffected side. One treated central incisor exfoliated 10 years post-retention, thus the results were based on the remaining 11 patients.

Statistically significant differences were found between the affected and control incisors in most of the periodontal parameters measured, although some were small and of minimal clinical importance. The increase in the mesio-labial pocket depth was associated with a highly significant 10 per cent reduction in bone level at this site ($P = 0.007$). A highly statistically significant increase in crown length ($P < 0.001$) and a reduction in the width of the attached gingiva ($P = 0.005$) were seen in these previously impacted teeth. An abnormal gingival contour was present in eight treated incisors and positional relapse in five cases. It is concluded that the convenience of the open-eruption technique must be weighed against the long-term negative aesthetic and periodontal effects on the treated tooth, although the findings of this study should be viewed with caution due to the limited sample size.

## Introduction

Impacted teeth may be exposed by the removal or repositioning of the soft tissue that envelopes them, to leave them in full view at the end of the surgical procedure. This has been termed 'open-eruption' exposure. Removal of the oral mucosa overlying the unerupted teeth, although more direct, has the disadvantage that the finally erupted tooth will have a non-keratinized labial gingival margin, while apical repositioning may be expected to provide an adequate width of attached gingiva. The teeth may then erupt spontaneously or, via a bonded attachment, an extrusive force may be applied to augment a diminished natural eruptive force (Vanarsdall and Corn, 1977; Kokich and Mathews, 1993; Becker, 1998). Alternatively, the closed-eruption technique has an attachment placed at the time of exposure and the tissues fully replaced to re-cover the impacted tooth. Traction is then applied to the twisted stainless steel ligature or gold chain, which is linked to the attachment, to bring about the full eruption of the tooth (McBride, 1979; McDonald and Yap, 1986; Kokich and Mathews, 1993; Becker, 1998).

Much discussion has been generated among the proponents of the two methods regarding the attributes of one over the other, and this has been almost exclusively with regard to the resolution of palatally impacted canines (McBride, 1979; Kokich and Mathews, 1993; Ferguson and Parvizi, 1997; Burden *et al.*, 1999). However, little research has been carried out in the context of impacted central incisors (ICI), until recently, when a study was undertaken to investigate the long-term periodontal, pulpal and aesthetic outcomes following the resolution of a group of impacted maxillary central incisors using a closed-eruption surgical–orthodontic treatment technique (Becker *et al.*, 2002).

The present study was undertaken to investigate the same parameters as in the latter study, in a similar sample of post-treatment impacted maxillary central incisor patients, treated using an open-eruption surgical–orthodontic treatment technique.

## Subjects and methods

### *Sample*

Unilaterally impacted maxillary central incisors are rarely seen in most orthodontic practices and locally open surgery is infrequently performed. Accordingly, the records of six orthodontic practices were screened and 12 patients were found who had undergone orthodontic and surgical treatment for the resolution of an impacted maxillary central incisor. The criteria for inclusion in the study group were unilateral impaction, open exposure and a minimum follow-up of 1 year post-retention.

The aetiology of the central incisor impaction was determined from the patient's history, from the records of referring dentists and from radiographs. Obstruction in the path of eruption was the cause of impaction in four central incisors, dilacerations were found in four, and trauma was reported for one incisor. The remaining three cases were due to less specific aetiologies.

From the panoramic view, the initial height of the crown of the incisal edge of each ICI was assessed in the vertical plane relative to the root of the adjacent erupted incisor, which was arbitrarily divided into three zones. The apical zone included the apical third of the root, the middle zone comprised the middle third and the remainder was classified as the coronal zone. Five incisors were classified as apical, six as middle and one as coronal.

All cases were treated with fixed orthodontic appliances and, following orthodontic reopening of the incisor space, a small attachment was bonded at or shortly after surgery and eruptive traction was applied at that time. In all cases, the crown of the impacted tooth was clinically visible and accessible at the completion of the surgery and the tooth was brought into the arch by light orthodontic extrusive traction, maintained on the ligature wire. Extrusion was performed with the aim of bringing the incisal edge of the affected tooth to the same level as that of the adjacent teeth, with no compensatory over-extrusion. Following removal of the fixed appliances, no precautions against vertical relapse of the achieved extrusion were taken.

Table 1 indicates the age at the time of this examination, the sex distribution, the duration of treatment (from surgical exposure to alignment) and the length of the follow-up of the patients.

Each of the cases was examined and evaluated by two of the authors (SC and AB) at a prearranged appointment.

Comparisons were made between:

1. the previously ICI and the normally erupted contralateral central incisor (CCI);
2. the lateral incisor adjacent to the previously ICI (ALI) and the contralateral lateral incisor (CLI).

The split-mouth design in clinical research, where the treated side is compared with the unaffected side in the same mouth, is an accepted method of generating reliable controls to test the validity of a hypothesis regarding treatment effects. In the present study, the experimental (impacted) and control (normally erupted) incisors were adjacent to one another and it may be claimed that the surgical procedure on one might have had a secondary effect on the other. Accordingly, a comparison of both lateral incisors was included, as the proximity of the ALI to the ICI was identical to that of the CCI. It was considered that similar findings in the parameters of the two lateral incisors would suggest an insignificant adverse impact of the surgical procedure on the adjacent teeth and would thus serve to support the suitability of a split-mouth comparison.

The individual effect of specific variables that could affect the ultimate result (such as aetiology, treatment time, height of impaction) was not studied because of the small numbers involved.

### *Clinical evaluation*

The periodontal status of the contralateral pairs of incisors was assessed as follows: the mesial, distal, buccal and palatal surfaces of the teeth were scored for their plaque index (PI) and gingival index (GI), on a scale of 0–3 according to the methods described by Silness and Löe (1964) and Löe and Silness (1963) and the mean PI and GI were determined for each tooth.

A Michigan No. 0 probe with Williams' markings (Star Dental, Lancaster, PA, USA) was used to examine the pocket depth (PD), using a non-standardized light force with measurements rounded to the nearest millimetre. Determinations were made at the mesio-labial, mid-labial, disto-labial, mesio-palatal, mid-palatal and disto-palatal surfaces of each tooth examined and a mean PD was calculated for each tooth.

The width of the keratinized gingiva was measured as the distance from the free gingival margin to the mucogingival junction and the width of the attached gingiva was calculated by subtracting the mid-labial PD from the width of the keratinized gingiva. The distance between

**Table 1** Description of the patient sample.

| | Age at follow-up (years) | | Treatment time* (years) | | Length of follow-up (months) | |
|---|---|---|---|---|---|---|
| | Median | Range | Median | Range | Median | Range |
| Males ($n$ = 4) | 30 | 22–38 | 12 | 10–12 | 11 | 11–25 |
| Females ($n$ = 8) | 20 | 15–34 | 8 | 3–18 | 8.3 | 3–24 |
| Total ($n$ = 12) | 22 | 15–38 | 10 | 3–12 | 10.5 | 3–25 |

*Duration of treatment from surgical exposure to alignment.

the incisal edge and the gingival margin represented the length of the clinical crown. Both the attached gingiva and crown length parameters were measured at the mid-labial line, to the nearest 0.1 mm, with the aid of a Vernier calliper (Dentaurum, Pforzheim, Germany) located in the mid-labial position.

Additionally, several other qualitative characteristics of all the previously ICI were subjectively clinically evaluated, as follows:

1. alignment relative to the adjacent teeth, especially in the vertical plane. The position was described as good, fair, or bad;
2. abnormal gingival contour was recorded when there was recession or irregularity;
3. discolouration relative to the adjacent teeth.

*Radiographic evaluation*

Bone support was assessed on periapical radiographs, which were standardized by the extension cone-paralleling technique (Rinn Corporation, Dentsply International, York, PA, USA) with a constant target-to-film distance of 27 cm at 80 kVp and 10 mA, and a Flexomatic 90 X-ray unit (S S White, Holmdel, NJ, USA). Bone support was assessed on the mesial and distal surfaces of the central incisors only. All films were scanned by the same operator, enlarged ×6 on a computer and the three points representing the cemento-enamel junction (CEJ), the crest of the interseptal bone and the tooth apex identified. The ratio of apex–crest of interseptal bone and apex–CEJ ×100 was used to represent the percentage bone support. This method has previously been employed by Becker *et al.* (1983) and Kohavi *et al.* (1984) as it minimizes errors due to radiographic distortion (elongation or shortening) of the roots. All these distances were measured on a line parallel to the long axis of the tooth.

In addition, pulpal and periapical pathology, such as obliteration or periapical radiolucency, were recorded as present or absent.

*Statistical analysis*

The Student's *t*-test for paired variables (two-tailed) was used to determine any statistically significant differences ($P < 0.05$) in the periodontal parameters, between the treated and untreated sides. $\chi^2$ tests were used to determine the significance of differences in the prevalence of irregular gingival contour, alignment, discolouration, pulp obliteration and periapical radiolucency between the two central incisors.

*Errors of method*

The errors of the clinical and radiographic measurements were assessed by analysing two sets of measurements made one week apart on 10 patients and on 10 radiographic views selected at random, according to the method of Dahlberg (1940). The error for the PD measurement was 0.30 mm, for keratinized gingiva 0.75 mm, for crown length 0.87 mm and for bone support 1.32 per cent.

## Results

Among the 12 cases examined, the treated central incisor in one case exfoliated, 10 years post-retention. This patient suffered from severe periodontal breakdown, which had affected all the teeth, although the formerly impacted tooth was the only one that had been lost. Thus, the results were based on the remaining 11 individuals.

*Clinical evaluation*

The PI and GI minor differences between the ICI and CCI are shown in Table 2. Similar scores were determined for the lateral incisors.

The difference between the mean PD of the ICI (2.36 mm) and that of the CCI (2.09 mm) was statistically significant ($P = 0.01$); this was especially true for the mesio-labial aspect ($P = 0.005$). The ALI and CLI registered similar PD results.

The reduction in width of the band of attached gingiva in the ICI cases (2.83 versus 3.89 mm in the unaffected teeth) and their increased crown length (12.12 versus 10.76 mm in the unaffected teeth) were both highly statistically significant (Figure 1). By contrast, when the lateral incisors were compared, attached gingival width and crown length were similar on both sides.

Unsatisfactory alignment was found in almost half the cases, with one showing poor alignment, four considered fair and only six well aligned (Table 3). These findings lack statistical significance due to the small numbers.

Statistically significant gingival abnormality was recorded in eight cases (72.7 per cent), while yellow discolouration or greater opacity of the crown was found in four subjects (36.4 per cent), which was not statistically significant.

*Radiographic examination*

On the distal aspects of the two central incisors, there was no significant difference in bone support (83.2 per cent for the ICI and 83.9 per cent for the CCI). In contrast, a statistically significant reduction was observed on the mesial aspects of the ICI (71.4 per cent compared with 81.6 per cent for the CCI) (Table 3, Figure 2).

Pulp obliteration was found in two cases, of which one was partial and one complete. Two ICI and one CCI had

**Table 2** Comparison of periodontal measurements and clinical appearance between the previously impacted central incisors (ICI), the contralateral central incisors (CCI), the adjacent lateral incisors (ALI) and the contralateral lateral incisors (CLI).

| | ICI | CCI | *P* value | ALI | CLI | *P* value |
|---|---|---|---|---|---|---|
| Periodontal measurements | | | | | | |
| Plaque index | | | | | | |
| Mean | 0.97 | 0.84 | 0.02 | 0.77 | 0.75 | NS |
| Mesial | 1.1 | 0.91 | NS | 0.7 | 0.5 | NS |
| Labial | 0.7 | 0.36 | 0.01 | 0.7 | 0.7 | NS |
| Distal | 0.9 | 1.18 | 0.04 | 0.7 | 0.7 | NS |
| Palatal | 1.18 | 0.91 | NS | 1 | 1.1 | NS |
| Gingival index | | | | | | |
| Mean | 1.32 | 0.98 | 0.02 | 1.22 | 1 | NS |
| Mesial | 1.64 | 1.5 | NS | 1.6 | 1.2 | NS |
| Labial | 1.18 | 0.64 | 0.04 | 0.8 | 0.6 | NS |
| Distal | 1.45 | 0.9 | 0.04 | 1.3 | 1.1 | NS |
| Palatal | 1 | 0.9 | NS | 1.2 | 1.1 | NS |
| Pocket depth | | | | | | |
| Mean | 2.35 | 2.09 | 0.01 | 2.29 | 2.16 | NS |
| Mesio-labial | 3 | 2.32 | 0.005 | 2.9 | 2.8 | NS |
| Mid-labial | 1.9 | 1.72 | 0.08 | 2 | 1.95 | NS |
| Disto-labial | 2.59 | 2.45 | NS | 2.4 | 2.35 | NS |
| Mesio-palatal | 2.59 | 2.15 | NS | 2.5 | 2.15 | NS |
| Mid-palatal | 1.82 | 1.81 | NS | 1.9 | 1.7 | NS |
| Disto-palatal | 2.2 | 2.09 | NS | 2.1 | 2.05 | NS |
| Attached gingiva | | | | | | |
| Mid-labial | 2.83 | 3.89 | 0.005 | 4.11 | 4.5 | NS |
| Crown length | | | | | | |
| Mid-labial | 12.12 | 10.76 | <0.001 | 8.75 | 8.67 | NS |
| Clinical appearance | | | | | | |
| Alignment | | | | | | |
| Good | 5 | 0 | NS | | | |
| Fair | 4 | 0 | NS | | | |
| Bad | 1 | 0 | NS | | | |
| Gingival abnormality | 8 | 0 | 0.01 | | | |
| Discolouration (yellow) | 4 | 0 | NS | | | |

NS, not significant.

**Figure 1** The maxillary right central incisor had been impacted due to a dilacerated root. Seen here 10.5 years post-retention, the treated tooth is easily identified by its increased crown length, a marked decrease in the width of attached gingiva and the positional relapse (rotation and intrusion). The crown is relatively opaque due to pulp obliteration.

undergone root canal therapy. Periapical radiolucency was not observed in the present sample. These small numbers did not allow statistically significant conclusions to be reached.

**Table 3** Radiographic evaluation of the previously impacted central incisors (ICI) as compared with the contralateral central incisors (CCI).

| | ICI (%) | CCI (%) | *P* value |
|---|---|---|---|
| Bone support mesial | 71.4 | 81.6 | 0.007 |
| Bone support distal | 83.2 | 83.9 | NS |

NS, not significant.

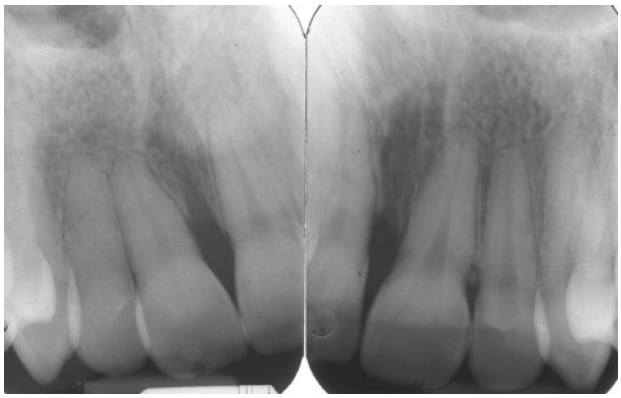

**Figure 2** The periapical radiographs of the same case show significant loss of bone support on the mesial aspect of the affected right central incisor, compared with the unaffected contralateral central incisor. The distal bone height is similar for the two teeth. The pulp is almost completely obliterated in the crown, and partially in the root of the treated tooth.

## Discussion

The present study investigated the long-term results of the successful orthodontic resolution of the impaction of maxillary central incisors, in which an open-surgical exposure technique had been used. The main clinical advantage of this technique, other than its simplicity, is that the crown remains in full view at the end of surgery, and bonding of an attachment may be subsequently performed in the orthodontic clinic in a bloodless environment and without the stress involved during the surgical procedure. Furthermore, in the event of bracket failure, there is no need for repeat surgery (Kokich and Mathews, 1993). However, the present results show several areas of reduced periodontal health and poor clinical appearance of the previously impacted teeth in comparison with the adjacent unaffected teeth.

Given the similarities in the periodontal parameters of the lateral incisors, the split-mouth technique appears to be a valid method for comparison between affected and unaffected sides, even in this area of the mouth.

The mean PD around the treated teeth was greater than in the controls, the difference being statistically significant especially on the mesio-labial aspect. This result differs from the findings of Vermette *et al.* (1995), but is in accordance with the studies of Woloshyn *et al.*

(1994) on impacted canines. It is imperative to note, however, that although statistically significant, these differences were small and of minimal clinical importance.

In agreement with the study of Vermette *et al.* (1995), the present findings indicate a greater risk of recession and uneven gingival margins of the formerly ICI, compared with the controls. A significant narrowing of 1 mm in the width of the attached gingiva was characteristic in the impacted teeth. The results seen in the present sample, where an open-exposure technique was used, show similarities with the orthodontic alignment of high labially erupted canine teeth, which also have shown a narrower band of attached gingiva (Årtun *et al.*, 1986). Although the importance of a minimal zone of attached gingiva has been disputed (Lang and Löe, 1972; Miyasato *et al.*, 1977; Wennström *et al.*, 1982), investigations have shown that an adequate zone of attached gingiva may prevent gingival recession. If the attached gingiva is narrow, inflammation leads to recession rather than pocketing (Ericsson and Lindhe, 1984; Baker and Seymour, 1976).

The direct consequence of the gingival recession was a mean increase of 1.36 mm in the length of the crown of the treated incisors in comparison with the contralateral controls. It should be emphasized that among all the clinical parameters measured, crown length showed the most statistically significant discrepancy.

From the aesthetic point of view, the uneven gingival margin and the longer crown may be extremely unsatisfactory for a patient with an increased gingival display in the incisor region. A poor gingival contour was seen in eight out of the 11 cases, a result that was statistically significant and aesthetically of considerable concern. The treated teeth were usually recognizable by the presence of a rolled band of gingival tissue around their crowns, in contrast to the appearance of the normal gingival contour around the contralateral teeth (Figure 1). Vermette *et al.* (1995) referred to this as 'gingival scarring', and reported its presence in 90 per cent of their open-exposure cases. Both their findings and those of the present study are in disagreement with the results of Vanarsdall and Corn (1977) who reported a good gingival condition around treated impacted teeth exposed by an apically repositioned flap.

Because of the relatively high prevalence of gingival defects in these studies, adjunctive post-orthodontic periodontal surgery may be required in a large proportion of cases treated with this method in order to achieve aesthetic gingival margin contour of the two central incisors, and to provide the teeth with an adequate zone of attached gingiva.

Post-treatment and post-retention alignment had deteriorated in half the patients. These results agree with the findings of Vermette *et al.* (1995), who reported positional relapse in over 61 per cent of the previously impacted maxillary anterior teeth in those cases treated with an open-exposure technique. They found significant intrusion, while in the present study relapse was expressed as both intrusion and rotation of the treated teeth. Thus, it may be suggested that following orthodontic alignment with this technique, long-term fixed retention and additional procedures such as circumferential fiberotomy should be considered.

Pulp obliteration caused opacity in the crowns in two cases. In a previous study on impacted canines (Woloshyn *et al.*, 1994), pulp obliteration was found in more than 20 per cent and failure to elicit any pulpal reaction to electric testing was found in eight out of 32 treated canines. Vermette *et al*. (1995) also reported partial obliteration in three of the 18 impacted teeth exposed by an open-surgical technique. The obliteration may be the result of changes in pulpal blood flow occurring during orthodontic extrusion of the impacted tooth (Mostafa *et al.*, 1991; McDonald and Pitt Ford, 1994). No periapical pathology was seen to suggest pulp morbidity in any of the cases, although root canal treatment had been performed in two of the treated incisors and one control incisor, presumably due to pulpal necrosis. However, because previous studies have indicated that teeth with partial or complete obliteration rarely develop pulp necrosis (Robertson *et al.*, 1996), prophylactic intervention on a routine basis does not seem to be justifiable.

The most important observation from the present study concerns the alveolar bone loss around the treated incisors. On the mesial side of the central incisors there was a 10 per cent discrepancy in bone support when compared with their untreated neighbours, a result that is both statistically and clinically of considerable significance. Vermette *et al.* (1995) also found a decrease in bone height on the mesial, distal, and labial surfaces of impacted teeth treated with the open-surgery technique. In their study, this parameter was not measured from radiographs, but assessed clinically by subtracting the distance CEJ to gingival margin from the distance gingival margin to bone.

The present results indicate a significant loss of periodontal attachment of the impacted teeth, which was associated with gingival recession, without significant deepening of the pockets on the labial side, but showing slightly deeper pockets and significant bone loss on the mesial side.

A comparison of the present results with those in a previous article that focused on central incisors treated with a closed-eruption technique (Becker *et al.*, 2002), suggests that the latter method of surgical exposure is capable of achieving a superior outcome, in terms of aesthetics and periodontal health. However, due to large differences in the individual subjects included in these two groups, who were unmatched, valid conclusions cannot be drawn.

## Conclusion

Although orthodontic alignment of ICI by an open technique is an accepted method in the orthodontic resolution of ICI, negative aesthetic and periodontal effects on the treated tooth should be anticipated. Patients should be informed of the possible need for additional periodontal procedures at the end of orthodontic treatment, to improve the aesthetics and periodontal health of the treated teeth. Long-term monitoring of the post-treatment stability and periodontal health of the impacted teeth should be undertaken.

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