Osseous repair in the presence of active tooth hypermobility

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Abstract. The present investigation was undertaken to evaluate the periodontal response after resolution of inflammation in a situation of established marginal periodontitis, but in the presence of active, continued tooth hypermobility. Periodontitis was induced unilaterally around mandibular second and third bicuspid in 4 squirrel monkeys by tying plaque retentive silk ligatures at the gingival margins. Jiggling trauma to the periodontium between these bicusps was begun 5 weeks later and continued for the remaining 20 weeks. Ligatures were removed 15 weeks after placement, whereupon regular oral hygiene was begun and continued. Periodontitis and trauma were produced around the corresponding contralateral teeth (control) so that the interproximal area represented the situation immediately prior to ligature removal. Infiltrated connective tissue, loss of connective tissue attachment and alveolar bone, and percentage of bone were determined histometrically for each coronal interproximal periodontium. In control specimens, 58% of the supracrestal tissue was infiltrated with inflammatory cells compared to 19% in experimental specimens. There were no differences in levels of connective tissue attachment or crestal alveolar bone. However, bone repair occurred in the experimental specimens which increased bone volume from 11 to 18% (P<0.05). It was concluded that osseous repair occurred in the presence of active, continued tooth hypermobility after resolution of inflammation.

In advanced cases of periodontitis with severe periodontal destruction and increased tooth mobility, the clinician is faced with the combined factors of marginal inflammation and trauma. Since the therapeutic literature lacked scientific evidence to indicate the type or sequence of therapy in these situations, investigations have been in progress to try and clarify the relative importance of trauma and inflammation in case management (Kantor et al. 1976, Polson et al. 1976b). In the first investigation (Polson et al. 1976b), periodontal destruction was produced by the co-destructive factors of inflammation and trauma, after which only traumatizing forces were discontinued. On a clinical level, there was no reduction in tooth hypermobility even though active jiggling forces had been stopped. Histometric evaluation revealed no differences between experimental and control specimens with respect to loss of connective tissue attachment, infiltrated supracrestal connective tissue, or alveolar bone morphology. Since no bone regeneration occurred following removal of the traumatic influence, the findings suggested that the presence of an existing marginal inflammation in the supracrestal connective tissue may have been exerting an inhibitory influence upon any potential for bone regeneration.

In order to address this question, periodontal destruction was produced by the co-destructive factors, and followed by resolution of both inflammatory and traumatic factors (Kantor et al. 1976). A marked reduction in clinical tooth hypermobility occurred. The histometric analyses showed that there had been no alteration...
in the level of connective tissue attachment, but a significant and dramatic regeneration of alveolar bone occurred. It was concluded, on the basis of the results from the 2 studies (Kantor et al. 1976, Polson et al. 1976b), that the presence of an existing marginal inflammation in the supracrestal connective tissue had inhibited a potential for alveolar bone regeneration. As a consequence of the dominating influence which inflammation appeared to be having upon periodontal healing potential, the present study was undertaken to evaluate the effect of resolution of inflammation in the presence of active, continued tooth hypermobility.

Material and Methods
The experimental animals were 4 young adult squirrel monkeys. Marginal periodontitis was induced unilaterally (experimental side) around the mandibular second and third bicuspids by tying a silk ligature at the gingival margin (Kennedy & Polson 1973). 5 weeks later, the interproximal periodontium between these teeth was subjected to repeated trauma by jiggling the teeth mesio-distally using previously described methodology (Polson et al. 1976a, b, Perrier & Polson 1982). 10 weeks after initiating the jiggling, the plaque retaining ligatures were removed, and an oral hygiene regime begun which consisted of mechanical plaque removal 3 times a week (Kantor et al. 1976, Polson et al. 1979, Perrier & Polson 1982). The mesio-distal jiggling was continued during the period of oral hygiene. The animals were sacrificed 10 weeks after initiating the oral hygiene procedures. On the contralateral side of each mandible (control side), induction of periodontitis and jiggling of the second and third bicuspids were scheduled such that the interproximal periodontium corresponded to the situation on the experimental side immediately prior to ligature removal and initiation of oral hygiene.

Marginal inflammation and tooth mobility were assessed during the period of the investigation (Kantor et al. 1976, Perrier & Polson 1982). The mandible was dissected out immediately after the sacrifice of the animal, placed in fixative, and processed for histologic evaluation as described previously (Polson 1974, Kantor et al. 1976, Perrier & Polson 1982). Mesio-distal sections of the interproximal area between the mandibular second and third bicuspids were cut with the microtome set at 6 μm. Step-serial sections representing intervals of 96 μm were stained with hematoxylin and eosin.

Methods of analysis
The coronal interproximal periodontium between the second and third bicuspids was examined histologically on 5 step-serial sections from each specimen (Polson et al. 1979, Perrier & Polson 1982), and the same sections were used for the histometric analysis. Measurements for the histometric analysis were made with a calibrated grid in the ocular of a light microscope at a magnification of X70. The percentage of supracrestal connective tissue which was infiltrated with inflammatory cells, the levels of connective tissue attachment and crestal alveolar bone, and the percentage of bone in the coronal interproximal area were measured using previously described histometric techniques (Polson et al. 1974, 1979, Kantor et al. 1976, Perrier & Polson 1982). Mean values for each of the measured parameters were calculated from the measurements obtained from the 5 step-serial sections from each specimen, and these means were used to calculate overall means for experimental and control specimens. Experimental and control values were compared by Student’s t-test, and a level of \( P<0.05 \) was accepted for statistical significance.

Results
Clinical
The gingival margins had little or no inflammation, and the teeth were without clinical mobility, prior to the induction of periodontitis. 5 weeks after periodontitis had been induced
(the time at which the jiggling was initiated), the gingival tissues were swollen, very inflamed, and bled upon slight provocation. The bicuspids were mobile in bucco-lingual and mesio-distal directions. During the first 10 weeks of tooth jiggling, the clinical appearance of the inflamed gingival tissues did not change; however, tooth mobility increased. In addition to greater mobility in mesio-distal and bucco-lingual directions, vertical mobility also developed.

After the plaque-retaining ligatures had been removed, and the oral hygiene had been in effect for 10 weeks, a marked resolution of gingival inflammation had occurred, and the tissues appeared as they had been prior to the initiation of periodontitis. Tooth mobility decreased during this latter 10-week period although the teeth were still being subjected to active jiggling forces. At the conclusion of the study, the bicuspids were no longer mobile in a vertical direction, and had reduced mobility in both mesio-distal and bucco-lingual directions compared with the situation immediately prior to ligature removal and initiation of oral hygiene.

**Histologic and histometric**

The histologic appearance of the coronal interproximal area between the second and third bicuspids of control specimens (Fig. 1), showed silk ligatures infiltrated with bacterial plaque adjacent to the gingival epithelium. Loss of connective tissue attachment was present on both the distal surface of the second bicuspid and mesial surface of the third bicuspid. The supracrestal connective tissue was densely infiltrated with inflammatory cells, and the infiltrate extended virtually to the crest of the alveolar bone (Fig. 2). The interproximal alveolar bone was narrow, tapered coronally, and appeared to consist primarily of lamellar bone, with some small areas of woven bone (Fig. 3). Osteoclasts were rarely present in marrow spaces and resorption lacunae. At the time of animal sacrifice, the bicuspids were being displaced in a mesial direction. Consequently, the periodontal ligament adjacent to the third bicuspid was narrower than the one next to the second bicuspid.
Fig. 2. Higher magnification from Fig. 1 showing the densely infiltrated supracrestal connective tissue. Hematoxylin & eosin stain, original magnification ×40.

Höhere Vergrößerung der Fig. 1, die das dicht infiltrierte Bindegewebe oberhalb der Knochenleiste zeigt. Färbung Hämatoxylin & Eosin, Originalvergrößerung ×40.

Agrandissement de la Fig. 1 montrant le tissu conjonctif supra-osseux très infiltré. Coloration à l'hématoxyline et à l'éosine, agrandissement original ×40.

Fig. 3. Higher magnification from Fig. 1 showing the coronal alveolar bone. Hematoxylin & eosin stain, original magnification ×40.

Höhere Vergrößerung der Fig. 1, die den koronalen Anteil des alveolaren Knochens zeigt. Färbung Hämatoxylin & Eosin, Originalvergrößerung ×40.

Agrandissement de la Fig. 1 montrant l'os alvéolaire coronaire. Coloration à l'hématoxyline et à l'éosine, agrandissement original ×40.
Fig. 4. Experimental specimen showing the coronal interproximal area between second (2) and third (3) bicuspids. 10 weeks earlier, the ligatures had been removed and the oral hygiene regime initiated. Active jiggling had been continued during the period of oral hygiene. The bicuspids were being displaced in a mesial direction at the time of animal sacrifice. Hematoxylin & eosin stain, original magnification X16.


Spécimen expérimental montrant la zone interproximale coronaire entre les 2èmes (2) et 3èmes (3) prémolaires. Dix semaines auparavant, les ligatures ont été enlevées et l’hygiène buccale a commencé. Une force de va-et-vient active a été exercée durant la période d’hygiène buccale. Les prémolaires ont été déplacées vers méssial lors du sacrifice du singe. Coloration à l’hématoxyline et à l’eosine, agrandissement original X16.

Fig. 5. Higher magnification from Fig. 4 showing well-organized supracrestal connective tissue. Hematoxylin & eosin stain, original magnification X40.

Höhere Vergrößerung der Fig. 4. die gut strukturiertes Bindegewebe koronal der Knochenleiste zeigt. Färbung Hämatoxilin & Eosin, Orginalvergrößerung X40.

Agrandissement de la Fig. 4 montrant un tissu conjonctif supra-osseux bien organisé. Coloration à l’hématoxyline et à l’eosine, agrandissement original X40.
The coronal interproximal area between the second and third bicuspsids 10 weeks after ligature removal and initiating oral hygiene, but continuing jiggling during this period (experimental specimens), is shown in Fig. 4. While there were accumulations of inflammatory cells adjacent to the epithelium, only 19.2% ± 2.3 (S.E.) of the supracrestal connective tissue was infiltrated with inflammatory cells. This represented a significant decrease compared to the control specimens (57.6% ± 5.5 (S.E.); t = 5.61; P < 0.01). The major portion of the supracrestal region in experimental specimens was free of inflammatory cell infiltrate, and exhibited well-organized connective tissue (Fig. 5). A long junctional epithelium lined each exposed root surface (Fig. 6), and the histometric measurements showed that there were no differences between the levels of connective tissue attachment* (mean ± S.E.: μm)

<table>
<thead>
<tr>
<th>Surface</th>
<th>Control**</th>
<th>Experimental***</th>
<th>t</th>
<th>P</th>
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</thead>
<tbody>
<tr>
<td>Distal second bicuspid</td>
<td>788 ± 64.8</td>
<td>904 ± 56.4</td>
<td>1.35</td>
<td>&gt;0.20</td>
</tr>
<tr>
<td>Mesial third bicuspid</td>
<td>803 ± 40.0</td>
<td>818 ± 71.5</td>
<td>0.18</td>
<td>&gt;0.80</td>
</tr>
</tbody>
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* Distance from the cemento-enamel junction (Abstand von der Schmelz-Zementgrenze, distance depuis la jonction émail-cément).
** Periodontitis plus jiggling for 15 weeks (Parodontitis und aktive Zahnlockerung (jiggling) während 15 Wochen, parodontite plus va-et-vient pendant 15 semaines).
*** Periodontitis plus jiggling for 15 weeks, then plaque-retaining ligatures removed and oral hygiene for a further 10 weeks. Active jiggling continued during the oral hygiene phase (Parodontitis und aktive Zahnlockerung (jiggling) während 15 Wochen, dann wurden die plakaretinierenden Ligaturen entfernt und während weiterer 10 Wochen orale Hygienemaßnahmen eingesetzt. Die aktive Zahnlockerung (jiggling) wurde während der oralen Hygienephase fortgesetzt, parodontite plus va-et-vient pendant 15 semaines ensuite les ligatures retenant la plaque ont été enlevées et l'hygiène buccale reprise pendant 10 semaines. Le va-et-vient a continué pendant cette phase d'hygiène buccale).

Surface (Oberfläche, surface), control (Kontrollzähne, contrôle), experimental (Experimenztähne, expérimental), distal second bicuspid (distal zweiter Prämolar, deuxième prémolaire distal), mesial third bicuspid (mesial dritter Prämolar, troisième prémolaire mesial).

Fig. 6. Higher magnification from Fig. 4 showing the long junctional epithelium adjacent to the mesial surface of the third bicuspid. Hematoxylin & cosin stain, original magnification ×40.

Höhere Vergrösserung der Fig. 4, die den langen Epithelansatz an der mesialen Oberfläche des 3. Prämolaren zeigt. Hämatoxylin & Eosin, Orginalvergrösserung ×40.

Agrandissement de la Fig. 4 montrant le long épithélium de jonction adjacent à la surface mesiale de la 3ème prémolaire. Coloration à l’hématoxyline et à l’éosine, agrandissement original ×40.
tissue attachment on these surfaces compared to controls (Table 1).

The coronal alveolar bone from experimental specimens, compared to control specimens, appeared to be more dense, and to have a proportionately greater amount of woven bone present (Fig. 7). Alveolar bone occupied 18.3% ± 1.7 (S.E.) of the coronal interproximal area, indicating that a significant amount of bone repair had occurred after ligature removal and institution of oral hygiene, even though the mechanical jiggling had been continued (control specimens, 11.0% ± 1.5 (S.E.); t = 2.63; P<0.05). The bone repair had not significantly raised the height of the alveolar crest adjacent to the respective tooth surfaces (Table 2).

Discussion
Immediately prior to ligature removal and initiation of oral hygiene, the gingival tissues exhibited severe clinical inflammation and, histologically, the supracrestal connective tissue was extensively infiltrated with inflammatory cells. After the plaque-retaining ligatures had been removed and the oral hygiene regime had been in effect, marked resolution of inflammation was apparent at clinical and histological levels, even though the teeth were being subjected to active jiggling forces. The degree of resolution of inflammation, and repair within the supracrestal connective tissue, was similar to that which occurred in a previous study where periodontal response was quantitated after ligature removal and oral hygiene around teeth which were not being subjected to active jiggling (Polson et al. 1979). Thus, an existing, and continued, tooth hypermobility did not appear to exert a detrimental effect upon the resolution of marginal inflammation following removal of local etiologic agents.

The findings of long junctional epithelia adjacent to the exposed root surfaces, and the lack of gain in connective tissue attachment levels, were consistent with results which have been reported after reduction of inflammation.

Fig. 7. Higher magnification from Fig. 4 showing the coronal alveolar bone. Hematoxylin & eosin stain, original magnification X40.

Höhere Vergrösserung der Fig. 4, die den koronalen Anteil des alveolaren Knochens zeigt. Färbung Hämatoxilin & Eosin, Orginalvergrösserung X40.

Agrandissement de la Fig. 4 montrant l'os alvéolaire coronaire. Coloration à l'hématoxylie et à l'éosine, agrandissement original X40.
OSSEOUS REPAIR AND TOOTH MOBILITY

Table 2. Level of crest of alveolar bone* (mean ± S.E.: μm)

<table>
<thead>
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<th>Surface</th>
<th>Control**</th>
<th>Experimental***</th>
<th>t</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distal second bicuspid</td>
<td>1583±79.2</td>
<td>1686±130.4</td>
<td>0.68</td>
<td>&gt;0.50</td>
</tr>
<tr>
<td>Mesial third bicuspid</td>
<td>1398±59.2</td>
<td>1400±95.4</td>
<td>0.02</td>
<td>&gt;0.90</td>
</tr>
</tbody>
</table>

* Distance from the cemento-enamel junction (Abstand von der Schmelz-Zementgrenze, distance depuis la jonction émail-cément).

** Periodontitis plus jiggling for 15 weeks (Parodontitis und aktive Zahnhckung (jiggling) während 15 Wochen, parodontite plus va-et-vient pendant 15 semaines).

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Surface (Oberfläche, surface), control (Kontrollzähne, contrôle), experimental (Experimentalzähne, expérimental), distal second bicuspid (distal zweiter Prämolär, deuxième prémolaire distal), mesial third bicuspid (mesial dritter Prämolär, troisième prémolaire mésial).

associated with marginal periodontitis (Caton & Zander 1976, 1979, Polson et al. 1979, Caton & Nyman 1980). The histometric findings that attachment levels remained unaltered in the experimental situation under investigation in the present study indicated that continued tooth hypermobility after resolving inflammation did not lead to further loss of connective tissue attachment. Consequently, if residual tooth hypermobility which remains after resolution of marginal inflammation associated with periodontitis is without effect upon connective tissue attachment levels, it indicates that there is no scientific basis for considering that this mobility should be reduced in order to preserve periodontal health. Connective tissue attachment levels will be maintained by control of marginal inflammation (Perrier & Polson 1982).

In the present study, bone regeneration occurred in the presence of active, continued tooth hypermobility after resolution of inflammation. This finding is in agreement with results from other recent investigations which have evaluated alveolar bone response after resolution of marginal inflammation (Kantor et al. 1976, Rosling et al. 1976a, b, Polson & Heijl 1978, Polson et al. 1979). Several of these studies were in humans, and quantitated osseous repair in infrabony periodontal defects in situations of optimal plaque control (Rosling et al. 1976a, b, Polson & Heijl 1978). Osseous repair, which incorporated coronal bone regeneration at the base of the defects, occurred throughout the circumferential extent of infrabony defects surrounding hypermobile teeth. Although no occlusal adjustment or splinting was done, each tooth tended to decrease in clinical hypermobility concomitant with the osseous repair (Polson & Heijl 1978). It should be recalled that, in our present study, tooth hypermobility also decreased, even though the individual teeth were being subjected to active jiggling forces.

Although reduction in clinical tooth mobility has been noted after resolution of inflammation in management of advanced periodontal disease in humans (Lindhe & Nyman 1975, Rosling et al. 1976a, Polson & Heijl 1978), the morphologic reason responsible for the reduction has not been clear. In a previous animal study directed toward clarifying the periodontal response after reduction of inflammation in a situation of established marginal periodontitis, the decrease in tooth hypermobility which occurred was associated with an increase in
bone density, rather than coronal gain in connective tissue attachment or crestal alveolar bone (Polson et al. 1979). In our present study, since there were no coronal gains in the levels of connective tissue attachment or crestal alveolar bone, the decrease in tooth mobility was also, most likely, due to the increase in bone density.

The present study was one of a series of investigations in an experimental, animal model system designed to try and provide information regarding the relative importance of inflammation and trauma in the management of advanced periodontal disease (Kantor et al. 1976, Polson et al. 1976a, 1979). Although caution must always be exercised when extrapolating results from animal studies to therapeutic implications for disease management in humans, there are certain consistencies in findings from studies in humans and animal model systems. Namely, the management of advanced periodontal disease must be based upon resolution of marginal inflammation. After the resolution of inflammation, continued tooth hypermobility does not result in further loss of connective tissue attachment. In addition, there appears to exist a potential for bone regeneration to occur in the presence of continued tooth hypermobility after resolution of marginal inflammation.

Acknowledgement
This investigation was supported in part by USPHS National Research Service Award No. DE-7061 and Research Grant No. D-1468 from the National Institute of Dental Research, Bethesda, MD, and the Pluta Periodontal Fund.

Zusammenfassung
Knochensehluß bei akuter Zahnlockerung
Die vorliegende Untersuchung wurde durchgeführt, um die Reaktion des Parodonts bei vorliegender marginaler Parodontitis, nach dem Abheilen der Entzündung aber bei aktiver und andauernder Zahnlockerung, zu studieren. Bei 4 Eichhörnchenaffen wurde, durch unilateral am Gingivalsaum der zweiten und dritten Prämolaren angebrachte Seidensäden, eine Parodontitis induziert. 5 Wochen später wurde ein intermittierendes Lockerungstrauma (jiggling) induziert und während der verbleibenden 20 Wochen belassen. Die Ligaturen wurden 15 Wochen nach ihrem Anbringen entfernt und danach wurde regelmäßig orale Hygiene eingesetzt, die dann weiterhin aufrechterhalten wurde. Parodontitis und Trauma wurden ebenfalls an den entsprechenden kontralateralen Zähnen (Kontrollzähnen) induziert, sodass die approximale Region die Experimentsituation direkt vor der Ligaturentfernung wiedergab. In dem koronalen Anteil eines jeden approximalen Parodonts wurde das infiltrierende Bindegewebe, der Verlust an bindegeweblichem Attachment, an alveolarem Knochen sowie der prozentuale Knochenverlust, histometrisch erfasst. Bei den Kontrollpräparaten waren 58% der gebbegeblichen Region oberhalb der Knochenleiste von Entzündungszellen infiltriert – im Vergleich dazu die Resultate der Experimentalpräparate, bei denen nur 19% des entsprechenden Gewebeschnittes entzündlich infiltriert war. Beim Vergleich zwischen den bindegeweblichen Attachmentniveaus oder den alveolaren Knochenleisten wurde kein Unterschied beobachtet. In den Experimentalpräparaten war es allerdings zur Knochenehung gekommen. Das Knochenvolumen erhöhte sich von 11 auf 18% (P<0.05). Es wird gefolgert, dass nach der Ausheilung einer gingivalen Entzündung, auch beim Vorhandensein akuter undauernder Zahnhypermobilität, eine Knochenehung durchaus möglich ist.

Résumé
Réparation osseuse en présence d'hypermobilité dentaire active
L'étude présente a été entreprise pour évaluer la réponse parodontale après résolution de l'inflammation dans un cas de parodontite marginale établie, mais en présence d'hypermobilité dentaire continue. La parodontite a été induite unilatéralement autour des deuxième et troisième prémolaires chez 4 sagouins en serrant des ligatures de soie pour retenir la plaque dentaire au niveau de la gencive marginale. Le traumatisme subi par le parodonte entre ces prémolaires, provoqué par le va-et-vient, a débuté 5 semaines plus tard et a continué durant les 20 semaines suivantes. Les ligatures ont été enlevées 15 semaines après leur placement et une hygiène buccale régulière a débuté et s'est poursuivie. Une parodontite et un traumatisme ont également été induits autour des dents contralatérales (contrôle) afin que la zone interproximale soit dans la situation précédant immédiatement l'enlèvement des ligatures. Le tissu conjonctif infiltré, la perte d'attache conjonctive et d'os
alvéolaire, et le pourcentage d’os ont été déterminés histométriquement pour chaque zone parodontale interproximale coronaire. Dans les spécimens contrôles, 58% du tissu supra-osseux était infiltré de cellules inflammatoires contre 19% dans les échantillons expérimentaux. Aucune différence de niveau d’attache conjonctive ou de hauteur de l’os alvéolaire n’apparaissait. Cependant, une réparation osseuse s’était établie dans les échantillons expérimentaux où le volume osseux était de 18% alors qu’il n’était que de 11% dans les spécimens contrôles ($P<0.05$). D’où la conclusion qu’une réparation osseuse intervient en présence d’une hypermobilité dentaire active et continue après résolution de l’inflammation.

References


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