Change in supporting tissue following loss of a permanent maxillary incisor in children

Rodd HD, Malhotra R, O'Brien CH, Elcock C, Davidson LE, North S. Change in supporting tissue following loss of a permanent maxillary incisor in children.

Abstract – Alveolar bone resorption is an inevitable consequence of tooth loss and may be detrimental to long-term dental aesthetics and function. The aim of the present study was to quantify the degree of tissue resorption following the loss of a permanent incisor in a young population. The study group comprised 11 boys and five girls who all required the extraction of a permanent maxillary central incisor due to trauma-related sequelae. Mean age at tooth loss was 10.8 years. Upper alginate impressions were taken at regular intervals following tooth loss and were cast in yellow dental stone. Study models were sectioned longitudinally through the mid-point of both the maxillary incisor socket and the contralateral incisor to provide a thin plaster section. Digital photographs were acquired of the edentulous (A1) and dentate (A2) surfaces of this section and image analysis software was employed to quantify the surface area of both A1 and A2. At 3 months postextraction, mean A1 was 15.7% less than mean A2. By 6 months mean A1 had further reduced and was 25.3% less than that of the corresponding dentate alveolus. However, at subsequent time intervals following tooth extraction (>6 months), tissue loss appeared to stabilise with an overall reduction in tissue area remaining at 22%. This reduction in supporting tissue area was found to be highly statistically significant ($P = 0.002$, ANOVA). Furthermore, girls appeared to have an overall greater degree of tissue loss than boys ($P = 0.015$). Further research is indicated to explore factors influencing the degree of tissue loss following incisor extraction and the benefit of therapeutic interventions in limiting this resorption.

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Alveolar bone resorption is an inevitable and undesirable consequence of tooth loss. The actual degree of postextraction atrophy appears shows considerable inter-individual variability. Local factors known to exacerbate the resorptive process include persistent infection, bony fracture of the thin buccal plate during tooth removal and subsequent loading of the alveolar ridge from a removable prosthesis (1–3).

A number of studies have attempted to quantify changes in supporting tissue following tooth loss. However, these investigations have been mostly limited to adult, and predominantly aged, populations. Adams and Wilding (4) employed sequential study models and stereophotogrammetry to measure changes in alveolar ridge volume after tooth removal. A 10% loss of ridge volume was determined at 2 months and 18% at 12 months. Other investigators have reported a 25% decrease in volume of the anterior maxilla during the first year postextraction (5, 6). Radiographic techniques have also been used to quantify bone loss, with one study estimating an annual 0.5-mm reduction in alveolar ridge height in adults following tooth removal (7).

One of the few studies to be undertaken in a young population investigated changes in alveolar ridge width, as measured on dental study casts, following the removal of ankylosed second primary molars (8). Alveolar ridge width was found to decrease 25% within 3 years after extraction.

Removal of a permanent maxillary incisor is not a common occurrence in paediatric dental practice. Indeed every effort is usually made to avoid such extractions. However, there are some clinical situations where incisor loss is inevitable. These mainly include trauma-related sequelae such as persistent uncontrollable periapical infection and vertical root fractures. British epidemiological data have shown that 19% of 12-year olds suffer some trauma to their maxillary incisors and three in every 1000 incisors will be lost as a result of trauma (9). In other young populations, up to 7% of traumatized incisors may ultimately be lost (10). Children may also require extraction of one or more incisors due to extensive caries or because of a localized developmental anomaly such as marked crown dilaceration, hypoplasia or ectopic eruption.

Following permanent maxillary incisor loss in a young population, clinical experience would suggest that a variable degree of alveolar resorption does ensue (Fig. 1). Reduction in alveolar bone mass may then have considerable impact on future treatment options. Implants, resin bonded bridges and dentures all require adequate bone mass for the successful and aesthetic replacement of missing anterior teeth. However, to date, no studies have attempted to quantify the degree or rate of tissue atrophy following incisor loss in a young population.

The aim of this study therefore was to quantify change in supporting tissues following unavoidable extraction of a permanent maxillary central incisor in paediatric dental patients. An additional objective was to determine whether gender had any effect on the degree of postextraction tissue resorption.

Fig. 1. Marked alveolar resorption following loss of an upper right permanent central incisor in a 12-year-old girl.

Materials and methods

The study group was drawn from children attending the Paediatric Dentistry clinic of the Charles Clifford Dental Hospital, Sheffield, UK. All subjects required simple forceps extraction of one permanent central incisor due to a variety of trauma-related sequelae. The study population comprised 11 boys and five girls. The mean age at which these patients had lost a permanent maxillary central incisor was 10.8 years (SD = 2.42, range = 7.7–15.8). Ethical approval for the study was obtained from the South Sheffield Research Ethics Committee.

Following tooth loss, children were routinely provided with a 'T-shaped' acrylic denture for the prosthetic replacement of their missing incisor (11). Patients thus required frequent upper alginate impressions for denture remake or repair prior to reaching an age where a resin-bonded bridge or dental implant could be provided. For the purposes of this study, a duplicate cast was requested on each occasion that an impression was taken as part of the child's routine treatment. Every effort was made to ensure that the impression extended fully into the anterior labial sulcus. If this anatomical detail was not clear on the dental cast, it was excluded from the study. The experimental models were cast in yellow dental stone to facilitate subsequent image acquisition and quantitative analysis. Two or more study models were available for each subject and, at the time of the study, subjects had been followed up for a mean period of 25 months (SD = 18.2, range = 4–61). For ease of data presentation and analysis, results for tissue changes were divided into five subgroups according to the time interval at which the impression had been taken:

1 pretooth extraction ($n = 5$);
2 <3 months postextraction ($n = 8$);
3 3.1–6 months postextraction ($n = 5$);
4 6.1–9 months postextraction ($n = 5$);
5 >9.1 months postextraction ($n = 14$).

The experimental dental casts were trimmed in a dedicated image-analysis laboratory using a microslice II cutting machine (Malvern, UK). Models were cut longitudinally through the mid-point of the extraction socket and the contralateral central incisor. This resulted in a thin plaster slice with a mean width of 9 mm (Fig. 2). The slice was then placed on a purpose-built frame and a digital image was obtained of both the edentulous (A1) and dentate (A2) surfaces. An image of each surface was taken under standard light conditions using a 32-bit digital camera (Kodak Nikon DCS410, Nikon Inc., Melville, NY, USA) with 1.5 megapixel resolution. Image processing software (Image-Pro Plus v3.0, Media Cybernetics, Silver Spring, MD, USA) was

Fig. 2. Longitudinal cuts were made through the trimmed cast at the mid-point of the incisor extraction socket and the contralateral tooth to obtain a thin plaster slice.

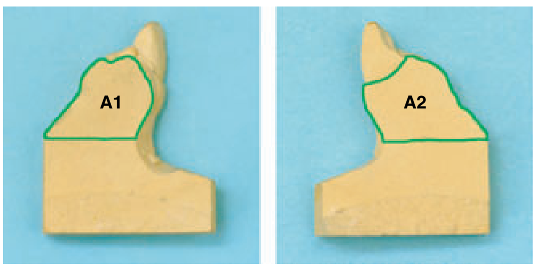

Fig. 3. Digital images were acquired of the edentulous (A1) and dentate (A2) aspects of the plaster slice. The supporting tissues were then outlined using image analysis software (green line) and the respective surface areas automatically calculated.

employed to obtain the surface area (mm^2) of A1 and A2. Essentially, the 'area-of-interest' drawing tool was employed to outline the periphery of A1 and A2, extending to the deepest concavity of the labial sulcus (Fig. 3). This was undertaken manually by one investigator (COB). The computer software could then automatically calculate the respective surface areas. It was assumed that A2 would remain constant on serial casts obtained from the same patient, but that A1 would decrease. Thus the percentage change between A1 and A2 at different time intervals was calculated as:

$$\frac{A2 - A1}{A2} \times 100\%.$$

To determine the repeatability of this stage of the methodology, 10% of the total number of initial digital images ($n = 74$) were reacquired 1 month later and repeat surface area measurements were obtained using the image analysis software.

Results

Figure 4 shows the mean percentage reduction in tissue area of the extraction site (A1) compared with the tissue area of the contralateral non-extraction site (A2). Although considerable inter-individual variation was seen in the degree of tissue change, it is clear that an overall marked tissue loss occurred within a 3-month period following extraction (15.7%). Tissue loss then appeared to continue to a maximum of 25.3% during the subsequent 3 months. Interestingly, at time periods >6 months following tooth loss, there appeared to be a stabilization of tissue reduction at around 22%.

Statistical analysis, using a one-way analysis of variance, revealed that a highly significant tissue reduction occurred at the extraction site following incisor loss ($P = 0.002$). Further multiple comparisons found that tissue area at the extraction site was significantly less than the pre-extraction area at all time periods >3 months ($P < 0.05$, Tukey's test).

Data were then analysed to determine whether gender had any significant effect on the degree of tissue loss occurring postextraction. Figure 5 shows

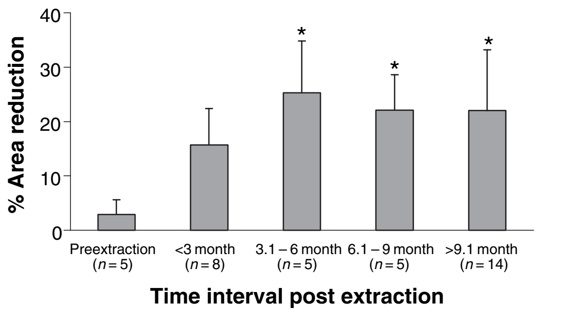

Fig. 4. Bar chart showing mean percentage reduction in surface area of the edentulous alveolar region compared with the contralateral dentate region according to time elapsed as incisor loss. *Significantly different from pre-extraction area, $P < 0.05$ ANOVA.

Fig. 5. Bar chart showing mean percentage reduction in surface area of the dentulous alveolar region compared with the contralateral dentate region according to gender and time elapsed as incisor loss.

that, overall, tissue resorption was more pronounced in females than males. This observation was supported by a two-way analysis of variance, which found gender to have a statistically significant effect on overall tissue loss ($P = 0.015$). However, multiple pair-wise comparisons of means did not reveal any significant differences at individual time periods ($P > 0.05$, Tukey's test). As predicted, there was no significant difference in mean A2 area (control non-extraction site) at the five time intervals ($P = 0.88$, ANOVA).

Repeatability of image acquisition and area analysis was found to be very good. There was no systematic error for initial and repeat area measurements ($P > 0.05$, paired t-test) and little random error (intraclass correlation coefficient = 0.93).

Discussion

This study has conclusively shown that there is a significant reduction in supporting tissue following the loss of a permanent maxillary central incisor in children. This was not an unexpected result as it confirmed initial clinical impressions and was consistent with findings in adult populations (5, 6). Nonetheless, the study has provided novel clinical data and has revealed quantifiable differences in the degree of postextraction tissue atrophy at various time intervals and according to gender.

The experimental approach was simple, reproducible and non-invasive, but did have acknowledged limitations. Firstly, it was not possible to specifically measure bony changes. Measurements obtained from the plaster sections represented both hard and soft tissue support and could not be individualized. However, findings from other studies, using complex radiographic methodologies, would suggest that postextraction tissue loss is predominantly due to alveolar resorption (12). Indeed, inclusion of gingival contour in our analysis may have actually masked the true extent of underlying bony atrophy as, in some cases, denture-induced gingival hyperplasia was present.

It should also be recognized that measurements taken from serial casts may be subject to minor inherent variability due to changes in the dimensional accuracy and stability of the impression material itself (13). However, the reproducibility and accuracy of serial alginate impressions for measurements of gingival and bone levels on stone casts has been recently validated (14).

Data derived from the present study only related to changes in overall area and not individual dimensions. It would therefore be interesting to know whether tissue loss preferentially affected one site or occurred uniformly throughout the alveolus. Clinical observations would seem to suggest that the labial alveolus is subject to the most marked resorption but this impression needs to be supported by objective data. The increasing availability of 3D imaging technologies may prove very useful to further this line of research. In addition, standardized references points would need to be developed to allow reproducible measurements in different planes.

The finding that female subjects demonstrated the greatest degree of tissue resorption is of note and warrants further discussion. It is possible that the increased tissue loss seen in females may reflect gender-related differences in bone healing and remodelling. Indeed there is a now a wealth of evidence to suggest that girls have significant differences in biochemical markers of bone turnover than their male peers, which may account for the lower peak bone mass seen in adult females (15–17). Furthermore, marked changes in bone turnover occur in both males and females during adolescence. Although there was no significant difference in the mean age at tooth loss according to gender in the present study, female subjects (mean age 10.6 years) would have been closer to the onset of puberty than the males (mean age 10.9 years).

A number of factors, other than gender and stage of sexual development, may also affect the degree of tissue resorption following tooth extraction. For example, the fit and loading of the removable prosthesis may be a contributory factor. Thus it has been suggested by some clinicians that the pontic be kept clear of the underlying edentulous ridge thereby limiting any loading forces and resultant tissue atrophy (18). Another design approach to limit tissue loading may be to incorporate occlusal stops on posterior teeth. However, the degree to which these interventions may reduce any tissue resorption has yet to be investigated.

Orthodontic status may also influence subsequent alveolar ridge atrophy. A subjective observation, made from this study, was that children with upper anterior crowding appeared to have less alveolar resorption than non-crowded subjects. This may have been due to the mesial eruption of a lateral incisor into the extraction site, which, in turn, would have stimulated the formation of new bone. Interestingly, Wong et al. (19) recently reviewed the role of orthodontic tooth movement in bone induction. However, due to the small number of subjects in this study, it was not possible to undertake further statistical analysis to explore the effect of all the above variables. Larger sample sizes would be required to more conclusively identify risk factors associated with postextraction alveolar resorption in children.

An important clinical consideration arising from this study relates to the prosthetic replacement of a missing incisor where there has been extensive bone resorption. In the short-term, an acrylic denture provides excellent aesthetics and retention. However, placement of a more definitive restoration, such as an adhesive bridge or a dental implant, may be severely compromised, both functionally and cosmetically, by insufficient bone mass.

In view of this, the authors have advocated intentional retention of maxillary permanent incisor roots as a means of maintaining bone in appropriate cases (20). For patients where tooth loss is unavoidable, alternative interventions are being sought to preserve the alveolar ridge using guided bone regeneration techniques and bone replacement materials (21–23). Recent studies have advocated augmentation of fresh extraction sockets with bioactive glass, demineralized freeze-dried bone allografts or bioabsorbable polylactide–polyglycolide sponges in order to facilitate future implant placement (24, 25). One of the few studies to be conducted in a young population (mean age 13.6 years) described the use of coral granules in fresh permanent incisor and primary molar extraction sockets as a means of preserving alveolar bone (18).

In summary, it is clear that children undergo marked alveolar resorption following loss of a permanent maxillary incisor. However, it would appear from the literature that very few clinicians routinely employ bone preservation therapies for their young patients. This is an area that deserves further consideration in view of increasing evidence to support the long-term benefit of such interventions.

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