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Alveolar ridge reduction after tooth extraction in adolescents: An animal study

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ABSTRACT

Objective: The mechanism for tooth extraction induced residual alveolar ridge reduction (RRR) during adolescence is poorly understood. This study investigated the alveolar bone morphology, growth, resorption and functional loading at normal and extraction sites using an adolescent pig model.

Design: Sixteen 3-month-old pigs were divided into two groups – immediate post-extraction (IE) and 6-week post-extraction (SE). The IE group received an extraction of one deciduous mandibular molar, immediately followed by a final experiment to record masseter muscle EMGs and strains from the buccal surface of the extraction and contralateral non-extraction sites during function (mastication). The SE group was given the same tooth extraction, then kept for 6 weeks before the same final functional recording as the IE group. Both groups also received baseline (pre-extraction) EMGs and fluorescent vital stains 10 and 3 days before the final functional recording. Immediately after the final functional recording, animals were euthanized and alveolar bone specimens from extraction and contralateral non-extraction sites were collected and used to analyse alveolar bone morphology, apposition and resorption based on fluorescent and hematoxylin and eosin stained histological sections.

Results: At control sites (IE-extraction, IE-non-extraction and SE-non-extraction), the alveolar ridges grew gingivally and buccally. Bone formation characterized the buccal surface and lingual bundle bone, whereas resorption characterized the lingual surface and buccal bundle bone. The SE-extraction sites showed three major alterations: convergence of the buccal and lingual gingival crests, loss of apposition on the lingual bundle bone, and decelerated growth at the entire buccal surface. These alterations likely resulted from redirected crestal growth as part of the socket healing process, loss of tongue pressure to the lingual side of the teeth which normally provides mechanical stimulation for dental arch expansion, and masticatory underloading during the initial post-extraction period, respectively.

Conclusions: These data indicate that the initial phase of RRR in adolescents is a product of modified growth, not resorption, possibly because of decreased mechanical stimulation at the extraction site.

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Abbreviations: RRR, residual ridge reduction; IE, immediately post-extraction; SE, six weeks post-extraction; dm2, second deciduous molar; MAR_T, transverse mineral apposition rate; MAR_V, vertical mineral apposition rate; MAZ_T, transverse mineral apposition zone; BV, bone volume; dLS, double-labelled surface; sLS, single-labelled surface; MARo, osteonal mineral apposition rate; BFR, bone formation rate; df, degrees of freedom.

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1. Introduction

A common sequela of tooth extraction is a progressive reduction of the residual alveolar ridge (RRR). In both humans[1–7] and animals,[8–11] the reduction tends to be greater in the transverse than in the vertical dimension, and transverse RRR is often more prominent at the buccal (labial) than at the lingual side.[12,13] Typically RRR proceeds rapidly during the first several months after tooth extraction,[7,14] then gradually slows. While most clinical studies on RRR have focused on edentulous alveolar ridges in senior patients, this problem does occur at isolated single-tooth extraction sites in adolescent patients and exhibits similar clinical manifestations.[7,15,16]

At present, the etiological mechanisms of RRR are not completely clear. Based on radiographic observations of alveolar bone dimensional changes in completely edentulous patients, Atwood[17,18] proposed that RRR is mainly a biomechanical problem. More specifically, he suggested that functional loading at the edentulous ridge was diminished because of the loss of direct occlusal contact, which subsequently induced bone resorption. This theory of disuse atrophy is now commonly considered responsible for resorption of the residual alveolar process. Alveolar bone resorption does occur reliably after tooth extraction in adult humans[12,19] and dogs.[20] The mechanical aspect of this theory, however, has never been substantiated. Specifically, it remains uninvestigated whether the local alveolar ridge is functionally unloaded after tooth extraction. Recently, it was found that alveolar bone lacking direct occlusal contact still sustains mechanical loading,[21] suggesting that the disuse atrophy mechanism of RRR is open to question.

For a single extraction site in adolescent humans or animals, it is even more uncertain whether the disuse atrophy theory is applicable. In this population, not only does the mechanical change after tooth extraction remain unknown, but the question of whether RRR results from bone resorption is also unanswered. During adolescence, the alveolar bone is still growing, vertically to adapt to jaw growth[22,23] and tooth eruption, and transversely to accommodate dental arch expansion.[24] Conceivably, RRR in adolescents could result from growth reduction rather than bone resorption. This conjecture, if confirmed, would suggest that RRR in adolescents has a different biological mechanism than that in adults despite similar clinical manifestations.

The main purpose of this study was to elucidate the mechanisms of RRR induced by tooth extraction in adolescents. An adolescent age is targeted because of several reasons. Tooth loss due to trauma[25–27] and dental caries is common during adolescence. A measure to prevent RRR effectively in adolescent patients after tooth extraction has not been established, which is at least partly due to a lack of clear understanding of its mechanism. Furthermore, implant restoration for the residual edentulous site, which may break the progression of RRR, often needs to be deferred for years until jaw growth is complete,[22] during which time RRR may have become extensive.[28]

In this study, a pig model was used to measure bone strain during mastication and to assess alveolar bone morphology, growth, resorption and remodelling. The immediate responses to extraction were compared to the responses after 6 weeks of adaptation. We hypothesized that bone strain would be lower (underloading) at the extraction site than at the contralateral non-extraction site at both time points. Further, although the pattern of bone growth immediately after extraction should be unchanged, we hypothesized that the 6-week sample would show reduced growth compared to the non-extraction site due to chronic underloading.

2. Materials and methods

2.1. Animals

Sixteen 3-month-old domestic pigs (*Sus scrofa*) were obtained from a local farm and divided into two groups (Table 1). Animals were similar in size as well as age, and all were healthy; they were obtained in groups of 2 or 4 representing 5–6 different litters. The immediate post-extraction (IE) group was used to examine the immediate effect of tooth extraction on functional loading, and to assess the baseline status of bone growth/resorption before any bone adaptation to extraction could occur. The six-week post-extraction (SE) group was used to examine the changes of functional loading and bone growth/resorption at a time that RRR is rapid.[7,14] In both groups, masseter muscle electromyography (EMG) was recorded at baseline (pre-extraction) and at the final functional recording, during which strain gage readings from the buccal alveolar bone surface (detailed below) were also collected. The buccal surface was targeted for strain measurements not only because of its accessibility but also because it is more severely affected than the lingual side.[12,13] All pigs also

Table 1 – Live animal procedures.

Pig age (weeks)	12	13–14	15	18–19	20
IE Group ($n = 7$)	Arrival, baseline EMG	Fluorescent bone labels	Tooth extraction, final functional recording (alveolar bone strain measurement, EMG), then euthanasia	–	–
SE Group ($n = 9$)	Arrival, baseline EMG	Tooth extraction	–	Fluorescent bone labels	Final functional recording (alveolar bone strain measurement, EMG), then euthanasia