OVERDENTURES:
A LONGITUDINAL PERSPECTIVE

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To my favorite teacher.

L. E.

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RONALD L. ETTINGER
BDS, MDS, FACD, FICD, FASGD

PROFESSOR

DEPARTMENT OF PROSTHODONTICS

and

DOWS INSTITUTE FOR DENTAL RESEARCH
COLLEGE OF DENTISTRY
UNIVERSITY OF IOWA
IOWA CITY
IOWA 52242

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A LONGITUDINAL PERSPECTIVE

CHAPTER 1

INTRODUCTION - THE PROBLEM

Alveolar ridge resorption following multiple extraction of teeth has always been a significant concern for prosthodontics. The increased longevity of the population[1] has made it an increasingly important factor in complete denture construction. As edentulous persons age, each set of complete dentures constructed becomes less satisfactory for them than the previous set, due to the continuous resorption of the residual ridge. Persons of advanced age have difficulty in learning the increased neuromuscular skills required to function comfortably with complete dentures, especially when there has been gross resorption of the residual ridge.[2] One preventive approach is to maintain teeth within the arch for as long as possible even if they are only root surfaces over which dentures have been constructed.

OVERDENTURES - HISTORY

The concept of leaving/using the roots of natural teeth to support a denture is not a new idea. The first reference in the English literature can be found in 1856 when Ledger[3] encouraged the dental profession to leave "stumps" under a full set of artificial teeth. In 1861 Atkinson[4] published a paper entitled "plates over fangs" in which he suggested that "the advantage, not to say necessity for the presence of fangs, to sustain, by lateral support, the alveolar arch, has not been, and is not at this present, properly considered by but a very few". He goes on to describe the advantage of maintaining residual ridges by preserving the cut down teeth. In 1862 in the

Dental Cosmos, Professor Barker[5] reported on the 1861 American Dental Convention in New Haven, Connecticut. At this meeting Drs. Butler, Roberts Atkinson, Sutton and Hayes presented a symposium entitled "Surgical preparation of the mouth for artificial dentures: should the roots of broken and decayed teeth always be removed?" All the presentors described situations where they would leave roots. However, Hayes described a patient in whom he had placed a maxillary denture over two roots 12 years previously, who was still wearing the denture comfortably. The use of teeth with telescope-like crowns was reported in 1896 in a textbook edited by Essig.[6] The European literature also had suggestions and case histories of the successful use of roots and teeth beneath complete and partial dentures.

On October 3rd 1910, William Hunter delivered an address at the opening session of the faculty of medicine of McGill University in Montreal which was published in the Lancet in 1911.[7] In this paper he stated "Gold fillings, gold caps, gold bridges, gold crowns, fixed dentures built in, on or around diseased teeth form a veritable mausoleum of gold over a mass of sepsis to which there is no parallel in the whole realm of medicine and surgery."

He went on to say:

"The worst cases of anaemia, gastritis, colitis of all kinds and degrees of obscure fever of unknown origin of purpura, of nervous disturbances of all kinds, ranging from mental depression up to actual lesions of the cord, of chronic rheumatic affections, of kidney disease are those which owe their origin to or are gravely complicated by the oral sepsis produced by these gold traps of sepsis."

Hunter's address was widely reported in the newspaper and created a minor panic with many people going to their physician and then to the dentist to have teeth extracted. In 1912 Billings[8] defined a "focus of infection" and he

claimed that "dead teeth" were harmful. Thus, began the era of "blood and vulcanite" which resulted in teeth both pulpless and vital being extracted in large numbers. This was especially the case when a person came to a physician with a disease of unknown origin or an illness which was chronic with no definitive therapy, such as arthritis or non-specific pain.

Grossman[9] (1976) in reviewing the history of endodontics of the last 200 years stated that Hunter's lecture "gave dentistry in general and root canal treatment in particular a black eye from which it did not recover for about 30 years." Interestingly Hunter's theory was not very widely supported in central Europe and the Swiss, Austrians and Germans continued to use endodontic therapy as well as overdentures throughout this period.

In 1936 Fish and McLean10 were able to show that all previous laboratory and animal studies on focal infection were invalid because the root surfaces of the teeth as well as the sockets, had became contaminated by organisms normally found in the oral flora during extraction. In spite of this it took until after the second world war for endodontics to find its place in the English speaking dental practice.

During World War II many U.S. dentists within the military service used overdentures in the treatment of military personnel. Boos11 in 1948 reported the treatment of a patient who in 1944 received a complete denture placed over two crowned retained molars.

In 1952 Rehm,[12] a German dentist described the use of a single front tooth for denture support in a paper published in a German monthly. The first English language publication began with Miller's13 1958 paper where he discussed the results of his ten year experience of retaining a few isolated "weak teeth" under complete dentures. He found that if he crowned the teeth with thimble copings, they regained their healthy status and could be retained for a significant amount of time.

At about this time a group of Europeans began to publish in the English literature. In 1955 Brill[14] summarized the ideas of a selection of European prosthodontists[15-17] who were using root treated abutments, with attachments, to retain partial or complete dentures placed over the teeth. He coined the term "hybrid-prosthesis" and stated that by reducing the crown - root ratio one was able to retain teeth which might otherwise be lost. He believed that the improved retention would help patients with problems make an easier adaptation to dentures. His examples included persons with extensive loss of residual ridges, elderly weak persons, persons with gagging problems, persons with resected mandibles, or those suffering from xerostomia.

It was not until Morrow and his colleagues[18] in 1969 advocated the use of gold copings over retained teeth, with the concomitant use of metal castings within the denture base, that these ideas began to become accepted by many English speaking dentists. In the same year Lord and Teel[19] (1969) published a paper in the Dental Clinics of North America which they entitled "The Overdenture." They advocated elective decoronation of the tooth with endodontic therapy to reduce the height of the teeth to 1 to 2mm above the ridge crest. They also believed that a rounded short gold coping was necessary to protect the tooth. They stated "the retained teeth shield the ridge from stress and help preserve the vertical height of bone". They also stated that "We have observed overdentures for a period of 7 years and are aware of over 100 cases. To our knowledge, no retained tooth has been extracted. Healthy tissue can be maintained, especially when the copings are short." Morrow et al.[20] came to the same conclusion and published their beliefs also in 1969. They suggested that four abutments in a rectangular distribution provided the maximum stability and stated "endodontics facilitate correction of unfavorable clinical situations." Up to this point no

scientific studies had been reported to support the clinical impressions of a growing number of practitioners.

OVERDENTURES - Scientific Studies

The rationale or major advantages for using overdentures can be summarized as:

A. To preserve alveolar bone.

B. To improve denture stability as compared to complete dentures.

C. To preserve sensory input from the teeth.

D. To reduce tooth mobility.

E. To improve masticatory performance.

F. To improve the psychological acceptance of dentures.

A. PRESERVATION OF ALVEOLAR BONE

All bone is constantly being remodeled. Following the loss of teeth, resorption of the alveolar ridges occurs. The rate varies between different individuals and also at different rates within the same individual. Tallgren[21] (1969) using serial cephalometric techniques reported on the longitudinal effect of wearing complete dentures. She found that during the first 6 months of denture use, the mean reduction of the anterior height of the mandibular process was about twice that of the maxillary residual ridge. After seven years the ratio of loss had increased to four to one. It was also noted that the greatest changes occurred within the first year. In another comparative seven year study Tallgren[22] (1969) found that the anterior part of the mandible lost 10 times more bone under complete dentures than under partial dentures. Atwood and Coy (1971)[23] found that the mean reduction of the residual ridge for the anterior maxilla was 0.1 mm per year while for the mandibular anterior area, it increased to 0.4 mm loss per year. Thus, they also reported a 1:4 ratio bone loss between the maxillary and mandibular

ridges. After 25 years of denture wearing, Tallgren[24] (1972) observed that these patients had an average reduction of anterior mandibular ridge height of 9 to 10mm. The mean reduction of maxillary ridge height during this same time period was measured at 2.5 to 3mm. Carlsson and Persson[25] (1967) also studied the morphological changes in the mandible after removal of teeth and the placement of dentures. They found that with cephalometric analysis after five years, the anterior part of the mandible lost 2mm in height during the first two months and that it increased to 4mm at the end of the first year. At the five year evaluation the mean loss was measured at 6.7mm.

Crum and Rooney[26] (1978) followed 16 men aged 46 to 67 years for 5 years with serial diagnostic casts and cephalometric radiographs. Eight of these patients were treated with overdentures made over decoronated, endodontically treated, mandibular canines which were 1.5mm above the gingival margin. The other eight patients had all the remaining teeth extracted and complete denture made. At the end of 5 years the loss of bone in the maxillary process was similar in both groups of patients, but the vertical bone loss in the mandibular process was 0.6mm in the overdenture group compared to 5.2mm in the complete denture group.

All of these studies suffer from significant flaws, in that the number of subjects are quite small, the age range of the subjects are quite large; the controls are not matched to the experimental group appropriately; there is inadequate reporting of the medical status, drug status, and oral habits of the individuals in the study. Nevertheless, the evidence available suggests that the concept of maintaining teeth within the dental arches may indeed help to preserve the resorption of the alveolar bone.

B. IMPROVEMENT OF DENTURE STABILITY

A number of authors have stated that denture stability and retention are greatly enhanced and that the preservation of the abutments prevented anterior-posterior slipping and any associated trauma to the edentulous ridge. Fenton and Hahn (1978)[27] modified an index for retention as described by Löe[28] in their study of 17 patients who were seen 4 to 25 months after placement of overdentures. They reported a distinct clinical impression that overdentures were more stable than conventional complete dentures. Toolson and Smith (1983)[29] using standard criteria, found that, 5 years after the placement of overdenture, the fit of both maxillary and mandibular dentures was well maintained. Ralph and Murphy (1976)[30] followed 6 patients for 3-15 months, after which they stated, "the clinical impression that the root abutment help to slow the process of alveolar resorption and to maintain the fit of the denture base was reinforced by analysis of a series of study casts." No adequate studies have specifically compared the fit of overdentures with complete dentures. However, it seems reasonable to assume that where there is preservation of the residual alveolar ridge, a denture placed over this ridge should be more stable.

C. PRESERVATION OF SENSORY INPUT

The success or failure of any removable prosthesis seems to be dependent upon the integration of sensory feedback and the appropriate motor response. In the masticatory system, effective functioning relies on feedback from receptors in the temporomandibular joint, muscle ligaments, the oral mucosa, and the periodontal tissues. The extraction of teeth should result in some loss in proprioception as the edentulous ridges cannot give the same sensory feedback to the system.

Manly and his colleagues (1952)[31] compared the perception of oral sensation of natural teeth to the perception in persons wearing complete dentures. These authors evaluated the effect of such stimuli as thickness, light touch, hardness and texture. They found that the anterior natural teeth could detect threshold loads of approximately 1 gram on the incisal surface in an axial direction whereas loads of 8 to 10 grams were required on the occlusal surface of the first molars. They reported no statistical difference in the ability of their subjects to determine the thickness of Lucite disks and concluded that proprioceptive ability might depend upon the temporomandibular joint and the muscles of mastication. However, they did find that their dentate subjects had 10 times finer tactile sensitivity (using von Frey's hairs) than the edentulous subjects, which they believed were due to proprioceptors in the periodontal tissues. Kawamura and Watanabe (1960)[32] refined these experiments using wires of small incremental difference and reported a 100 fold difference. The dentate group were able to discriminate differences in size of 0.2 to 0.3 mm. Siirilä and Laine (1967)[33] studying dentate persons found that 75 percent of their test subjects could perceive a piece of metal foil 60 μm thick even after the mandibular teeth had been anaesthesized by a mandibular nerve block injection. Kay and Abes[34] in reviewing the existing literature in 1976 concluded that the periodontal tissues which remain in overdenture abutment teeth preserve sufficient receptors to play a role in proprioception and that "pressure perception by the periodontal ligament remains a primary stimulus for the jaw opening reflex."

Loiselle et al. (1972)[35] proposed that maintenance of teeth as overdenture abutments preserved sensory input and that overdenture subjects in their study could better discriminate thickness of stainless steel rods than persons

wearing complete dentures. However, they did not present a data analysis to support their conclusions. Fenton (1973)[36] studied occlusal thickness perception in persons who had natural dentitions, complete dentures and overdentures. In this study persons wearing overdentures were found to have less ability to perceive occlusal thickness than persons wearing complete dentures. Levin (1976)[37] at an IADR meeting in South Africa reported on a study which compared the discriminatory ability of three groups of adults who were either dentate, or were using complete dentures or overdentures. The subjects were asked to discriminate between 2 rods, 2.0 and 2.5mm in diameter. The subjects were then anesthesized. He concluded that prevention of resorption, not periodontal perception, was the principal advantage of overdentures as no significant reduction in discrimination of thickness with anesthesia was found in overdenture patients. This abstract does not disclose how many subjects were in each group, the ages of the subjects or their health. As a result it is difficult to assess the value of this study.

Pacer and Bowman 1975[38] compared the ability of 14 subjects aged 29 to 81 year, eight of whom received complete dentures and six received overdentures. When the patients had accommodated to their dentures, perpendicular forces were applied to the mandibular denture and subjects were asked to discriminate between the differences in value of the forces. Although all subjects with dentures showed sensory threshold values close to natural teeth, the profiles of the overdenture patients were more similar to persons with natural teeth. The small number and large age range of these subjects make interpretation of the data difficult to assess.

Although there are no definitive studies on sensory feedback it would seem reasonable with the evidence available to make these points:

1. The periodontal ligament is only one of the sites of sensory feedback in the oral cavity.
2. If teeth are retained as overdenture abutments, the overdenture is more likely to be stable and such a denture should improve tactile sense when compared to complete denture wearers.
3. Natural anterior teeth seem to exhibit more sensitivity and discrimination than posterior teeth and so are supposed to give more discreet sensory imput.[31,32] However, there is no evidence that these differences have any clinical significance. Kay and Abes (1976)[34] in their review of the literature stated that proprioception of the mandible is partially a function of receptors in the temporomandibular joint and the muscles of mastication and that the receptors in the periodontal membrane of the remaining overdenture abutment may also have a tactile function. They concluded that the pressure of a rigid overdenture on the underlying abutment teeth would be more sensitive in halting damaging forces than the soft tissues of an edentulous patient.

D. <u>REDUCTION OF TOOTH MOBILITY</u>

The decision to construct a removable partial denture or an overdenture often depends upon the ratio of the length of crown to the length of the root of the reamining teeth. If an unfavorable ratio exists, shortening the crowns of these teeth for use as overdenture abutments will immediately improve this crown-root ratio.[39] Dolder and Durrer (1978)[40] in their textbook summarized Shrärer's 1961[41] thesis on assessing the mobility of teeth using a

periodontometer. Sha?rer found that after shortening the abutment teeth, which were being prepared for a bar-joint prosthesis, buccolingual mobility was immediately reduced by 66.5 percent. One month after placement of the prosthesis there was a further reduction of 13.3 percent.

In a two year study Davis et. al. (1981)[42] measured mobility by "placing a periodontal probe on the root and attempting to move it facially and lingually. Mobility was graded on a scale of I to III. Of the 20 roots examined there was an improvement in 10, no change in nine, and one had an increase in mobility. A 0 to 3 scale was used by Toolson et al. (1982)[43] to measure mobility after 2 years of denture wearing. No significant changes were found in the 253 abutments examined and continuous wearing of the dentures did not affect the mobility of the abutment teeth. Renner et al. (1984)[44] evaluated seven patients with 12 abutment teeth after four years of denture wearing. No significant changes in mobility from baseline were recorded. After five years of denture wearing Toolson and Smith (1983)[29] were unable to find any significant change in the retained teeth they examined in their population of 54 persons with 133 overdenture abutments. These studies seem to suggest that provided the patient practices adequate oral hygiene, the reduction of the crown improves the crown - root ratio. Denture wearing does not in itself result in mobility of the abutments.

E. IMPROVEMENT OF MASTICATORY PERFORMANCE

Very few studies have evaluated masticatory performance in overdenture subjects. Rissin et al. (1978)[45] evaluated masticatory function in association with electromyographic activity in 10 dentate males and compared them to 10 successful complete denture wearers and 9 men wearing overdentures. When carrots were used as the test food, the persons with natural teeth had a masticatory performance of 90 percent compared to 79 percent for overdenture subjects and 59 percent for persons wearing complete dentures. They concluded that while chewing a test food for a constant number of strokes, overdenture patients chewed more slowly but more efficiently than complete denture wearers. Nagasawa et al. (1979)[46] used electromyographic recordings in seven complete mandibular overdenture patients. The first recordings were made with the overdentures having mucosal contact only, and then the recordings were compared with the same overdentures in which tooth contact has been restored with stud attachments. Using selected test foods, these investigators developed a masticatory index as an indicator of the efficiency of masticatory movement. They found that when tooth contact was restored to the overdentures the masticatory index was higher. However, no significant differences were found in masticatory performance when tooth contact was restored to the subjects overdentures when compared to completely mucosally supported overdentures.

Sposetti et al. 1986[47] studied six patients who complained of an inability to function with conventional complete maxillary denture opposed by a mandibular complete overdenture. Maximum biting force and EMG activity during mastication were measured. Maximum biting force was measured before (denture was tissue supported) and after placement of Zest Anchor attachments on the lower overdentures with a gnathodynamometer at a vertical dimension of

10 mm. EMG recordings were also made with pairs of surface electrodes over the anterior digastric and mylohyoid muscles as well as the right and left anterior fibers of the temporal and masseter muscles. There was a mean increase of bite strength of about 50 percent from 50.8 lbs to 76.1 lbs after placement of the attachments in the mandibular overdentures. This finding supports the longitudinal study of Ralph (1986)[48] who showed that over an 8 year period, persons with mandibular teeth opposing a maxillary complete denture had greater biting strength than persons with conventional complete dentures. In 1983 Meng and Rugh[49] reported on the biting force of 6 overdenture patients compared to 9 patients wearing conventional complete dentures. They found that patients with load bearing abutments had a greater mean biting strength (71.2 lbs) compared with conventional complete dentures (29.3 lbs).

EMG activity of the temporal and masseter muscles in the Sposetti et al. study[47] increased in all phases of chewing after placement of the attachments. They suggested that this may indicate a visualization of the greater biting strength recorded with overdentures, as well as an indicator of the improved stability of the overdentures.

F. IMPROVEMENT OF THE PSYCHOLOGICAL ACCEPTANCE OF DENTURES

It has been suggested by several authors (Brill 1955[14], Cooper and Ellinger 1971,[50] Dodge 1973,[51] De Franco 1977,[52] Renner and Levy 1978[53]), that the loss of the remaining teeth could be a disturbing emotional experience for many people. Some people associate the loss of teeth with growing old, which is emotionally depressive. It has been argued that the retention of some teeth in the form of overdenture abutments prevents this negative feeling of total loss and allows the patient to adjust more easily to the acceptance of denture wearing.

Apart from anecdotal reports there is very little evidence to support this hypothesis. The only study is by Toolson and Smith 1983[29] who used a patient satisfaction (PDS) questionnaire developed by Guckes et al.[54] at all their recall appointments over a period of five years. No significant changes in satisfaction were found in their population at 2 years of overdenture wearing or after 5 years.

OVERDENTURES - THE ABUTMENT TEETH

The rationale of the benefits of utilizing overdentures has suggested that they are a useful treatment modality. However this review has not yet discussed the issues related to selection of the abutment teeth.

ABUTMENT SELECTION

The characteristics of an ideal overdenture abutment tooth have been described by Morrow et al. (1969)[20] and Lord and Teel (1969)[19]. Such a tooth should have good bone support, minimum mobility and be surrounded by healthy soft tissue with minimum pocket depth. The gingiva should have an adequate band of attached gingiva. The abutments should be selected so that they are retained in regions where the occlusal forces have the greatest destructive potential and where the greatest amount of resorption is likely to occur.

NUMBER OF ABUTMENTS

Morrow et al (1969)[18] suggested that the optimal distribution for one arch should be rectangular with the preservation of two canines and two second molar abutments. Lord and Teel[19] state that "the mandibular canines are most commonly used because they are usually the last teeth to be lost." They suggest that because of their root length and position, canines are the most strategically beneficial teeth to save as abutments. They also warn against keeping teeth which are in such close proximity that brushing of the interdental papillae may be a problem.

Bolender et al. (1984)[55] suggested that when "selecting teeth to keep in the arch," diagonal fulcrum lines should be avoided." They state that, in their experience, overdenture patients who have such a configuration of abutment teeth tend to complain of "difficulty in maintaining even contact between overdenture teeth and soft tissue." One presumes this to mean that the dentures tend to rock. The authors do not give any details of how long after construction this occurs, how many patients were involved or what percentage of subjects were involved or what percentage of subjects received this configuration and were unhappy with it.

ABUTMENT HEIGHT AND CONTOUR

In 1958 when Miller[13] published his description of placing complete dentures over natural teeth, he did not advocate routine endodontic therapy or significantly reducing the teeth in height. His only suggestion was for a gold thimble with a 4 to 5mm collar on all surfaces at the cervical margin to provide fixation for the veneer crown. However both Morrow et al (1969)[18] and Lord and Teel in 1969[19] suggested the use of endodontic procedures to correct unfavorable crown - root ratios and "drastic" reduction of the occlusal height for adequate space for the artificial teeth. Both groups believed in using gold abutment copings with chamfer margins.

There is no concensus of opinion amongst clinicians as to the optimal height of the overdenture abutments except that they should be a few millimeters above the gingival crest. Bolender et al.[55] suggested that for the maxillary arch the height should be 2mm and for the mandibular arch 3mm above the ridge crest.

Very few investigators have evaluated the effect of height and contour of the abutment teeth on periodontal health. According to Morris (1958)[56] axial contours of teeth seem to be important in determining the position of the

gingival margin. If the gingival margin is altered this may lead to proliferation of the gingival tissue, plaque accumulation and periodontal pocket formation. Morrow et al. (1969)[18] found only a small amount of change in the 9 patients they followed from 3 to 8 months. Mobility of the abutment teeth decreased by 1.3 percent and pocket depth increased by 9 percent. Davis et al. (1981)[57] and Renner et al.[58] have suggested that the dome-shaped coping has been associated with a plaque free environment and a healthy periodontium.

Bolender et al. (1984)[55] are convinced that the dome-shape is ideal for overdenture abutments. They state that it is easy to reproduce in an impression and that it allows denture movement without trauma to the overdenture abutment teeth. Thus, it supplies support and stability, but not retention for the overdenture.

In response to all this speculation, Graser and Caton (1987)[59] evaluated the effect of the contour of overdenture abutment on plaque retention and periodontal health in four patients. Two mandibular canine abutments for each subject were reduced to a height of 2mm above the gingival margin, one was dome-shaped, the other was cut so that the occlusal surface followed the gingival margin. Small amalgam dots were placed on the buccal, lingual, mesial and distal surfaces of both abutments to serve as fixed reference points for probing and radiographic measurements.

After one year[59] the interpretation of the data suggested that the contour of the overdenture abutments did not play an important role in determining either plaque accumulation or periodontal status. After 5 years[60] there were significant increases in mean plaque scores, pocket depth and attachment level for all abutment teeth. As a result, it was determined that these differences were due to the presence of plaque and not differences in any of the parameters which could be attributed to abutment tooth contour.

OVERDENTURES - RESEARCH QUESTIONS

The evidence from this review of the literature can be interpreted to suggest that the maintenance of teeth as overdenture abutments has significant value to a patient. What is not known is what happens to patients wearing overdentures over longer time periods? Which patients will be at risk to develop caries or periodontal disease? What individual characteristics or profiles of patients make a particular individual a successful overdenture wearer? What preventive measures are necessary for the maintenance of overdenture abutments? This thesis attempts to answer some of these questions by longditudinally evaluating an overdenture population.

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MATERIALS AND METHODS

CHAPTER 2

All patients scheduled for overdenture treatment in the removable prosthodontics clinic at The University of Iowa from 1973 to 1985, were included in this study. Restorative care for 254 patients was provided by undergraduate dental students, graduate students, or faculty.

Prior to the reduction of the abutment teeth for all patients there was an attempt to establish optimal gingival health. Then, all the abutment teeth were reduced to a level of 1.5 to 2mm above the gingival margin. For most patients, root canal therapy was completed in one visit and the access opening restored with an amalgam or composite restoration. Cast gold copings were used only when it was impossible to prepare sound supragingival root faces on the abutment teeth. If the root canal space appeared to have diminished radiographically to a level below the free gingival margin and no pulp exposures were noted at the time of reduction, no endodontic therapy was carried out. All vital teeth were responsive to electric pulp testing and were without discernable periapical radiolucencies prior to reduction.

At the time of denture insertion, baseline measurements and photographs for all patients were made by the author. The measurements included evaulation of the restorations, dentures, abutment height above the gingival margin, and periodontal pocket depth. The height above the gingival margin was measured with a periodontal probe in millimeters at four separate locations on each tooth: mid-mesial, mid-distal, mid-facial and mid-lingual. The distance measured was from the gingival margin to the highest point on the tooth which was determined by the intersection of the periodontal probe with a metal ruler placed horizontally over the tooth. The periodontal probing depth was determined at the same four sites.

In 1976 permission was sought to place small amalgam restorations, on the mid-mesial, mid-distal, mid-facial and mid-lingual sites on the overdenture abutments. Periapical film stents would then be made for each patient so that accurate reproducible radiographic films could be made and repeated at the six month recall appointments. The Institutional Review Board did not agree to the proposal and ordered radiographs to be taken only when required for diagnosis or treatment of the patient.

The health of the periodontal tissues was measured by evaluating plaque and calculus levels. These were measured as:

0 - No plaque visible

1 - Plaque visible at or near gingival margin

2 - Plaque and supragingival calculus visible on the abutment

The tissues were also evaluated for bleeding on probing.

0 - No bleeding on probing

1 - Bleeding after probing

2 - Spontaneous bleeding - tissues so inflamed that touching them with the denture was enough to precipitate bleeding

If there was horizontal mobility greater than 1mm it was recorded. The treatment of periodontal problems was recorded for each abutment as:

0 - No treatment required

1 - Cleaning and scaling

2 - Deep root planning, associated with periodontal surgery

3 - Extraction of abutment due to periodontal disease

Patients who had a history of rheumatic fever, valvular defects, prosthetic valves, mital valve prolapse or prosthetic joints were only probed if they had taken the appropriate prophylactic medication.

Patients were asked to return to the removable prosthodontics clinic at six months intervals. At these recall appointments, overdenture abutment teeth were evaluated with respect to the condition of the restorations, caries, and periodontal problems. Maintenance care was performed on the dentures, the abutments, and the soft tissues as needed. After 1976, five patients were selected each year for re-examination to determine intra- examiner reliability which was measured by the test-retest method.[1]

A series of sociodemographic and medical data were collected at each visit. These included variables such as location of domicile, age and gender.

The medical problems were a list of ten systemic entities either past or present (e.g. history of cardiovascular problems, etc.), which were noted as absent or present and are listed below.

MEDICAL PROBLEMS

Central Nervous System Disease	Renal Disease	Rheumatic Fever
Cardiovascular Disease	Hepatic Disease	Joint Replacement
Pulmonary Disease	Arthritis	Other
Gastro-Intestinal Disease	Malignancy	

Drug usage was also recorded, as a listing of medications being used at the time of examination. From this data a total number of drugs could be computed as well as drugs which could be defined as having potential oral side effects such as:

POTENTIAL ORAL SIDE EFFECTS

Xerostomia, e.g. Elavil

Hyperplasia, e.g. Dilantin

Taste Alteration, e.g. Lithium

Ulceration/Oral Lesion, e.g. Aldomet

Neural Side Effects e.g. Haldol

All the patients were asked if they had any dryness in their mouth which was recorded as a subjective Yes or No from the patient.

Details of the patients' preventive habits such as frequency of daily tooth brushing, use of home fluorides, type of fluorides being used were also collected.

The patients' denture usage was documented and their satisfaction with the overdenture therapy was sought as an open-ended question. This was followed by a standard denture examination procedure which evaluated the dentures for:

extensions	occlusion
retention	cleanliness
stability	

The treatment needs were characterized as either dentures requiring cleaning, repair, and/or adjustment of denture bases or of the occlusion. If significant changes had occurred the dentures were classified as requiring a reline or a remake.

The stability of the dentures was determined by placing a finger on the occlusal surface of the premolars on each side of the dentures and rocking them from side to side. They were graded as:

0 - Adequate stability

1 - Movement or treatment required

Treatment of loss of stability was determined by the use of pressure indicator paste to be either:

1 - Adjustment of the denture base

2 - Relining of the dentures

3 - Remaking of the dentures

The retention of the maxillary dentures was determined by trying to break the peripheral and post-dam seal with the thumb and first finger in the

anterior midline area or in the premolar region. For the mandible the dentures were seated with the mouth open and an attempt was made to lift the dentures with a periodontal probe. The dentures were graded as:

0 - Adequate retention

1 - Unacceptable movement or treatment required

Treatment for loss of retention was either to adjust the denture base, to replace the post-dam seal, or to reline or remake the dentures.

The extensions were evaluated to make sure that the dentures bases were not chipped or broken and that there were no over-extension or under- extensions. Treatment for these problems were either to adjust the dentures or to reline or remake them.

The occlusion was evaluated by examining the occlusal surfaces for wear. The dentures were stabilized and the patient was asked to close into a posterior retruded unstrained position. Visual examination was used to determine if there was equal contact of the posterior teeth in maximum intercuspation on both sides of the arch. If there were unstable contacts, a centric relation record was made in wax and the dentures were remounted. The treatment was either an occlusal adjustment by selective grinding, rebuilding of the occlusion in tooth colored, chemically cured acrylic resin, replacement of the posterior teeth or remaking of the dentures.

Thus, the treatment needs of the patients were divided into either cleaning of the dentures only or cleaning combined with repair of a defect of the denture base, adjustment of the denture bases or the occlusion and where required, a reline or remaking of the denture.

At this point the dentition was evaluated for caries. Presence of caries was noted when there was a discrete well defined and/or discolored soft area or the explorer entered easily and displayed some resistance to withdrawal. The categories of the problems identified were:

0 - None

1 - Occlusal caries

2 - Occlusal caries and lost restoration

3 - Root caries only

4 - Caries and Endodontics (periapical) problem

5 - Other

The treatment required for each abutment tooth was recorded as any one or more combination of these therapies.

<u>Periodontal therapy</u>

0 - None

1 - Clean and scale

2 - Periodontal Surgery

3 - Extract tooth

<u>Restorative therapy</u>

0 - None

1 - Replace restoration

2 - Gold coping required

3 - Reduce and recountour tooth and restore

4 - Endodontics and restore

5 - Extract teeth

6 - Other

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CHAPTER 3

THE STUDY POPULATION - BASELINE DATA

During the period from 1973 to 1985, 254 persons received overdentures. The distribution of the subjects by year is shown in Table 1. The mean number of persons receiving overdentures each year was 19.5. The distribution of the overdentures placed each year by arch is also shown in Table 1. Nearly twice as many mandibular overdentures were placed for every maxillary overdenture, the rate was 1.8 to 1. The age and sex of the 254 persons at the time the overdentures were inserted is shown in Table 2. There were nearly twice as many men as women in the study group. The mean age at the time of insertion of the dentures was 58.6 years, with an age range of 17 to 91 years.

To evaluate the effect of general health on the oral health of the subjects in the study, a medical history of past and current problems was recorded. The distribution of these medical problems by gender is shown in Table 3. The most common medical problems reported by this group was a history of cardiovascular disease with just over 40 percent of the subjects at risk. Hypertension was the disease most often cited and accounted for over 75 percent of these cardiovascular diseases. The next most common problem was arthritis (30.3 percent) with osteoarthritis the most reported form. Gastro-intestinal disease was a problem for 18.5 percent of the population with ulcers the dominant problem. Pulmonary disease was the next most common problem (15.4 percent) usually in the form of a history of asthma.

In general the rate of medical problems was higher in women than in men except for pulmonary diseases and this may be related to a higher number of men who smoked. Women seemed to be at a higher risk for all malignancies. In fact, women reported more lesions of the head and neck and nearly five times

as many other treated lesions which were either tumors of the breast, of the cervix, or of the uterus.

In Table 4 the same information is broken down by age group. In general the older the patients were the more medical problems they had. However, in most instances the profile of the patients' aged 55-64 was no different from the other two older age groups, but the group of subjects aged under 55 years had significantly fewer medical problems.

Medications the subjects were taking were recorded and divided into those which might have potential oral side effects and those which had no known potential oral side effects. More men than women reported using drugs (Table 5). Over 40 percent of both sexes were taking at least one drug which had a xerostomic potential. Drugs which had the potential to create other oral side effects or problems were being taken by less than 5 percent of the sample. In the youngest age group only about 20 percent of the study population were taking at least one drug with a xerostomic potential, but that number doubled to 44.7 percent in the 55-64 year old age group. In the age groups over 65 years of age the number of persons taking these drugs rose to over 60 percent of the population. The use of medications with other potential oral side effects increased in the older subjects had remained under 10 percent even in the oldest age, that is, persons aged over 75 years.

THE DENTITION

In Table 6 the teeth which were retained as overdenture abutments are identified. More mandibular (414) than maxillary (265) teeth were utilized and the most common teeth saved were the lower canines (249) followed by the upper canines (163) which represented about 30 percent of the abutments in each arch. A series of other teeth around the canines were also used for abutments, these were the lower first and second premolar, the other lower anterior teeth and in the maxilla, the central incisors.

The number of abutments retained per person are listed in Table 7. the range was from one to 13 in the maxilla and one to 11 in the mandible. Retention of two teeth was the most common pattern with nearly 60 percent of all the abutments in each arch showing this pattern.

The distribution of abutments by arch, gender, and by year of placement is shown in Table 8. The greatest number of abutments were used in 1981 (96), while the average over the 13 years of the study has been about 32 dentures per year. The philosophy of the department has been to preserve bone. If teeth could be saved we tried to do it, but the aim was to selectively preserve abutments on the mandibular arch. If natural teeth were being retained in one arch we tried to keep overdenture abutments in the opposing arch. This philosophy is reflected in Table 9 as the majority of the abutments were maintained in the mandibular arch. In only a small number of patients (30) were we able to convince the patients to keep overdenture abutments in both arches.

The most common dentures placed were mandibular complete overdentures of which 105 were in men and 69 in women (Table 10). This was followed by maxillary complete overdentures with 63 in men and 30 in women. Partial overdentures made up less than 6 percent of the 284 overdentures placed in this population. In general, more men than women of the same age group had complete maxillary overdentures constructed for them. Only in the age group 55-64 was this reversed. However, more mandibular complete overdentures were constructed for women than for men. These differences were not large enough to be significantly different. The number of partial overdentures constructed was so small that no particular trends could be seen except to state that they were less likely in persons under the age of 54 years.

The distribution of the overdentures placed is shown in Table 11 by type, gender, and age group. The subjects were divided into three age groups for this analysis. The most common combination placed was a complete maxillary denture opposing a mandibular complete overdenture. The next most common combination was a complete maxillary overdenture opposed by a natural dentition supporting a partial denture. A very small number of overdentures just opposed a mandibular natural dentition. Less than 10 percent of the subjects had complete maxillary and mandibular overdentures constructed for them. There were also a variety of other conditions but these made up only 10 percent of the total numbers.

In 1973 when the study began it was accepted procedure to cover all root surfaces with gold thimble copings. We questioned this philosophy and did not do it routinely. After 1978 cast gold copings were used only when it was impossible to prepare sound supragingival root faces on the abutment teeth or if precision attachment were to be used. Copings were used on 23 abutments in 8 patients (Table 12). To seal the access opening of the root canal after endodontic therapy, amalgam was used. However, in 1984 when we had had some experience with dentin bonding agents, these were also used in the following manner:

(a) If the abutment was a single tooth then only amalgam (Tytin*) was used.

(b) If there were two or more teeth in one arch then the abutments on one side were restored with amalgam, the other with Scotchbond**, and a posterior composite P30.** The order was the reversed for the next patient.

*SS White Dental Products International, PA 19102
** 3M Co., MA 55101

(c) If there were teeth on both arches then a cross over pattern was used, the side being determined by what had been used for the previous patient. In this way we hoped to eliminate, left or right bias. In that period of time 50 abutments were restored in 29 patients.

For 17 patients it was possible to cut down 94 teeth for overdenture abutments without root canal therapy. The canal space in these teeth appeared to have diminished radiographically to a level below the alveolar mucosa. All teeth were responsive to electric pulp testing and without discernable periapical radiolucencies at the time of reduction.

TABLE 1

NUMBER OF SUBJECTS AND NUMBER OF
OVEDENTURES PLACED BY ARCH EACH YEAR

	Number of Subjects	Number of Overdentures		
		Maxilla	Mandible	Total
1973	2	0	2	2
1974	4	0	4	4
1975	9	3	6	9
1976	10	3	7	10
1977	18	4	16	20
1978	22	10	17	27
1979	28	9	21	30
1980	22	9	17	26
1981	33	15	22	37
1982	20	9	13	22
1983	22	10	15	25
1984	32	16	22	38
1985	32	15	19	34
TOTAL	254	103	181	284

TABLE 2

DISTRIBUTION OF THE SUBJECTS BY
AGE AND SEX

Age Group	Male	Female	Total
>55	57 (36.3%)	29 (29.9%)	86 (33.9%)
55-64	42 (26.8%)	34 (35.1%)	76 (29.9%)
65-75	44 (28.0%)	23 (23.7%)	67 (26.4%)
75+	14 (8.9%)	11 (11.3%)	25 (9.8%)
TOTAL	157 (100.0%)	97 (100.0%)	254 (100.0%)

TABLE 3

SELECTED MEDICAL PROBLEMS
BY GENDER

Medical Problems	Total N = 254	Male N= 157	Female N = 97
Central Nervous System	26 (10.4%)	14 (8.9%)	12 (12.4%)
Cardiovascular	102 (40.2%)	59 (37.6%)	43 (44.3%)
Pulmonary	39 (15.4%)	27 (17.2%)	12 (12.4%)
Gastro-Intestinal	47 (18.5%)	26 (16.6%)	21 (21.6%)
Hepatic	33 (13.0%)	17 (10.8%)	16 (16.5%)
Renal	20 (7.9%)	9 (5.7%)	11 (11.3%)
Diabetes	22 (8.7%)	11 (7.0%)	11 (11.3%)
Arhritis	77 (30.3%)	44 (28.0%)	33 (34.0%)
Head or Neck Malignancy	12 (4.7%)	6 (3.8%)	6 (6.2%)
Other Malignancy	20 (7.9%)	4 (2.5%)	16 (16.5%)
Rheumatic Fever	11 (4.3%)	5 (3.2%)	6 (6.2%)
Joint Replaced	6 (2.4%)	4 (2.5%)	2 (2.1%)
Other	70 (27.6%)	47 (29.9%)	23 (23.7%)

TABLE 4

SELECTED MEDICAL PROBLEMS
BY AGE GROUP

Medical Problems	Age in Years >55 N=86	55-64 N=76	65-74 N=67	75+ N=25
General Nervous System	8 (9.3%)	8 (10.5%)	7 (10.4%)	3 (12.0%)
Cardiovascular	17 (19.8%)	24 (31.6%)	46 (68.7%)	15 (60.0%)
Pulmonary	14 (16.3%)	11 (14.5%)	11 (16.4%)	3 (12.0%)
Gastro-Intestinal	14 (16.3%)	13 (17.1%)	11 (16.4%)	9 (36.0%)
Hepatic	9 (10.5%)	10 (13.2%)	10 (14.9%)	4 (16.0%)
Renal	2 (3.3%)	6 (7.9%)	9 (13.4%)	3 (12.0%)
Diabetes	5 (5.8%)	8 (10.5%)	6 (9.0%)	1 (4.0%)
Arhritis	15 (17.4%)	25 (32.9%)	27 (40.3%)	10 (40.0%)
Head or Neck Malignancy	2 (3.3%)	4 (5.3%)	4 (6.0%)	2 (8.0%)
Other Malignancy	7 (8.1%)	6 (7.9%)	3 (4.5%)	4 (16.0%)
Rheumatic Fever	4 (4.7%)	4 (5.3%)	3 (4.5%)	0 (0.0%)
Joint Replaced	1 (1.2%)	1 (1.3%)	2 (3.0%)	1 (4.0%)
Other	22 (25.6%)	17 (22.4%)	23 (34.3%)	8 (32.0%)

TABLE 5

MEDICATIONS BY POTENTIAL SIDE EFFECTS

BY GENDER

Medications	Total N=254	Male M=157	Female N=97
Xerostomia	112 (44.1%)	66 (42.0%)	46 (47.4%)
1 Drug	56 (22.0%)	31 (19.7%)	25 (25.8%)
2 Drugs	32 (12.6%)	20 (12.7%)	12 (12.4%)
3 Drugs	24 (9.4%)	15 (9.6%)	9 (9.3%)
Hyperplasia	7 (2.8%)	5 (3.2%)	2 (2.1%)
Neural	10 (3.9%)	8 (5.1%)	2 (2.1%)
Taste Alterations	5 (2.0%)	5 (3.2%)	0 (0.0%)
Ulceration	5 (2.0%)	4 (2.5%)	1 (1.0%)
Other Drugs	93 (36.6%)	53 (33.8%)	40 (41.2%)

BY AGE GROUP

	Age in Years			
Medications	> 55 N=86	55-64 N-76	65-74 N=67	75+ N=25
Xerostomia	21 (24.4%)	34 (44.7%)	42 (62.7%)	15 (60.0%)
1 Drug	13 (15.1%)	19 (25.0%)	22 (32.8%)	2 (8.0%)
2 Drugs	3 (3.5%)	10 (13.2%)	15 (22.4%)	4 (16.0%)
3+ Drugs	5 (5.8%)	5 (6.6%)	5 (7.5%)	9 (36.0%)
Hyperplasia	1 (1.2%)	3 (3.9%)	2 (3.0%)	1 (4.0%)
Neural	1 (1.2%)	2 (2.6%)	5 (7.5%)	2 (8.0%)
Taste Alteration	1 (1.2%)	3 (3.9%)	0 (0.0%)	1 (4.0%)
Ulceration	1 (1.2%)	1 (1.3%)	0 (0.0%)	3 (12.0%)
Other Drugs	21 (24.4%)	21 (27.6%)	33 (49.3%)	12 (48.0%)

TABLE 6

DISTRIBUTION OF ABUTMENTS
BY TOOTH

MAXILLA N= 265

TOOTH NO:	2	3	4	5	6	7	8	9	10	11	12	13	14	15
N	4	3	8	9	82	9	24	18	10	83	3	7	3	1
PERCENTAGE	1.5	1.1	3.1	3.4	31.4	3.4	9.2	6.9	4.4	31.8	1.1	2.7	0.8	0.4

NO. OF SUBJECTS = 105
MEAN NO. OF ABUTMENTS = 2.5
RANGE 0-13

MANDIBLE N=414

TOOTH NO:	18	19	20	21	22	23	24	25	26	27	28	29	30	31
N	1	0	17	27	126	20	16	19	20	123	20	17	1	3
PERCENTAGE	0.2	0	4.2	6.6	30.8	4.9	3.9	4.6	4.9	0.1	4.9	4.2	0.2	0.5

NO. OF SUBJECTS = 179
MEAN NO. OF ABUTMENTS = 2.3
RANGE 0-11

TABLE 7

DISTRIBUTION OF OVERDENTURE ABUTMENTS
BY ARCH

No. of Abutments	Maxilla N = 265		Mandible N = 414		Total N = 679	
	N	%	N	%	N	%
1	1	(0.4)	25	(6.0)	26	(3.8)
	75	(56.6)	120	(58.0)	195	(57.4)
3	15	(17.0)	11	(8.0)	26	(11.5)
4	7	(10.6)	17	(16.4)	24	(14.1)
5	3	(5.7)	1	(1.2)	4	(2.9)
6	1	(2.3)	3	(4.3)	4	(3.5)
7	1	(2.6)	2	(3.4)	3	(3.1)
11	0	(0.0)	1	(2.7)	1	(1.6)
13	1	(4.9)	0	(0.0)	1	(1.9)

TABLE 8

DISTRIBUTION OF THE OVERDENTURE ABUTMENTS
BY ARCH GENDER
AND YEAR OF PLACEMENT

	MAXILLA			MANDIBLE			
	MALE	FEMALE	TOTAL	MALE	FEMALE	TOTAL	GRAND TOTAL
1973	0	0	0	2	6	8	8
1974	0	0	0	2	11	13	13
1975	4	3	7	13	4	17	24
1976	17	4	21	17	11	28	49
1977	6	2	8	18	13	31	39
1978	13	8	21	20	13	33	54
1979	17	6	23	43	10	53	76
1980	19	7	26	23	15	38	64
1981	27	14	41	32	23	55	96
1982	12	12	24	19	13	32	56
1983	16	10	26	19	8	27	53
1984	22	14	36	32	10	42	78
1985	20	11	31	19	18	37	68
	173	91	265	259	155	414	679

Table 9

DISTRIBUTION OF OVERDENTURES
IN SUBJECTS BY GENDER AND YEAR OF PLACEMENT

	ABUTMENTS BOTH ARCHES		ABUTMENTS MAXILLA ONLY		ABUTMENTS MANDIBLE ONLY		
	MALE	FEMALE	MALE	FEMALE	MALE	FEMALE	TOTAL
1973	0	0	0	0	1	1	2
1974	0	0	0	0	1	3	4
1975	0	0	3	0	4	2	9
1976	0	0	2	1	3	4	10
1977	1	1	2	0	7	7	18
1978	3	2	4	2	5	6	22
1979	2	0	4	3	12	7	28
1980	3	1	4	2	6	6	22
1981	2	2	9	2	12	6	33
1982	1	1	3	4	7	4	20
1983	3	0	3	4	8	4	22
1984	4	2	6	4	13	3	32
1985	1	1	9	4	9	8	32
Total	20	10	49	26	88	61	254

TABLE 10

NUMBER OF OVERDENTURES PLACED BY AGE GROUP AND GENDER

	AGE GROUP IN YEARS							
	<55		55-64		65+		TOTAL	
	M	F	M	F	M	F	M	F
CUO	29	13	12	8	22	9	63	30
CLO	30	21	34	23	41	25	105	69
PUO	--	--	1	--	1	2	2	2
PLO	2	--	4	1	4	2	10	3
Total	60	34	51	32	68	38	180	104

C= Complete Denture
P= Partial Denture
O= Overdenture

U= Maxilla (Upper)
L= Mandible (Lower)

PERCENTAGE OF OVERDENTURES PLACED BY AGE GROUP AND GENDER

	AGE GROUP IN YEARS							
	< 55		55-64		65+		TOTAL	
	M	F	M	F	M	F	M	F
N	60	34	51	32	68	38	180	104
CUO	47.5	38.2	23.5	25.0	32.4	23.7	35.0	28.9
CLO	49.2	61.8	66.7	71.9	60.3	65.8	58.3	66.3
PUO	--	--	2.0	--	1.5	5.3	1.1	1.9
PLO	3.3	--	7.8	3.1	5.9	5.3	5.6	2.9

TABLE 11

PERCENTAGE DISTRIBUTION OF OVERDENTURES BY TYPE GENDER AND AGE GROUP

	<55		55-64		65+		Total		
	M N=57	F N=29	M N=42	F N=34	M N=58	F N=34	M M=157	F F=97	P
CUO/CLO	12.3%	17.2%	4.8%	2.9%	10.3%	5.9%	9.6%	8.2%	N.S.
CU/CLO	43.9%	55.1%	59.5%	70.6%	56.9%	55.9%	52.9%	60.8%	N.S
CUO/LP	17.5%	6.9%	9.5%	17.6%	13.8%	8.8%	14.0%	11.3%	N.S.
CUO/NAT.	19.3%	20.7%	7.1%	2.9%	8.6%	11.8%	12.1%	11.3%	N.S.
CUO/PLO	--	--	4.8%	--	5.2%	--	3.2%	--	
UP/CLO	--	--	4.8%	--	1.7%	5.1%	1.9%	2.1%	
NAT/CLO	1.8%	--	2.4%	2.9%	3.4%	--	2.5%	1.0%	
CU/PLO	1.8%	--	4.8%	--	--	5.9%	1.9%	2.1%	
PUO/LP	--	--	2.4%	--	--	2.9%	0.6%	1.0%	
OTHER	3.5%	--	--	2.9%	--	2.9%	1.9%	1.0%	

C= Complete denture
U= Maxilla (Upper)
L= Mandible (Lower)

O= Overdenture
P= Partial denture
NAT= Natural dentition

TABLE 12

NUMBER AND TYPE OF RESTORATIONS

	MAXILLA		MANDIBLE		TOTAL	
	N	%	N	%	N	%
Copings	6	2.3	17	4.1	23	3.4
Amalgam	195	73.6	317	76.6	512	73.4
Composite	24	9.1	26	6.3	50	7.4
Vital	40	15.1	54	13.0	94	13.8
Total	265	100.0%	414	100.0%	679	100.0%

THE STUDY POPULATION

CHAPTER 4

The 254 patients treated over this period were asked to return for re-evaluation at 6 monthly intervals. Only a small percentage of patients followed this advice. In Table 1 is shown the number of overdentures placed each year and the number of patients who returned on recall. The recall rate varied from a low of 44 percent in 1976 to a high of 92 percent in 1979. The difference in the success of recalling reflects changes in the efficiency and the enthusiasm of the clerical staff responsible for scheduling appointments. The success of the recall system was dependent upon their personal efforts to contact by telephone persons who failed to keep appointments.

A total of 57 persons were lost from the study over the 13 year period. The distribution of these persons by gender and by the year they were lost from the study is shown in Table 2. A total of 37 men which represent 23.6 percent of the male sample were lost while 20 women or 20.6 percent female sample were lost. The greatest number were lost in 1983.

The reasons for the loss of patients from the study are shown in Table 3. Death was responsible for 31.6 percent of the loss. It was not possible to contact 14 (24.6 percent) of the subjects while 11 (14.3 percent) moved permanently to another state. Another 10 subjects refused to come back because they were seeing their local dentist or did not feel a need to return, or were too ill to travel. Three subjects had all their overdenture abutments 'extracted and so were dropped from the study and one elderly lady was unable to accommodate to wearing her mandibular overdenture and so she was also dropped from the study.

TABLE 1

NUMBER OF PATIENTS RECALLED PER YEAR

Year	Placed	Lost	Total Available	No. of Patients Recalled	% of Patients Recalled
1973	2	-	2	2	100.0
1974	4	-	6	4	66.7
1975	9	-	15	10	66.7
1976	10	-	25	11	44.0
1977	18	1	43	24	55.8
1978	22	-	65	32	49.2
1979	28	4	88	81	92.0
1980	22	10	100	75	75.0
1981	33	11	123	96	78.0
1982	20	8	135	101	74.8
1983	22	16	140	84	60.0
1984	32	1	171	112	65.5
1985	32	6	197	142	72.1
Total	254	57	197		71.3%
Mean					

TABLE 2

DISTRIBUTION OF PATIENTS LOST FROM THE STUDY BY GENDER AND YEAR

Year Lost	Male	Female	Total
1977	0	1	1
1979	4	0	1
1980	6	4	10
1981	6	5	11
1982	5	3	11
1983	10	6	16
1984	1	0	1
1985	5	1	6
	37	20	57

Total Loss = 22.4%

TABLE 3

REASONS FOR LOSS OF PATIENTS
FROM THE STUDY

Reasons for Loss	Male	Female	Total
Deceased	14	4	18 (31.6%)
Unable to contact	11	3	14 (24.6%)
Moved	5	6	11 (14.3%)
Refused	6	4	10 (17.5%)
All teeth extracted	1	2	3 (5.3%)
Not wearing	0	1	1 (1.8%)
	37	20	57

TOOTH LOSS IN THE OVERDENTURE POPULATION

CHAPTER 5

INTRODUCTION

Tooth loss has not been reported as a significant problem in the longitudinal studies of overdenture populations.[1-6] In Table 1 the available data from some past studies is summarized.[7-14] The overall rate varied from a low of 1.5 percent to a high of 14.3 percent, however, as the time frame varied within and between studies it was hard to determine the true yearly rate. The main reported cause of tooth loss was periodontal disease followed by caries. In Toolson and Smith's[12] 5-year study of 133 overdenture abutments in 54 patients, 16 abutments were extracted. Of these, five were extracted because of periodontal disease and 10 because of caries. They concluded that periodontal problems were not a major cause of tooth loss. In their 10 year follow up,[14] they reported a similar pattern, in that four of the 11 teeth were extracted because of periodontal disease and seven due to caries. On the other hand, Reitz et al.[10] study of 35 patients in whom 95 overdenture abutments had been retained, lost 13 teeth of which 12 were caused by periodontal disease. This chapter presents data for tooth loss in the on-going study.

RESULTS

Table 2 summarizes the characteristics of the group that lost abutments. The mean age of this group at the time of insertion of their dentures was 62.0 years. All but one person had medical problems and were taking medications which had the potential to affect the salivary glands. Table 3 shows the abutment failures which resulted in tooth loss in this study. The number of abutments, the number of persons, and the number of years since the

overdentures were placed are identified. The percentage of abutments lost was 3.4 percent for the maxilla and for the mandible, 4.6 percent.

The causes of abutment loss are listed in Table 4. The most common causes of failure were caries, (21.4 percent of the abutments were unrestorable) or periodontal disease where 35.7 percent of the abutments had lost virtually all their bone support. For 14.3 percent of the abutments, recurrent caries had resulted in loss of the coronal restoration and this loss of coronal seal was associated with periapical pathosis. Other causes of failure were two vertical root fractures and one vital tooth which developed a periapical pathosis and one tooth which developed internal resorption.

DISCUSSION

This study identified a total of 28 abutment failures in 16 persons or a failure rate of 41 per thousand abutment teeth or 63 per thousand persons at risk. Periodontal disease played a role in 50 percent of the teeth lost while caries also was a significant factor in 50 percent of the cases. Brewer and Morrow[15] in discussing tooth loss have observed that "most cases are associated with poor oral hygiene and inadequate follow up which leads to caries and periodontal disease." However, they go on to say that "almost all abutment failures occur as a result of periodontal disease. Fewer are lost as a result of caries....." The data from this study is not in agreement with their observations but is similar to the five year findings of Toolson and Smith.[12]

In teeth with periodontal deficits, bone loss resulted in a communication between the sulcus and the apex. In 4 other abutments, restorations were lost and the patient failed to return for treatment for several weeks or months. The *in vitro* studies of Swanson and Madison[16] have demonstrated that dye takes only 3 to 7 days to reach the apex of endodontically treated teeth if the

coronal restoration is missing. This suggests that in this clinical study, the periapical lesions associated with the five abutment teeth may have been due to penetration of organisms from the oral cavity through the voids in the root canal sealer and gutta-percha after the loss of the coronal restorations.

Although there was no visible or detectable entry into the pulp on the vital teeth which were cut down or polished, these teeth were at risk. In a later chapter it will be shown that 14.9 percent of the vital teeth in this study were at risk to develop periapical pathosis due to microexposures into the pulp.

Thus, all but four teeth in this study were lost due to caries and periodontal disease which are diseases associated with plaque accumulation. The poor oral hygiene practices in this group may reflect the older age of these patients, and an associated inability to clean teeth adequately due to loss of fine motor coordination or poor eyesight. This poor oral hygiene may also be explained by failure to act on the information given by the dentist because of poor self-image or emotional problems such as depression or alcohol abuse. Nevertheless, a tooth loss rate of 4.1 percent after twelve years suggests that long term success can be achieved with the use of overdenture therapy in the majority of patients.

CONCLUSION

In this study the rate of tooth loss of overdenture abutments was only 4.1 percent. Retrospectively, most of the failures could have been prevented. Caries and periodontal disease were the main causes of failure. For the majority of patients, maintenance of adequate oral hygiene was a problem. This study suggests that improved communications between the patient and the dentist with regard to oral hygiene practices as well as regular recall appointments are critical to the success of overdenture therapy.

TABLE 1

LOSS OF ABUTMENTS

	Time	No. of Patients	No. of Abutments	Teeth No.	Lost %
A Frantz 1975[7]	6-42 months	?	268	7	2.6
B Reitz *et al*. 1977[8]	6-47 months	50	131	2	1.5
C Fenton & Hahn 1978[9]	4-25 months	17	57	2	3.5
D Reitz *et al*. 1980[10]	38-80 months	35	95	13	13.7
E Davis et al. 1981[11]	2 years	11	23	3	13.0
F Toolson & Smith 1983[12]	5 years	54	133	16	12.0
G Lauciello & Ciancio 1985[13]	2-6 years	25	70	10	14.3
H Toolson & Taylor 1989[14]	10 years	29	77	11	14.3

CAUSE OF LOSS OF ABUTMENTS

	A	B	C	D	E	F	G	H	Total
Caries	3	-	-	-	-	10	2	7	22
Periodontal disease	-	2	1	12	-	5	8	4	32
Vertical fracture	-	-	1	1	1	-	-	-	3
Endodontic failure	4	-	-	-	2	1	-	-	7
Total	7	2	2	13	3	16	10	11	64

TABLE 2: CHARACTERISTICS OF

Gender	Age	Drugs	Medical Problems	Oral Fluoride	Lost Hygiene	Cause Teeth #	of Loss
F	83	Chlorothiazide (Diuril) Aspirin (radiation)	Hypertension, arthritis, mastectomy	No	Poor	30	Periodontal disease
M	60	Diuril	Hypertension	No	Poor	7	Periodontal disease+caries
F	73	Triamterene + hydrochlor othiazide (Dyazide)	Hypertension	No	Poor	20-27	Periodontal disease
M	65	Naproxen (Naprosyn) Aspirin + mag. aluminum hydroxide (Ascriptin) myocardial infarct	Gall Bladder disease, hepatitis A, arthritis,	Yes	Adequate	11	Vertical root fracture
M	75	Nifedipine (Procardia), digoxin (Lanoxin), Dyazide, indomenthacin (Indocin)	Diabetes, arthritis, angina, (pacemaker)	No	Poor	23-26	Caries
M	71	Quinidine, Lanoxin arrhythmia, angina, (hip replaced)	Arthritis, cardia	Yes	Adequate	10	Vertical root fracture
M	82	Sulfamethoxazole, choline mag. trisalicylate (Trilisate), cimetidine (Tagamet), probenecid	Prostate disease, peptic ulcer, hypertension, cataracts, arthritis	No	Poor	11	Periodontal disease and caries
M	49	Aspirin	Alcoholic, (hip replaced)	No	Poor	11	Vital tooth with periapical pathosis
M	57	-	-	Yes	Adequate	22	Internal resorption
F	37	Chlorpropamide (Diabinese)	Diabetes, gall bladder disease, depression	No	Poor	6, 11	Caries
F	63	Diuril	Hypertension	Yes	Poor	23	Periodontal disease
M	61	Anhydrous theophylline (Theo-Dure)	Asthma, arthritis	No	Poor	6, 11	Caries with periapical pathosis
F	60	Propranalol (Inderal), furosemide (Lasix) digoxin, dilantin, Tagamet, Naprosyn, nitrofurantoin macrocrystals (Macrodantin)	Seizure, peptic ulcer, chronic urinary infection, cardiac arrhythmia	No	Poor	26	Caries with periapical pathosis
F	63	Diuril	Hypertension	No	Poor	27	Caries with periapical pathosis
M	52	Aspirin	Arthritis	No	Poor	22, 27	Periodontal disease
M	41	Diuril,Diabinese	Hypertension,	No	Poor	22, 27	Caries & periodontal disease

TABLE 3

ABUTMENT PROBLEMS BY ARCH, PERSONS AND YEARS POST-INSERTION

Year Since Placed	Maxilla N=265		Mandible N=414		Total = 679	
	Abutment	Persons	Abutment	Persons	Abutment	Persons
<1 year	1	1	-	-	1	1
1 - 2	2	2	-	-	2	2
2 - 3	1	1	4	3	5	4
3 - 4	1	1	8	4	9	5
4 - 5	-	-	6	1	6	1
5 - 6	3	2	1	1	4	3
6 - 7	-	-	-	-	-	-
7 - 8	1	1	-	-	1	1
8+	-	-	-	-	1	1
Total	9	8	19	9	28	17*

* One subject lost a tooth and then two years later another tooth. Total number of persons = 16.

TABLE 4

OVERDENTURES
CAUSES FOR ABUTMENT LOSS

	Maxilla	Mandible	Total
Periodontal disease	-	10	10 (35.7%)
Caries (Unrestorable)	2	4	6 (21.4%)
Caries with periapical pathosis	2	2	4 (14.3%)
Caries with periodontal disease	2	2	4 (14.3%)
Vertical root fracture	2	-	2 (7.1%)
Vital tooth-periapical pathosis	1	-	1 (3.6%)
Internal resorption	-	1	1 (3.6%)
Total	9	19	28 (100.0%)

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ENDODONTIC PROBLEMS IN THE OVERDENTURE POPULATION

CHAPTER 6

INTRODUCTION

Morrow et al.[1], in 1969 suggested that teeth should be reduced to a few millimeters above the free gingival margin. However, this methodology requires routine root canal therapy prior to reducing the overdenture abutment teeth. A past barrier to acceptance of this procedure for overdentures has been the negative perception of root canal therapy by the public. Only recently have the public and the profession accepted root canal therapy as a reliable and successful modality for treatment.[2]

Although several cross-sectional and longitudinal studies[3-14] of overdentures have been reported, only three have specifically identified endodontic problems in their populations and these results are summarized in Table 1. This chapter reports on the endodontic problems experienced by the overdenture patients in this clinical study.

RESULTS

Table 2 shows the abutment failures associated with subsequent pulp necrosis of vital teeth and endodontic treatment identified in this study. The number of abutments, the number of persons, and the number of years since the overdentures were placed are identified. The percentage of abutment failures was 1.5 percent for the maxilla and for the mandible, 5.3 percent.

The causes of abutment failure are listed in Table 3. The most common cause of failure (53.8 percent) were vital teeth developing periapical lesions due to pulp necrosis. The next most common cause for failure, accounting for 23.1 percent of the failure rate for abutments, was recurrent caries resulting in loss of the coronal restoration and loss of the coronal seal of the root canal. Other causes of failure for abutments included: two vertical root

fractures; one unidentified second canal in a lower premolar; and three teeth with periapical lesions, gross loss of bone, and active periodontal disease.

DISCUSSION

This study identified a total of 26 abutment failures in 14 persons, or a failure rate of 38 per thousand abutment teeth or 55 per thousand persons at risk. Over one half of these failures were due to pulp necrosis in previously vital teeth. Of the remaining failures, only the vertical root fractures and unidentified second canal could be viewed as purely endodontic failures. This represents 3 abutment failures out of 679 potential abutments or a 0.44 percent endodontic failure rate.

Inability of the patients to maintain adequate oral hygiene was associated with abutments lost due to recurrent caries and periodontal disease (9 of 26). Poor oral hygiene could reflect ineffective communication by the dentist, or the patients' unwillingness to act on the information supplied, or the patients' inability to clean the teeth. In teeth with periodontal defects, bone loss resulted in a communication between the sulcus and the apex. In 6 other abutments, restorations were lost and the patient failed to return for treatment for several weeks. The *in vitro* studies of Swanson and Madison[15] have demonstrated that dye takes only 3 to 7 days to reach the apex of endodontically treated teeth if the coronal restoration is missing. This suggests that in this clinical study, periapical lesions associated with the six abutment teeth may have been due to penetration of organisms from the oral cavity through the voids in the root canal sealer and gutta-percha after the loss of the coronal restorations.

Although there was no visible or detectable entry into the pulp on the vital teeth which were cut down and polished, these teeth were at risk. In the maxilla, 2 of 40 vital teeth developed periapical lesions. In the

mandible 12 of 54 vital teeth developed lesions. This means that 14.9 percent of the vital teeth were at risk in 7 of the 17 people treated by this modality. Cutting down the teeth may open a microexposure into the pulp allowing access for organisms. Kuyk and Walton (1985)[16] have stated that a histological space is always present in the reparative or secondary dentin which is laid down as the root canal becomes calcified. Interestingly, in our study it took at least 3 years for lesions to be recognized. The majority of these previously vital abutments, that is 10 of 14 teeth were totally symptomless when periapical pathosis was first identified. In one patient, an additional periapical lesion was found because radiographs of both the vital abutment with discomfort and the contralateral vital symptomless abutment were taken. Both previously vital abutments were found to have periapical pathosis and necrotic pulps. After that single experience, yearly radiographs were taken of all patients with vital abutment teeth. The results of this study suggest that it is necessary to seal even the calcified roots canals of vital teeth with a restorative material if vital teeth are to be cut down for overdenture abutments. The maximum failure ratio of almost 1 to 7 for vital abutments is too high a ratio to be easily ignored. Root canal treatment in these failures should be attempted if the abutments are essential, even in calcified canals. If the root canal space cannot be identified, restoration of the access and subsequent semi-annual follow up with radiographs is recommended. If periapical pathosis then develops in these calcified canals, these "failures" can be surgically managed when no periodontal defects exist.

CONCLUSION

In this study the rate of subsequent periapical pathosis in overdenture abutments due to pulp necrosis or endodontically associated problems was only 3.8 percent. In retrospect, most of the failures could have been prevented. Improved communication between the patient and the dentist concerning the importance of adequate oral hygiene and of regular recall appointments is crucial. The dentist should be aware of the potential for microexposures into the pulp when using vital teeth as overdenture abutments. All of these vital teeth should be clinically examined for canal space after reduction and if none is found, a restorative material should be used to seal the unexposed root canal orifice. With regular visits and routine radiographs, early signs of periapical pathosis may be identified and alternative surgical endodontics performed when indicated.

TABLE 1
ENDODONTIC PROBLEMS

Author	Time	Abutments	Dentures	Vertical Root Fracture	Periapical Pathosis	Perforation
Frantz (14) 1975	6-42 months	268	112	0	4	0
Fenton & Hahn (7) 1978	4-25 months	57	21	1	3	0
Davis et al. (10) 1981	2 years	23	11	1	2	0

TABLE 2

ABUTMENT PROBLEMS BY ARCH,
PERSONS AND YEARS POST-INSERTION

Year Since Placed	Maxilla N = 265		Mandible N = 414		Total N = 679	
	Abutment	Persons	Abutment	Persons	Abutment	Persons
<1 year	---	---	---	---	---	---
1 - 2	---	---	3	2	3	2
2 - 3	---	---	3	1	3	1
3 - 4	1	1	10	3	11	4
4 - 5	1	1	2	1	3	2
5 - 6	1	1	2	1	3	2
6 - 7	1	1	1	1	2	2
7 - 8	---	---	---	---	---	---
8 - 9	---	---	1	1	1	1
9+	---	---	---	---	---	---
Total	4	4	22	10	26	14

TABLE 3

CAUSE FOR ABUTMENT FAILURE OF REDUCED TEETH

	No. of Teeth	Percentage
Vital Teeth Developing Lesions	14	53.8%
Vertical Root Fracture	2	7.7%
Unidentified Second Canal	1	3.8%
Caries, Loss of Restoration	6	23.1%
Perio-Endo Lesions	3	11.5%
Total	26	100.0%

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CARIES IN THE OVERDENTURE POPULATION

CHAPTER 7

INTRODUCTION

Many of the cross-sectional and longitudinal studies of overdenture populations have reported that caries and periodontal disease were the primary problems associated with overdenture therapy.[1-10] The highest rate of caries was reported by Ragnarson and Astrand (1963),[1] with a caries rate of 50 percent of the abutment teeth among their patients after 5 years. A summary of the more recent longitudinal studies is shown in Table 1. The caries rates reported in these studies were much lower and varied from a high of 39 percent (Rantanen et al. 1971)[2] to a low of 13.6 percent of all abutments examined after five years (Ettinger et al. 1984).[11] These data suggest that in each of the studies there was a group of individuals who were at a higher risk for developing caries. Identifying this group of high risk individuals, so that extra preventive measure could be developed for this target group, would be useful to the clinical care of overdenture patients.

STATISTICAL ANALYSIS

Patients entered this study and returned for evaluation at different points in time. Each patient had one or more return visits. The objective of the analysis was to find among the factors or covariates measured at each visit those related to the occurrence of caries in overdenture abutment teeth. Presence of caries was the dependent variable, and was noted when there was a discrete well-defined and discolored soft area or the explorer entered easily and displayed some resistance to withdrawal.

The independent variables were:

AGE

SEX

MEDICAL PROBLEMS
CNS Disease
Cardiovascular Disease
Pulmonary Disease
GI Disease
Renal Disease
Hepatic Disease
Arthritis
Malignancy
Rheumatic Fever
Joint Replacement

DRUG--TOTAL NUMBER

DRUG EFFECTS
Xerostomia
Hyperplasia
Taste Alteration
Ulceration
Neural Side Effects

FLUORIDE USE

TYPE OF FLUORIDE

BRUSHING HABITS

PERIODONTAL STATUS
Plaque and Supragingival
Calculus
Bleeding on Probing

The medical problems were a list of ten systemic entities (e.g. history of cardiovascular problems, etc.) which were indicated as being absent or present. Drug effects similarly were defined as a set of five potential side effects, (i.e. xerostomia, etc.). Periodontal status was given by a measure of plaque and calculus and bleeding on probing. For the analysis, periodontal status was divided into a dichotomous variable at the point where bleeding on probing was elicited.

An index on caries risk was defined as the number of days the condition was present which was used as the covariate value at the visit of the first occurrence (detection) of a caries lesion, or at the final visit for those patients that did not develop caries during the time they were in the study. The number of days from placement of the restorations to the occurrence of the first carious lesion (failure time) was regressed on the covariate of interest. A regression model was developed.

The Model (the Cox's regression model) (Cox 1972)[16] assumes that the hazard function (the function that represents the force of occurrence of the

event that is the occurrence of caries over time) depends on the covariates of interest,

$$h(t) = h_o(t) \exp (Zb).$$

The model would help to profile the characteristics of individuals who develop caries and can be used to predict those persons who might be at risk for caries.

RESULTS

The incidence of caries in the abutment teeth is presented in Table 2. The number of years since the overdentures were placed and the percentage of caries in the abutment teeth examined are presented. It can be seen that the rate of caries was computed on the number of abutments examined within a specific time frame. Therefore, a patient returning on recall at six month intervals would be included in the data analysis twice for that year. Great variation in caries incidence from year to year was seen, with the highest rate in the maxilla occurring during the 5th year (15.4 percent) and in the mandible in the 4th year (11.0 percent). The overall rate for new caries was 6.5 percent of the abutment teeth per year.

The lesions initially were seen as points of decalcification at the interface between the restoration sealing the root canal and the dentin. The lesions began as an area of decalcification or softening of the dentin which tended to progress by encircling the restoration. If the lesions progressed, the result was sufficient loss of tooth structure so that the restoration eventually was lost.

The lesions occurred in a minority of individuals. The distribution of males (65.8 percent) and females (34.2 percent) with caries was very similar to the distribution by gender in the whole group (males 61.8 percent, females 38.2 percent). Of the 73 individuals who experienced caries, 40 (54.8

percent) had one episode only, 22 (30.1 percent) had two episodes and 11 (15.1 percent) had more than two episodes. In Table 3 the distribution of these individuals is shown by the time of the first caries episode. It can be seen that patients who had a single caries lesion tended to have them later than those who had multiple attacks.

In an attempt to determine which factors or covariates measured at each recall visit might be related to the occurrence of caries, a regression model was tested for all individuals. When the model was used in a stepwise mode, that is, the factors or covariates were included in the model as long as they had a significant association (at the 0.05 level) with the dependent variable. This logistic regression model identified several independent variables such as reduced frequency of brushing, non-use of fluoride at home, and reduced severity of periodontal problems of the mandibular arch as the best predictors of caries. However, two other factors, one medical and one drug factor, were also found to influence caries incidence (Table 4). Discriminant function analysis showed that although specificity was very high (98.5 percent), sensitivity was very low (7.9 percent). As a result, the model was unable to predict those persons who were in the high risk category although it could identify those who were at low risk for caries.

In an attempt to characterize further the high risk group, a regression model was also developed for persons having more than one episode of caries. Three independent variables were identified: (a) use of drugs with potential xerostomic effects; (b) a history of central nervous system disease, and (c) poor oral hygiene (Table 5). Discriminant function analysis again showed high specificity (98.3 percent) and low sensitivity (10.5 percent). Thus the model was still inadequate for identifying the high risk cohort.

DISCUSSION

The etiology and natural history of dental caries in patients with overdenture abutment teeth is presumed to be essentially the same process as that which occurs in adults without such dentures. Caries incidence of the root surface lesion has been similarly related to factors such as the frequency and type of carbohydrate ingested, which in the presence of cariogenic microrganisms, results in a reduction of pH with a subsequent decalcification of dentin. Other factors such as the level of personal oral hygiene and an adequate production of saliva mediate the caries attack. In all cases in this study, the zone of vulnerability was the interface between the restoration and the dentin of the cut root surface. Initially when a softened area was detected with an explorer, the dentin was removed and a new restoration placed. However, it was subsequently found that if the patients were willing to use a fluoride gel daily, the area could be remineralized within two weeks.

Of the 254 persons in the study, only 73 experienced caries of the abutment teeth. Of these, 40 had one episode only. If caries occurred soon after insertion of the overdenture, it was usually related to poor home care and if the patient accepted advice, significant improvement was noted. In those patients who had an episode of caries many years after denture wearing began, occurrence was often related to a significant life change such as an illness, a hospitalization, the death of a spouse, etc. This leaves a high risk group of 33 patients (45.2 percent of the caries group) who had multiple episodes of caries where no adequate explanation could be found. In an attempt to characterize the population at risk for caries and to identify the independent variables related to caries, a regression model was computed. Using this model, it was only possible to predict accurately about eight

percent of the sample (sensitivity 7.9 percent), who had more than one episode of caries. Thus, the predictor variable evaluated may not be the most sensitive to characterize the high risk population in this sample.

Nevertheless, the data suggests that the less individuals brushed or failed to use fluoride, the more likely they are to be at risk for caries. It is interesting that the fewer periodontal problems they have, the more likely they were to have caries. An adequate explanation of this finding is not available. Possibly, the organisms responsible for root caries are very different from those causing periodontal disease. Of the list of diseases and medications evaluated only drugs which might cause neural side effects and a history of cardiovascular diseases were found to show a relationship. An explanation for this relationship is not possible at this time. However, there may be interactions which are not visible because of the way data was combined for the analysis. However, root surface caries seems to appear in conjunction with a variety of diseases,[17] one might speculate that the etiology of root caries may involve changes in general health status such as a depression of specific immune responses which might manifest as changes in the oral flora and a higher risk for root surface caries. Factors known to have a potential effect on root caries such as the rate of salivary flow and snacking habits, which were not measured in this study, need to be included in any further studies.

TABLE 1

CARIES

	Time	No. of Patients	No. of Abutments	Caries N*	Caries %
Rantanen *et al*. 1971[2]	6 mo.-4 yrs.	31	52	20	39.0
Toolson & Smith 1978[5]	Initial	89	233	68	29.2
	1 year	79	210	73	34.8
	2 year	74	190	36	19.0
Toolson & Smith 1983[9]	5 year	54	135	21	15.7
Reitz *et al*. 1977[4]	6-47 mo.	50	131	8*	16.0**
Reitz *et al*. 1980[11]	38-80 mo.	35	95	3*	8.6**
Fenton & Hahn 1978[6]	4-25 mo.	17	57	9	15.8
Ettinger *et al*. 1984[11]	1-6 years	44	131		13.6
	1 year	8	36	1	2.7
	2 year	16	46	8	17.4
	3 year	20	64	13	20.6
	4 year	26	93	10	10.8
	5 year	15	55	7	12.7
	6+ years	14	37	6	16.2
Hussey & Linden[13]	1-3 years	40	165	37	22.4
Budtz-Jorgensen & Thylstrup[14]	1 year	40	92	10	10.9
Toolson & Taylor[15]	10 years	28	66	8	12.1

* Number of subjects with caries
** Percentage of subjects with caries

N*= Number of abutments with caries

TABLE 2

INCIDENCE OF CARIES OF OVERDENTURE ABUTMENT TEETH

Year Since Placed	Maxilla (N=265)		Mandible (N=414)		Total (N=679)	
	Exam	% Carious	Exam	% Carious	Exam	% Carious
<1 year	400*	1.3	608*	1.2	1008	1.2
1 - 2	176	10.8	211	9.9	387	10.3
2 - 3	115	6.1	197	9.1	312	8.0
3 - 4	115	10.4	185	10.8	300	10.7
4 - 5	95	9.5	182	11.0	277	10.5
5 - 6	39	15.4	123	9.8	162	11.1
6 - 7	47	0	102	8.8	149	6.0
7 - 8	35	8.6	74	4.0	109	5.5
8 - 9	2	0	57	8.8	59	8.5
9+	14	0	39	12.8	53	9.4
Mean		5.9%		6.7%		6.5%

* This is the number of abutments examined within the time frame and may include the same subject more than one time.

TABLE 3

OVERDENTURES - PATIENTS
TIME TO FIRST CARIES EPISODE

Time of 1st Caries Episode	Multiple	Single	Total	
0-6 months	3	4	7	(9.6%)
7-12 months	3	7	10	(13.7%)
13-24 months	12	6	18	(24.7%)
25-36 months	4	4	8	(11.0%)
37-64 months	8	11	19	(26.0%)
65+ months	3	8	11	(15.1%)
Total	33	40	73	

TABLE 4

REGRESSION MODEL FOR CARIES OF THE OVERDENTURE ABUTMENT

Cox's regression analysis
(Time to first lesion)

BETA	CHI SQUARE	p	
Frequency of brushing	-0.0005	29.38	0.0000
Periodontal status mandible	-0.0012	30.23	0.0000
Use of fluoride at home	-0.0003	15.71	0.0001
Drugs which may cause neural side effects	-0.0013	8.89	0.0029
Presence of cardiovascular disease	-0.0003	4.37	0.0366

DISCRIMINANT FUNCTION ANALYSIS

Predicted Values	Actual Values: Caries	No Caries	
Caries	6	2	8
No Caries	70	127	197
	76	129	205

Sensitivity = 6/76 x 100 = 7.9%

Specificity = 127/129 x 100 = 98.5%

$$\text{Percent Correct} = \frac{6 + 127}{205} \times 100 = 64.9\%$$

$$\text{Proportional Reduction} = \frac{\frac{6+70}{205} - \frac{2+70}{205}}{\frac{6+70}{205}} \times 100 = 5.26\%$$

TABLE 5

REGRESSION MODEL FOR CARIES

COX'S REGRESSION ANALYSIS
(Time to Second Lesion)

	BETA	CHI SQUARE	p
Drugs which may cause xerostomia	-0.0116	4.98	.0257
Presence of central nervous system disease	0.0177	6.15	.0132
Frequency of brushing	-0.0032	4.98	.0257

DISCRIMINANT FUNCTION ANALYSIS

Predicted Values	Actual Values: Caries	Actual Values: No Caries	
Caries	2	4	6
No Caries	17	230	247
Total	19	234	253

Sensitivity = 2/19 x 100 = 10.5%

Specificity = 230/234 x 100 = 98.3%

Percent Correct = $\frac{2 + 230}{} \times 100 = 91.7\%$

Proportional Reduction = $\dfrac{\frac{2+17}{253} - \frac{4+17}{253}}{\frac{2 + 17}{253}} \times 100 = 10.7\%$

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PERIODONTAL PROBLEMS IN THE OVERDENTURE POPULATION

CHAPTER 8

Several cross-sectional[1-4] and longitudinal studies[5-9] of overdentures have been reported and periodontal disease[6-9] has been identified as one of the major problems associated with this modality of treatment. This data of periodontal problems has been summarized in Table 1. Lord and Teel[10] in 1974 stated that to maintain periodontal health, the tissues should be free from inflammation, should not bleed when probed, should have an adequate band of attached gingiva (3-4 mm) and have a vestibular depth that was free of deep undercuts. Becker and Kaldahl[11] have suggested that adequate alveolar bone support is important for tooth stability, so that only teeth with an adequate crown-root ratio should be chosen as abutments. Toolson and Smith[12] stated that the crown-root ratio should be at least 1:2. Zamikoff[13] has suggested that radiographically at least 5 mm of alveolar bone support is required for an overdenture abutment. The mobility of teeth is influenced by the crown-root ratio. Shärer[14] has shown that reducing the height of a tooth decreases the mobility of a tooth by 40%. Fenton and Hahn[4] measured the mobility of prepared overdenture abutments and compared them to control teeth not involved with any type of prosthesis in the same patients. They reported that the mobility of the overdenture abutments decreased over the 4 to 25 months of the study. This study is flawed, because base line examinations were not carried out, so it is not a true longitudinal study. Renner _et al_. on the other hand reported no changes in the mobility after 1 1/2[15] and 4 years[16] of overdenture use. Reitz _et al_.[3] showed a 6.1 percent increase in mobility of the 131 overdenture abutment teeth which had supported dentures from 6 to 47 months. In this same population[17] after 38 to 80 months of overdenture

wearing, 95 abutment teeth were left in the sample and of these 9.5 percent increased in mobility.

The results of Davis and his colleagues[7] 2-year study of overdenture abutments were confusing, in that 50 percent of the abutments they examined decreased in mobility and another 45 percent were unchanged. In another 5 percent the mobility of the overdenture abutments were unchanged from the measurements taken at the time of insertion of the overdentures. The majority of the abutments in Toolson and Smith's study were unchanged with regard to mobility after 2 years[8] and also after 5 years.[12] After 10 years,[18] 90.9 percent of the remaining abutments were unchanged when compared to their mobility at insertion.

The consequences of poor oral hygiene are plaque accumulation followed by gingival inflammation. Even with good oral hygiene, the oral environments of patients' wearing overdentures is not conducive to gingival health. The gingival inflammation index developed by Löe[19] has been an accepted method to measure periodontal health and a number of studies have used this index. Reitz et al.[3] reported severe problems in 6.1 percent of their subjects after 47 months, whereas no severe problems were reported after 80 months of denture wearing.[17] Fenton and Hahn[4] found 14 percent of their subjects had severe gingival inflammation, however, the overall gingival index decreased (improved) after 10 months. The inflammation of this change was attributed to improvement in the denture base adaptation over time. Davis et al.[7] reported a 35 percent increase in bleeding upon probing after 2 years of denture wearing while Renner's[16] group reported an 84 percent increase after 4 years of denture use. Toolson and his colleagues found no significant changes in gingival inflammation over time.[6,8,18]

Another consequence of plaque accumulation is bone loss around the abutments, which can be expressed as either an increase in periodontal probing depths or attachment loss. Hussey and Linden[20] found that only 4 percent of the 660 sites they examined in six years had periodontal probing depths greater than 3 mm. Toolson and his colleagues[8,21] believe that when choosing teeth as overdenture abutments, the periodontal probing depths of the teeth should be 3 mm or less. In fact, Basker et al.[22] are of the opinion that pocketing of 3 mm or more should be eliminated before teeth should be used as overdenture abutments. The data on changes in periodontal probing depths are variable and contradictory, no changes over time were reported in six studies,[4,7,8,12,16,18] five reported an increase[1,3,17,22,24] while one reported a decrease.[25]

It has been suggested that an adequate zone of keratinized tissue (attached gingiva) is required for overdenture abutment teeth to remain healthy under the trauma induced by wearing overdentures. Lang et al.[26] have shown that chronic inflammation is significantly associated with teeth which have less than 1 mm of attached gingiva. Changes in the width of the attached gingiva were measured by a number of researchers. No significant change was found by Derkson and MacEntee[27] after one year of denture wearing, or after two years by Toolson and Smith[8] or Renner et al.[16] after four years. Interestingly, after five years Toolson and Smith[12] found a significant decrease in attached gingiva. The mean width decreased from 2.72 to 1.10 mm, however, periodontal probing depths did not increase significantly. After 10 years Toolson's group[18] reported attachment loss in 78 percent of the abutments they examined.

The consensus of opinion of the authors of these longitudinal studies which are summarized in Table 1 is that periodontal disease continues to be a

major problem in overdenture therapy and that effective plaque control is critical to the maintenance of the abutments. This chapter reports on a longitudinal study of the periodontal problems experienced by overdenture patients in this clinical study and attempts to identify the high risk individuals who are especially susceptible to periodontal disease.

STATISTICAL ANALYSIS

Five patients were selected each year since 1977 for replicate examinations to determine intra-examiner reliability which was measured by the test - retest method.[28] Probing measurements were recorded in millimeters and probing errors of ± 1 millimeter were considered acceptable. It was found that less than 9% of repeat probing measurements fell outside of this range. This paper reports on the periodontal problems experienced by the subjects in this study from 1973 to 1985.

Patients entered this study and returned for evaluation at different points in time. Each patient had one or more return visits. The objective of the analysis was to find among the factors or co-variates measured at each visit those related to the occurrence of periodontal problems in overdenture abutments. Loss of attachment of 2mm or more or increase in periodontal probing depth of 2mm or more were the dependent variables.The independent variables were:

AGE
SEX

MEDICAL PROBLEMS:
CNS Disease
Cardiovascular Disease
Pulmonary Disease
GI Disease
Renal Disease
Hepatic Disease
Arthritis
Malignancy
Calculus
Rheumatic Fever
Joint Replacement
DRUG--TOTAL NUMBER

DRUG EFFECTS
Xerostomia
Hyperplasia
Taste Alteration
Ulceration
Neural Side Effects
FLUORIDE USE
TYPE OF FLUORIDE
BRUSHING HABITS
PERIODONTAL STATUS
Plaque and Supragingival

Bleeding Probing

The medical problems were a list of ten systemic entities (e.g. history of cardiovascular problems, etc.), which were noted as absent or present. Drug effects were defined as a set of five potential side effects, (i.e. xerostomia, etc.). Periodontal status was given by a measure of plaque and calculus and bleeding on probing. For the analysis, periodontal status was divided into a dichotomous variable at the point where bleeding on probing was elicited.

In an attempt to determine which factors or co-variates measured at the recall visits might be related to the occurrence of periodontal disease a logistic regression model was tested for all individuals who had 2mm or more loss of attachment between any consecutive appointment. Another logistic regression model was developed for all individuals who had an increase of 2mm or more probing depth between any consecutive appointment. Discriminant function analysis was also carried out with these models to determine sensitivity and specificity.

RESULTS

Periodontal health is dependent on keeping the oral tissue as plaque-free as possible, therefore the measurement of plaque levels is one way of evaluating the potential health of the oral tissues. Over the years of the study, no consistent pattern evolved (Table 2). Significant amounts of plaque and calculus around the abutments varied from a low of 10.7 percent of the sample the first year to 50 percent in the eighth year in the maxilla, while in the mandible, the rates varied from a low of 15.1 percent in the first year to just over 40 percent in the third year. The measurement of "plaque only" was higher in the maxilla while plaque and calculus were seen more often in the mandible.

It has been suggested that bleeding on probing is a sign of active periodontal disease. Over the years of the study no consistent pattern evolved (Table 3). Some patients were able to keep their tissues healthy over the whole study while others had difficulty. Some would improve significantly after they had been reminded of the problem as they returned on recall. Thus, after the first year, the recall system had to be tailored to the needs of the individual subjects in the study.

A small minority of patients had continual problems with periodontal disease. In an effort to identify this high risk group we evaluated those persons who had an increase of 2mm or more of probing depth between appointments. The distribution of these persons is shown in Table 4. The mean time between appointments decreased progressively. The periodontal probing depth increase was not site specific and no particular pattern evolved.

The logistic regression model (Table 5) identified two independent variables which were a "history of arthritis" and "bleeding on probing of the mandibular teeth" as the best predictors of persons at risk for progressive loss of periodontal attachment. Discriminant function analysis showed the sensitivity of this model was 71.6 percent and the specificity was 59.7 percent. Thus the model was able to predict persons who were in the high risk category for increase of periodontal probing depth.

Another measure of periodontal disease is loss of attachment. In Table 6 are shown persons who had 2mm or more of attachment loss from one appointment to the next. The mean time between appointment decreased progressively. The loss of attachment was quite site specific, being greatest on the facial, followed by the lingual and least on the mesial and distal surfaces of the overdenture abutment teeth.

The logistic regression model (Table 7) developed for persons with attachment loss identified four independent variables as being the best predictors. These variables were "bleeding on probing in the mandibular arch" "the absence of drugs which have the potential to cause hyperplasia of the gingival tissues", "the absence of a history of pulmonary disease", and "the presence of drugs which have the potential to precipitate xerostomia". The discriminant function analysis showed that the sensitivity for this model was 70.2 percent and the specificity was very similar at 69.3 percent. There was a proportional reduction of 50.8 percent. These data indicate that this model was able to predict persons who were in the high risk category for periodontal disease expressed as attachment loss.

Table 8 shows the number of persons who had both attachment loss and increase in periodontal probing depth. The term "episode" is used here to refer to losses measured in at least one tooth at a recall appointment, thus two "episodes" would mean that an individual had changes occurring in one or more teeth between two separate recall appointments. The data suggest that attachment loss can occur without a measurable increase in periodontal probing depth.

DISCUSSION

An overdenture prevents normal, natural stimulation of the supporting structures and therefore there is a potential for the accumulation of plaque which may precipitate periodontal disease. Gingival inflammation, loss of attached gingiva and pocket formation associated with bone loss are all possible sequelae to the wearing of overdentures. The denture itself may also be a direct source of injury to the gingival tissues. It has been shown that periodontal destruction seems to occur in bursts of activity for short

periods, followed by periods of inactivity rather than in a continuous spectrum.[29-31]

In this study the levels of plaque accumulation and gingival inflammation were high. In Table 2 it is interesting to note that the abutments designated as having "no plaque" were more common in the maxilla than the mandible. An explanation for this observation may be that, as most of these teeth were canines, anteriors or premolars they were relatively easy to see and, therefore easy to clean. These teeth are also further from Stensen's duct. In the abutments designated as having "plaque only" there were no differences between the arches. Abutments that were designated as having visible "plaque and calculus" were more common in the mandibular arch than in the maxilla and this may be due to their proximity to the orifice of the duct of the submandibular glands.

The evaluation of periodontal health in Table 3 shows that overall, less than five percent of the abutments had severe periodontal problems. It was surprising that teeth designated as having "no bleeding on probing" were more common in the mandible than in the maxilla. Theoretically, the mandibular arch has four times the resorption rate of the maxilla[32,33] and less surface area to support dentures. Therefore, one would expect more trauma to the mandibular overdenture abutments, which might cause gingival inflammation resulting in bleeding on probing. This did not occur in spite of the fact that in this study the need for adjustment of the mandibular overdentures was more than three times greater than that for maxillary overdentures.[34] An explanation for this finding may be that trauma from the overdentures is not a major contributing factor to gingival inflammation.

There are several recent reviews[35-37] of the significance of periodontal probing as diagnostic tools. Probing can determine the presence and severity

of periodontal defects. Variables that reduce the accuracy of probing, include probing force, diameter and shape of the probe, degree of gingival inflammation, narrowness of the pocket, presence of calculus, and consistency of probe placement and angulation.[35] In this study there was only one examiner who was carrying out these evaluations over a ten year period and who used the same kind of probe in a standard fashion for all measurements. However, no matter how skilled and how careful the clinician, the error of measurement is at least ± 1 mm. This minimum was achieved in this study.

Bleeding on probing is a subjective diagnostic test for gingival inflammation and pocket ulceration.[37] Hirsch et al.[38] state that "bleeding on probing is a sensitive indicator of early gingival change and may precede gingival color change." However, bleeding on probing is not believed to be a good indicator of ongoing periodontal disease activity as measured by loss of attachment.[39]

The results of this study did suggest that among these overdenture patients there was a high risk group who were susceptible to periodontal disease. In Table 4, persons who had changes in periodontal probing depth of 2mm or more at any site on the abutment teeth from one appointment to the next are shown. We chose 2 mm because we believe, as do Hirsch and Clarke[35], that "true increases in probing depth must be of the order of two millimeters to be detected by probing." There was no particular site that seemed to be at a higher risk than any other. This differs from Walter's[24] study of 20 mandibular canines supporting immediate overdentures which were followed from 3 months to 1 year post-insertion. He found significant localized bone loss on the distal surfaces of the abutment teeth which he attributed to the forward and upward anterior displacement of the denture base as it settled, directing forces toward the distal of the abutments. The logistic regression

to determine risk factors identified "bleeding on probing" and a "history of arthritis" as the best predictors. Two factors which are known to significantly affect plaque accumulation, salivary flow rate, and microbiology, were not gathered for this study. However, in spite of this, the model was able to accurately predict 71.6 percent of the at risk subjects, yet, proportional reduction in error was only 14.6 percent, which suggests that the ability to predict at risk subjects accurately has not been achieved with this model. If one tries to explain the significance of a "history of arthritis" by suggesting that patients with arthritis might have had difficulty brushing their abutments, then it would not be illogical to expect "brushing habits" and "fluoride use" to be identified as risk factors in the model. However, they were not identified as risk factors. Another possible explanation could be related to the use of aspirin or other non-steroidal anti-inflammatory agents on a daily basis which could affect the ease of bleeding or the extent of bleeding in response to the injuries associated with periodontal probing. It seems that the clinical indicator "bleeding on probing" is still the best predictor for persons who are at risk of progressive loss of periodontal attachment. These data support the findings of Lange et al.26 who, in a retrospective study of a population who had been treated for periodontitis, found that pockets which consistently bled when probed, had a 30 percent chance of losing attachment.

In Table 6 persons who had attachment loss of 2mm or more from one appointment to the next are shown. Although the measure of attachment loss in this study was very crude a site specific risk emerges. The facial surface of the overdenture abutment was at highest risk followed by the lingual or palatal and then the mesial and distal surfaces. This is not so difficult to explain, as overdentures are much more likely to have bucco-lingual rather than mesio-distal movement. Thus, attachment loss here may be an expression

of the trauma induced by the denture in function. The risk factors identified in the logistic regression shown in Table 7 are very hard to explain except for "bleeding on probing".

The width of the attached gingiva both buccally and lingually seems to be a significant issue. Lang and Löe[40] have shown an increased risk of marginal inflammation with a decrease in the width of the attached gingiva. Overdentures may create a greater potential stress on the tooth so that a tooth with little or no attached gingiva would be at higher risk for gingival inflammation. In this study the width of the attached gingiva was not measured so that relationship between gingival inflammation and attached gingiva could not be evaluated.

From the data presented and summarized in Table 8 the clinical marker, bleeding on probing, is still the best indicator for risk of periodontal disease in overdenture abutments. It also seems that attachment loss is possible without pocketing. These data suggest that a controlled study evaluating microbiology, salivary flow rates and other clinical markers may help to more fully identify the at-risk subjects.

TABLE 1 - PERIODONTAL PROBLEMS OF OVERDENTURES

Study	Time	No. of Patients	No. of Abutments	Attached Gingiva	Pocket Depth	Mobility	Gingival Inflamation
					<3,3-6,6+	0 1 2	N MILD MED SEVERE
Morrow et al. 1969 (1)	80-221 days	9	20	--	9% incr. (NS)	1.3% decr. (NS)	--
Reitz et al. 1977 (3)	6-47 months	50	131	16.0% loss	12.2% incr.	6.1% inc.	0.0% 49.9% 51.0% 6.1%
1980 (17)	38-80	35	95	25.3% loss	17.9% incr.	9.5% incr.	0.0% 71.4% 28.6% 0.0%
Fenton & Hahn 1978 (4)	4-25 months	17	57	--	No change	77.2% 17.5% 5.3% 0.0%	15.8% 38.6% 31.6% 14.0%
Davis et al. 1981 (7)	2 years	11	20	2.3-1.6m (sig.loss)	2 incr. 2 decr. 7 no change	10 decr. 9 no change 1 incr.	Bleed on probe 7 abutments 35% incr.
Toolson & Smith 1979 (8)	baseline	89	233	2.7 mm	2.02mm		
	1 year	79	210	2.5 (NS)	1.9 (NS)		
1982 (12)	2 years	74	190	2.5 (NS)	2.1 (NS)	60.5% 10.0% 2.6% 1.1%(NS)	3.2% 3.2% 33.7% 5.3% (NS)
	5 years	54	133	1.1 (S)	1.8 (NS)	87.2% 2.5% 0.8% 3.0%(NS)	0.0% 46.7% 35.3% 16.5% (NS)
Bolender et al 1984 (21)	1 year	54	133	2.72 mean	2.02	---	---
	2 year	54	133	2.50	2.11	---	---
	5 year	54	133	1.10	1.83	---	---
Renner et al 1984 (16)	4 year	7	12	NS	NS	NS	All roots bleed on probing (84% increase)
Lauciello & Ciancio 1985 (23)	2-6 yrs	25	70	---	Increase 1.69 to 2.10	Increase	Increase 0.77 to 1.90
Hussey & Linden 1986 (20)	1-3 yrs	40	165	---	90.0% 10.0% 0.0%	80.0% 15.0 % 5.0% 0.0%	18.0% 12.0% 70.0% 0.0%
Walters 1987 (24)	1 year	20	40	---	75% of patients bone loss 0.4 m		
Budtz-Jorgensen and Thylstrup 1988 (25)	6 months	40	92	---	Decrease	No change	46.1% 44.6% 9.3% 0 %
	1 year	40	92	---	Decrease	No change	19.6% 74.1% 6.3% 0 %
Toolson & Taylor 1989(18)	10 years	28	66	Loss in 78%	93.9% 3.0% 1.5%	90.9% 6.1% 1.5% 3.0%	9.0% 78.8% 12.1% 3.0%

TABLE 2

Periodontal Health
Plaque Levels: Expressed as
the Percentage of Subjects Examined

	Maxilla				Mandible			
Years Since Placed	N*	No Plaque	Plaque Only	Plaque Calculus	N*	No Plaque	Plaque Only	Plaque Calculus
<1 year	168	16.7%	72.6%	10.7%	350	13.8%	71.1%	15.1%
1-2	65	47.6%	26.2%	26.2%	122	32.8%	27.9%	39.3%
2-3	47	40.5%	34.0%	25.5%	100	34.0%	37.0%	29.0%
3-4	43	41.8%	41.9%	16.3%	89	27.0%	32.6%	40.4%
4-5	34	50.0%	32.4%	17.6%	83	32.6%	33.7%	33.7%
5-6	16	31.3%	50.0%	18.7%	49	22.5%	57.1%	20.4%
6-7	13	--	76.0%	23.1%	40	30.0%	37.5%	32.5%
7-8	13	30.7%	46.2%	23.1%	31	29.0%	35.5%	35.5%
8-9	2	--	50.0%	50.0%	21	28.6%	47.6%	23.8%
9+	7	28.6%	57.1%	14.3%	20	25.0%	35.0%	40.0%

N* = Number of persons who were examined during that time period.

TABLE 3

Periodontal Health
Bleeding Index: Expressed
As the Percentage of Subjects Examined

Years Since Placed	MAXILLA N*	MAXILLA No Bleeding On Probing	MAXILLA Bleeding On Probing	MAXILLA Spontaneous Bleeding	MANDIBLE N*	MANDIBLE No Bleeding On Probing	MANDIBLE Bleeding On Probing	MANDIBLE Spontaneous Bleeding
>1 year	168	82.1%	17.3%	0.6%	350	86.2%	12.9%	0.9%
1-2	65	52.3%	40.0%	7.7%	122	67.2%	27.9%	4.9%
2-3	47	59.6%	40.4%	--	100	66.0%	32.0%	2.0%
3-4	43	58.1%	41.9%	--	89	74.2%	24.7%	1.1%
4-5	34	50.0%	44.1%	5.9%	83	67.7%	31.1%	1.2%
5-6	16	66.7%	33.3%	--	49	77.5%	14.3%	8.2%
6-7	13	100.0%	--	--	40	70.0%	30.0%	--
7-8	13	69.2%	23.1%	7.7%	31	71.0%	25.8%	3.2%
8-9	2	100.0%	--	--	21	71.4%	28.6%	--
9+	7	71.4%	28.6%	--	20	75.0%	25.0%	--

N* = Number of persons who where examined during that time period.

TABLE 4

INCREASE IN PERIODONTAL PROBING DEPTH OF 2mm OR MORE COMPARED TO PREVIOUS APPOINTMENT

Mean Time in Months Between Appointments	No. of Teeth With Change	No. of Persons With Change	% of Teeth With Change	Mesial %*	Distal %*	Facial %*	Lingual %*
15.8	66	40	2.9	54.5	43.9	42.4	37.9
11.6	57	43	3.7	33.3	24.6	2.3	38.6
10.9	49	31	4.3	34.7	34.7	36.7	30.6
9.8	45	26	4.8	33.3	40.0	26.7	40.0
9.1	11	8	1.7	63.6	27.2	27.2	9.1
7.5	12	9	2.6	16.7	16.7	41.7	50.0
10.0	18	11	5.5	44.4	38.9	55.6	44.4
7.3	3	3	1.5	0	33.3	0	66.7

%* this is the percentage of teeth with change at each site

TABLE 5

INCREASE IN PERIODONTAL PROBING DEPTH OF 2mm OR MORE

LOGISTIC REGRESSION

VARIABLE	BETA	CHI SQUARE	p
History of arthritis	1.2107	16.73	0.0000
Bleeding on Probing (Mandible)	1.2716	16.94	0.0000

DISCRIMINANT FUNCTION ANALYSIS

PREDICTED VALUES	ACTUAL VALUES: PROBING DEPTH INCREASE	ACTUAL VALUES: NO PROBING DEPTH INCREASE	
PROBING DEPTH INCREASE	68	54	122
NO PROBING DEPTH INCREASE	27	80	107
	95	134	229

SENSITIVITY $\frac{68}{95} \times 100 = 71.6\%$

SPECIFICITY $\frac{80}{134} \times 100 = 59.7\%$

PERCENT CORRECT $\frac{68 + 80}{229} \times 100 = 64.6\%$

PROPORTIONAL REDUCTION IN ERROR

$$\frac{\frac{68 + 27}{229} - \frac{54 + 27}{229}}{\frac{68 + 27}{229}} \times 100 = 14.6\%$$

TABLE 6

ATTACHMENT LOSS OF 2mm OR MORE

COMPARED TO THE PREVIOUS APPOINTMENT

NO. OF TEETH WITH CHANGE	NO. OF PERSONS WITH CHANGE	MEAN TIME IN MONTHS BETWEEN APPOINTMENTS	MESIAL %*	DISTAL %*	FACIAL %*	LINGUAL %*
140	88	15.8	20.7	20.0	77.9	45.7
93	59	11.6	15.1	21.5	66.7	41.9
87	54	10.9	24.1	16.1	63.2	43.7
44	29	9.8	22.7	22.7	56.8	40.9
48	28	9.1	25.0	12.5	56.3	41.7
16	13	7.5	25.0	25.0	56.3	25.0
26	15	10.0	23.1	30.8	50.0	34.6
13	8	7.3	7.7	23.1	69.2	23.1
4	4	5.2	0.0	25.0	50.0	75.0

%* This is the percentage of teeth with change at each site.

TABLE 7

LOSS OF ATTACHMENT OF 2mm OR MORE

LOGISTIC REGRESSION MODEL

VARIABLE	BETA	CHI SQUARE	P
Bleeding on probing (Mandible)	1.3333	14.91	0.0001
Drugs which may cause Hyperplasia	-1.7749	3.68	0.0549
History of Pulmonary Disease	-0.9266	5.49	0.0191
Drugs which may cause Xerostomia	0.4743	9.25	0.0024

DISCRIMINANT FUNCTION ANALYSIS

PREDICTED VALUES	ACTUAL VALUES: ATTACHMENT LOSS	ACTUAL VALUES: NO ATTACHMENT LOSS	
ATTACHMENT LOSS	99	27	126
NO ATTACHMENT LOSS	42	61	103
	141	88	229

SENSITIVITY $\frac{99}{141} \times 100 = 70.2\%$

SPECIFICITY $\frac{61}{88} \times 100 = 69.3\%$

PERCENT CORRECT $\frac{99 + 61}{229} \times 100 = 69.9\%$

PROPORTIONAL REDUCTION IN ERROR

$$\frac{\frac{99 + 42}{229} - \frac{42 + 27}{229}}{\frac{99 + 42}{229}} \times 100 = 50.8\%$$

TABLE 8

NUMBER OF PERSONS

EPISODE	ATTACHMENT LOSS	INCREASE IN PERIODONTAL PROBING DEPTH	BOTH
1	74 (9)*	51 (9)*	21 (7)*
2	32 (2)	31 (5)	10 (1)
3	17 (4)	7 (1)	1
3+	23 (3)	8 (3)	1
	146	97	33

( )* = Persons with spontaneous bleeding or tooth loss

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DENTURE AND DENTURE RELATED PROBLEMS

IN THE OVERDENTURE POPULATION

CHAPTER 9

Over the years there have been a number of longitudinal studies[1-4] of persons wearing removable partial dentures (RPD). These studies have demonstrated that success of treatment depends upon adequate design and construction of the R.P.D., as well as good oral hygiene to keep the teeth and the supporting tissues healthy. The available evidence tends to suggest that these conclusions are equally appropriate for overdentures. Only a few studies have reported[5-9] on the denture treatment needs of persons wearing overdentures and these studies are summarized in Table 1.

The earliest study was published by Morrow et al.[5] who followed nine patients with 20 abutments for a maximum of 221 days. They found few problems except that two persons fractured their dentures. A slightly larger study by Fenton and Hahn[6] of 17 persons wearing 21 dentures over 57 abutments supported the earlier positive finding of Morrow et al. In a period of 25 months, one person needed a reline and one person had changes in the occlusion and articulation. A much larger and longer study by Toolson and Smith[7] found that when the fit of the overdentures were evaluated, retention remained consistently high. They stated that most of the dentures needed to be relined after the initial examination and before the two year recall. They also found that after five years, 52 of the 54 patients examined had centric occlusal relationships which were rated as good. In fact this relationship improved significantly at five years from the two-year examinations. They suggested that this was because they had used plastic teeth which accommodated to the individuals relationship by allowing the teeth to wear into equalized contact.

The longitudinal study of Ettinger et al.[8] found that the subjects had significant treatment needs. The most common needs were relines, followed by fractures. The most common complaint of the subjects in the study was a loss of retention followed by loss of stability. An explanation for these treatment needs could be the significant number of persons in this study who had received immediate dentures and so needed follow up treatment. The most recent study was that of Toolson and Taylor[9] who found a similar pattern of need at ten years in their overdenture population as they did after five years of denture wearing. This chapter reports on a longitudinal study of the denture and denture related problems experienced by the overdenture patients in this clinical study.

STATISTICAL ANALYSIS

Five patients were selected each year since 1977 for replicate examinations to determine intra-examiner reliability. This was measured by the test/retest method[10]. Percent agreement was calculated and disagreement occurred in less than ten percent of the measurements. Differences between variables were evaluated by gender, arch, and age groups. The Pearson chi square goodness- of-fit test was used to determine differences at the 0.05 level of significance. This paper reports on the denture treatment needs experienced by the subjects in this study from 1973 to 1985.

RESULTS

A summary of the evaluations by the examining dentist of problems associated with wearing overdentures is shown in Table 2. Loss of stability of the overdentures was the most common problem identified, especially in the mandibular arch. Loss of stability occurred about equally during the first 5 years at about 17 percent for maxillary overdentures, while for mandibular dentures the rate was approximately twice that of the maxillary and was at its

highest (36.6 percent) during the 6th year. Loss of retention was the next most common problem. This was reported at about half the rate of the loss of stability and with a similar pattern, with the highest rate being for mandibular overdentures (23.1 percent) during the 6th year. Changes in the occlusion occurred generally in less than 10 percent of the subjects per year with the higher rates occurring in the first six years of denture wearing. There were more problems with the peripheral extensions of mandibular overdenture bases than with the maxillary bases, especially during the 2nd, 3rd, and 4th years.

The treatment rendered for these overdenture problems is summarized in Table 3. Virtually all the overdentures needed cleaning when the subjects returned on recall. The need to remake dentures was fairly low but peaked for the maxillary overdentures at 5.8 percent in the 6th year while for the mandibular dentures it was in the 7th year at 7.1 percent. The need for relines was much higher for mandibular than maxillary overdenture. The highest rate was 17.3 percent in the 6th year. The need for adjustment was more than three times greater for mandibular overdentures than for those in the maxilla, with the highest rate occurring in the 9th year at 23.8 percent.

To determine the influence of placing immediate dentures rather than waiting at least six weeks after extraction, before beginning treatment, the treatment needs of the two groups of overdenture wearers were compared by gender and are shown in Table 4. As expected in the maxilla, the need for relines and remakes was higher in the group of persons who received immediate dentures. This pattern also was seen for mandibular dentures for relines but not for remakes. Persons who received immediate overdentures were more likely to need occlusal adjustments. For men, the only dimension of treatment need that was greater in persons who did not receive immediate dentures was in those persons who required repairs to their maxillary overdentures. For

women, treatment need was greater in persons who did not receive immediate dentures, only in those persons who required peripheral denture adjustments for their mandibular overdentures.

To assess treatment needs by age group, the denture treatment needs of the subjects were divided into three age groups (Table 5). Overall, men had greater treatment needs than women. The greatest treatment need was for mandibular denture adjustments in males aged 65 years and older (32.8 percent) and in those aged 55-64 (23.8 percent). This was followed by the need for relines of mandibular dentures in men aged 60 years and older (24.1 percent). Only in males requiring adjustments or relines were there consistent age trends; that is, the older subjects tended to need more treatment than younger ones. By comparison, females in the youngest age group had the greatest treatment need which was adjustment of their mandibular dentures (17.2 percent). There were no significant differences between any of the age groups or between males or females except that more men than women required relines, especially those in the oldest age group wearing mandibular overdentures (Chi square = 13.6, p = 0.001).

The relationship between the patients' complaints about their dentures and the dentist's determination of their treatment needs is shown in Table 6. In this table the number of persons who were determined to have denture treatment needs are expressed as a percentage of the total number of persons in each of the three age groups by dental arch. Persons of this group who did or did not have complaints about their dentures are shown along with their treatment needs. For both sexes, for all age groups and for both arches, a majority of persons had complaints about their overdentures. The only exceptions were males and females in the youngest age group. Fewer females in the two older age groups had complaints about their overdentures (Chi square = 14.98, p = 0.02).

The distribution of the patients' complaints by age and sex are shown in Table 7. The most common complaint was that dentures had became loose. The next most common were sore gums and complaints associated with the overdenture abutment tooth being sore. There was no completely consistent age pattern or distribution by gender. Males seemed to have more complaints than women. Females in the youngest age group had significantly more complaints about speech, esthetics, and feelings of fullness than any other group. (Chi square = 6.80, p = 0.03).

DISCUSSION

It was hypothesized that after an initial period of adaptation the denture treatment needs of this population would increase with time. The data did support this hypothesis to some degree as treatment needs were greatest during the sixth year. To test the hypothesis accurately, one would need to control the frequency of recalls and treatment received on previous recall appointments. In such an analysis, one would need to use the overdentures as the unit of analysis rather than the patient which was what was used in this study. The overall need for treatment for the mandibular dentures was more than twice that of the maxillary dentures. In fact, Tallgren[11] and Atwood and Coy[12] have shown that the rate of resorption for the mandible is four times greater than that of the maxilla. As a result it does not seem surprising that the needs for relines and remakes were higher for the mandible than the maxilla. The need for adjustment was more than three times greater for the mandibular overdentures and this may be due to the decreased surface area of the mandibular dentures and the greater potential for movement. The need for occlusal adjustment was not seen to be a problem after the 5th year. This may be because it was at or near the 5th year that we began to replace worn posterior teeth on dentures or to remake the dentures.

It was postulated that persons receiving immediate complete overdentures would have greater treatment needs than those without immediate overdentures. The data seem to support this hypothesis. Even though it was believed that older patients were more likely to have more treatment needs than younger patients, this trend was seen only in males requiring adjustments or relines of their overdentures.

It was presumed that people needing treatment were more likely to have complaints about their dentures. This proved to be true for all age groups and for both men and women except those persons in the youngest age group wearing maxillary overdentures. Finally, as seen in Table 6 and 7 one must not confuse complaints with dissatisfaction. Apart from 13 patients, the rest were well satisfied with the overdenture therapy they had received. Of these 13 persons, one had discomfort from a vertical root fracture, four had extensive caries, five had severe discomfort from periodontal disease and three were simply unable to accommodate to wearing dentures. In contrast, a few patients were so pleased with their overdentures that they refused to have abutment teeth removed, even when these teeth no longer had any supporting bone.

SUMMARY

1. There were 284 overdentures placed in 254 persons of which only 17 were partial overdentures.
2. The majority of overdentures were well tolerated and patients in general were satisfied with their dentures.
3. Problems with the mandibular dentures were seen more often than in the maxilla and loss of stability was the most common problem. The highest rate of loss of stability was 36.6 percent of the subjects examined in the 6th year.
4. The need for adjustments of the mandibular overdentures were the most common treatment needs followed by relining of these dentures.
5. Persons needing immediate dentures were more likely to have more treatment needs at recall appointments.
6. About 40 percent of persons with denture treatment needs were dissatisfied with the dentures.
7. The most common complaint was that the dentures were loose. The next most common complaint was of sore gums and sore teeth.

TABLE 1 - DENTURE TREATMENT NEEDS

	Time	No. of Persons	No. of Abutments	No. of Dentures	Fractures	Occlusion P, F, G			Reline	Remake	Retention P, F, G			Stability P, F, G		
Morrow *et al.* (5) 1969	20-221 days	9	20	9	2	0	9	0	0	0	0	0	9	0	0	9
Fenton & Hahn (6) 1978	4-25 months	17	57	21	0	1	0	16	1	0	NP			0	1	56
Toolson (7) & Smith 1983	0y	89	210	104	0	0	1	88	0	0	1	18	46	0	12	52
	2y	74	190	65		0	27	47	Most	NP	0	6	59	0	13	51
	5y	54	133	65		0	2	52	NP	NP	3	15	47	8	16	41
Ettinger *et al.* 1984 (8)	1y	8	36	8	1	1	2	5	1	1	2	2	4	2	2	4
	2y	16	46	17	1	1	4	12	4	1	4	2	11	4	2	11
	3y	20	64	22	0	3	11	8	2	0	4	3	5	4	3	5
	4y	26	93	28	2	2	6	20	9	1	8	3	17	8	3	17
	5y	15	55	15	1	1	4	10	3	0	5	1	9	5	1	9
	6+	14	37	16	1	1	2	13	2	0	6	2	8	6	2	8
Toolson & Taylor (9) 1989	10y	28	66	31	0	1*	5*	22*	17	6	1+	10+	20+	0+	5+	26+

P = Poor
F = Fair
G = Good

NP = Not reported
* = Number of persons
\+ = Number of ovedentures

RLL:TB03

TABLE 2

DENTURE EVALUATION

EXPRESSED AS A PERCENTAGE OF SUBJECTS EXAMINED

MAXILLA

No.of Years	N*	Loss of Stability	Loss of Retention	Unstable Occlusion	Inadequate Extensions
<1	245	17.2%	11.1%	7.4%	6.1%
1-2	136	21.3%	15.4%	10.3%	5.9%
2-3	107	18.7%	13.1%	8.4%	5.6%
3-4	94	16.0%	9.6%	6.4%	6.4%
4-5	88	18.2%	11.4%	9.1%	6.8%
5-6	52	17.4%	11.6%	7.7%	5.8%
6-7	42	2.4%	2.4%	2.4%	----
7-8	35	8.6%	8.6%	2.9%	----
8-9	21	4.8%	4.8%	4.8%	----
9+	21	9.6%	4.8%	----	4.8%

MANDIBLE

<1	380	14.7%	7.9%	3.7%	6.8%
1-2	136	32.3%	11.8%	7.4%	20.5%
2-3	107	28.9%	12.1%	7.5%	16.8%
3-4	94	29.9%	13.9%	3.2%	16.0%
4-5	88	30.7%	19.3%	10.2%	11.4%
5-6	52	36.6%	23.1%	9.6%	13.5%
6-7	42	28.5%	14.2%	7.1%	14.3%
7-8	35	14.5%	8.6%	2.9%	5.7%
8-9	21	33.4%	9.6%	4.8%	23.8%
9+	21	14.3%	4.8%	4.8%	9.5%

N* = Number of persons who were examined during that time period.

TABLE 3
DENTURE TREATMENT NEEDS
EXPRESSED AS A PERCENTAGE OF THE SUBJECTS EXAMINED

MAXILLA

No.of Years	N*	Clean	Occlusal ADJ	Repair	ADJ	Reline	Remake
<1	245	49.8%	4.5%	3.7%	6.1	8.2%	2.9%
1-2	136	97.1%	5.9%	5.1%	5.9%	11.0%	4.4%
2-3	107	95.3%	5.6%	2.8%	5.6%	10.3%	2.8%
3-4	94	91.5%	3.2%	6.4%	6.4%	6.4%	3.2%
4-5	88	93.2%	5.7%	----	6.8%	8.0%	3.4%
5-6	52	90.4%	1.9%	1.9%	5.8%	5.8%	5.8%
6-7	42	90.5%	----	----	----	----	2.4%
7-8	35	91.4%	----	----	----	5.7%	2.9%
8-9	21	90.5%	----	----	----	----	4.8%
9+	21	100%	----	----	4.8%	4.8%	----
Mean		89.0%	2.7%	2.0%	4.1%	6.0%	3.3%

MANDIBLE

<1	380	28.2%	2.6%	1.5%	6.8%	6.8%	1.1%
1-2	136	80.9%	5.9%	5.1%	20.5%	10.3%	1.5%
2-3	107	81.3%	4.7%	1.9%	16.8%	9.3%	2.8%
3-4	94	76.6%	2.1%	4.3%	16.0%	12.8%	1.1%
4-5	88	81.8%	5.7%	1.1%	11.4%	14.8%	4.5%
5-6	52	88.5%	3.8%	3.8%	13.5%	17.3%	5.8%
6-7	42	81.0%	----	9.5	14.3%	7.1%	7.1%
7-8	35	85.7%	----	----	5.7%	5.7%	2.9%
8-9	21	95.2%	----	4.8%	23.8%	4.8%	4.8%
9+	21	85.7%	----	----	9.5%	----	4.8%
Mean		78.5%	2.5%	3.2%	13.8%	8.9%	3.6%

N* = Includes all dentures worn by the patient.

TABLE 4

TREATMENT NEEDS RELATED TO USE OF IMMEDIATE DENTURES BY ARCH AND GENDER

	Immediate Denture		No Immediate Denture	
	Male N = 35	Female N = 27	Male N = 122	Female N = 70
MAXILLA				
Occlusal Adjustment	17.1%	25.9%	9.8%	5.7%
Repair	----	7.4%	11.5%	5.7%
Adjustment	17.1%	11.1%	12.3%	10.0%
Reline	34.3%	33.3%	18.9%	12.9%
Remake	17.1%	11.1%	9.0%	9.7%
MANDIBLE				
Occlusal Adjustment	17.1%	25.9%	9.8%	5.7%
Repair	11.4%	7.4%	10.7%	1.4%
Adjustment	40.0%	14.8	33.6%	25.7%
Reline	37.1%	29.6%	24.6%	17.1%
Remake	5.7%	7.4%	10.7%	5.7%

TABLE 5

PERCENTAGE OF PATIENTS WITH
DENTURE TREATMENT NEEDS
BY ARCH, AGE GROUP
AND GENDER

MALE

		Adjust Peripheries		Adjust	Repair		Reline		Remake	
Age	N	Max	Mand	Occlusal	Max	Mand	Max	Mand	Max	Mand
<55	57	10.5	14.0	10.5	5.3	3.5	19.3	10.5	8.8	5.3
55-64	42	4.8	23.8	9.5	4.8	14.3	4.8	21.4	7.1	---
65+	58	3.4	32.8	3.4	1.7	5.3	1.7	24.1	1.7	1.7
TOTAL	157	10	37	12	6	11	14	29	9	4

FEMALE

<55	29	3.4	17.2	3.4	3.4	3.4	13.8	13.8	10.3	6.9
55-64	34	14.7	14.7	8.8	11.8	2.9	2.9	5.9	2.9	---
65+	34	5.9	11.8	8.8	2.9	2.9	8.8	11.8	---	---
TOTAL	97	8	14	7	6	3	8	10	4	2

TABLE 6

RELATIONSHIP OF DENTURE COMPLAINTS TO TREATMENT NEEDS BY AGE GROUP GENDER AND DENTAL ARCH

MALE

			No Complaints		Complaints			
AGE	N	ARCH	No Treatment	Treatment	No Treatment	Treatment	Chi Square	p
<55	29	Maxilla	38.0%	17.2%	17.2%	27.6%	2.66	0.100
	32	Mandible	46.8%	9.4%	9.4%	34.4%	12.26	0.002
55-64	13	Maxilla	69.2%	--	--	30.8%	13.0	< 0.001
	38	Mandible	57.9%	2.6%	--	39.5%	34.10	< 0.001
65+	25	Maxilla	68.0%	4.0%	12.0%	16.0%	8.38	0.003
	45	Mandible	42.2%	8.9%	6.7%	42.2%	21.41	< 0.004

FEMALE

			No Treatment	Treatment	No Treatment	Treatment	Chi Square	p
<55	13	Maxilla	30.8%	23.1%	15.4%	30.8%	0.74	0.390
	21	Mandible	38.2%	9.5%	19.0%	33.3%	4.07	0.043
55-64	38	Maxilla	73.7%	--	13.2%	13.2%	16.12	< 0.001
	24	Mandible	50.0%	4.2%	20.8%	25.0%	6.33	0.012
65+	11	Maxilla	45.5%	--	9.1%	45.5%	7.64	0.006
	27	Mandible	52.9%	3.7%	18.5%	25.9%	8.54	0.004

TABLE 7

PERCENTAGE OF PATIENTS WHO HAD COMPLAINTS
WITH THEIR OVERDENTURES BY AGE GROUP AND GENDER

AGE GROUPS IN YEARS

Denture Complaints	<55 M N=57	<55 F N=29	55-64 M N=42	55-64 F N=34	65+ M N=58	65+ F N=34	Total M N=157	Total F N=97	P
Dentures Loose	22.8	24.1	26.2	5.9	22.4	20.6	23.6	16.5	NS
Teeth Sore	7.0	6.9	7.1	8.8	3.4	2.9	5.7	6.2	NS
Gums Sore	3.5	13.8	26.2	23.5	20.7	8.8	15.9	15.5	NS
Cannot Eat	5.3	---	---	---	---	2.9	1.9	1.0	NS
Other (e.g. Speech Fullness)	1.8	24.1	14.3	5.9	3.4	2.9	5.7	10.3	.03

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SUMMARY AND CONCLUSIONS

CHAPTER 10

The loss of teeth, especially those in the mandibular arch, often leads to rapid reduction of bone of the remaining residual ridge. This morphological change has been described by Atwood[1] as a major oral disease. Any effort to preserve this bone has been limited by an incomplete understanding of the interplay of biomechanical and biosystemic factors which control the integrity of the residual ridge.[2]

It is an accepted belief that the presence of teeth with a healthy periodontium in an alveolar ridge helps to maintain the morphology of the supporting bone around the teeth.[3] In fact overdenture therapy is based on the philosophy that retained roots, used as abutments to support dentures, preserve the alveolar bone.[4] These abutments help to slow the resorption of bone associated with the loss of natural teeth and the wearing of dentures. The success of overdenture therapy therefore depends on maintaining the overdenture abutment teeth in a healthy state, free from caries and periodontal disease.

This longitudinal clinical study was designed to evaluate the health status of overdenture abutments and the treatment needs of these individuals over the time period 1973 to 1985. There were 254 persons who agreed to participate in this study. Among the participants, men were nearly twice as numerous as women and the group had a mean age of 58.6 years. More mandibular (414) than maxillary (265) teeth were maintained as overdenture abutments and about 30 percent of the abutments saved in each arch were canines. A total of 57 persons were lost from the study over the last 13 years. About 30 percent of the losses were due to the subjects' dying, another approximately 25 percent were due to our inability to contact the subjects.

Tooth loss was not a significant problem in this population. There were 28 abutment failures in 16 persons or a failure rate of 41 per thousand abutment teeth or 63 per thousand persons at risk. The two most significant problems were caries and periodontal disease. Our rate of 4.2 percent was lower than most of the previously reported studies.[5-9] The rate of periapical pathosis due to pulp necrosis or endodontically associated problems of the overdenture abutments was very low, at 3.8 percent. More than half (14 of 26) of the abutments which developed lesions were vital abutments which had been cut down. The results of this study suggest that cutting down vital teeth may cause micro-exposures, which allows penetration of organisms into the pulp. The surface of such teeth need to be sealed, although no appropriate restorative material has been developed at this time. As a result, it is necessary to warn these patients that they are at risk for periapical infection and that they should return on regular recalls which must include a radiographic investigation. Apart from the two vertical root fractures the rest of the endodontic problems were avoidable and it has been suggested that there is a strong relationship between the competence of the dentist performing the endodontic treatment and the success of the endodontic treatment. As vertical fractures were relatively rare, it was difficult to determine whether the fractures were caused by occlusal loading or from condensation during endodontic therapy and obturation of the root canal with gutta-percha. One way to reduce the number of fractures would have been to use gold copings over the abutments. However, in our experience and that of others, copings place the abutments at higher risk for caries and periodontal disease.[10-13]

Overall, the rate for new carious lesions was 6.5 percent of the abutment teeth per year, which was lower than most of the other previously reported studies.[10,13-18] It became evident that within this population there was a high risk group who were more susceptible to caries. A regression model was developed to try and identify these at-risk persons, however, discriminant function analysis showed that although

specificity was high (98.5 percent), sensitivity was very low (7.9 percent). As a result, the model was not able to help identify who the individuals in this high-risk category were. This study did not include several factors known to be associated with caries, such as dietary factors, the microbiology of the plaque on the abutment teeth, the rate of salivary flow and the content of the saliva. It seemed surprising that neither the use of fluoride nor the type of fluoride used, was a significant factor identified in this regression model. In fact the role of fluoride in the protection of overdenture abutments has not been fully investigated. All the topical fluorides which have been developed for home use were developed to protect enamel surfaces in young populations.18 Further, no studies have determined what is an appropriate restorative material to seal the orifice of the root canal.

Increases in periodontal probing depths and loss of attachment were found in a group of these patients. A regression model was developed to predict individuals who were at risk for periodontal disease. Two models were developed for periodontal problems, one identified persons who had an increase in periodontal probing depth of 2mm or more, the other persons who had attachment loss of 2mm or more from one appointment to the next. Both of these models were relatively successful in being able to predict high-risk individuals. Interestingly, brushing habits were not one of the independent variables which was identified by the model. The only easily explainable independent variable which appeared in both models was "bleeding on probing." Studies[19-21] have shown that there is no direct correlation between pocket depth and attachment loss. This study tended to support this concept.

The patients who participated in this study had significant denture treatment needs. Over time most of the patients needed maintenance care for their dentures and after the fifth year many needed to be relined or remade. Apart from a few patients the greater majority of the subjects were very satisfied with their overdentures.

This study of patients wearing overdentures identified several areas which need further study such as:

1. The identification or development of appropriate restorative materials or techniques to seal the surface of vital teeth to prevent penetration of organisms into the pulp via micro-exposures.
2. The identification or development of an appropriate restorative material or techniques to seal the orifice of the root canal of overdenture abutments.
3. An appropriate fluoride type, regimen and concentration needs to be developed and tested specifically for dentin or root surfaces.
4. An appropriate preventive regimen for plaque control to reduce the risk of periodontal disease needs to be developed.
5. An appropriate clinical diagnostic tool to identify persons who would be at high risk for caries.
6. The clinical ability to identify persons who would be at high risk for periodontal disease.
7. An ability to predict persons who would comply with and practice appropriate home oral health care.

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SECTION B

IN-VITRO STUDIES

SECTION B

IN-VITRO STUDIES

PUBLICATION

No. 1 Phankosol, P., Ettinger, R.L., Hicks, J.M., and Wefel, J.S. Histopathology of the initial lesion of the root surface: An *in vitro* study. J. Dent. Res. 64:804-809, 1985.

No. 2 Phankosol, P., Ettinger, R.L., Hicks, J.M., and Wefel, J.S. Depth of penetration of *in vitro* root surface lesions. J. Dent. Res. 64:897-899, 1985.

This study was initiated and designed by the applicant. Dr. Phankosol, a Masters candidate in the Prosthodontic Department used these studies as his thesis project, therefore he carried out the work. Dr. Hicks was a member of the thesis committee and helped Dr. Phankosol with some of the histological techniques, while Dr. Wefel (also a member of the committee) helped especially with the microradiography. Dr. Phankosol helped write the first draft of the paper which was essentially written by the applicant with editorial comment from Dr. Hicks and Dr. Wefel.

No. 3 Kambhu, P.P. , Ettinger, R.L., and Wefel, J.S. An *in vitro* evaluation of artifical caries-like lesions on restored overdenture abutments. J. Dent. Res. 67:582-584, 1988.

This study was initiated and designed by the applicant. Dr. Kambhu, a Masters candidate in the Prosthodontic Department used this study as his thesis project and therefore he carried out the work. Dr. Wefel, a member of the committee helped especially with the microradiography. Dr. Kambhu helped write the paper with editorial comment from Dr. Wefel.

No. 4 Ettinger, R.L., Manderson, D., Wefel, J.S. and Jensen, M.E. An *in vitro* Evaluation of the prevention of caries on overdenture abutments. J. Dent. Res. 67:1338-1341, 1988.

This study was initiated and designed by the applicant. Ms. Manderson was a final-year dental student working on a summer extramural fellowship from the University of Cardiff in Wales. Dr. Wefel helped with advice especially with the microradiography while Dr. Jensen supplied some of the funds to help with the study. The paper was written by the applicant with editorial comment from Dr. Wefel.

No. 5 Ettinger, R.L., Ahmad, R., and Wefel, J.S. An *in vitro* evaluation of the effect of fluoride concentrations on overdenture abutments. Submitted J. Dent Res.

This study was initiated and designed by the applicant. Dr. Ahmad was a visiting faculty member from the Prosthodontic Department, University of Malaya who spent her sabbatical at Iowa. Dr. Wefel again helped with advice, especially with the microradiography. The paper was written by the applicant with editorial comment from Dr. Wefel.

SECTION B - IN VITRO STUDIES

Overdentures are only effective as long as the abutment teeth remain healthy. The environment beneath an overdenture makes it difficult to maintain the area plaque free, because it is not possible to make the area self-cleansing. If severe dental caries occurs, then it is possible that the abutment teeth may have to be extracted and the advantage of maintaining these key teeth within the arch will be lost. Therefore,prevention of dental caries will depend upon developing a good home oral hygiene program for the patient, supplemented by the use of an appropriate topical fluoride regimen.

ROOT SURFACE CARIES

The histopathology and progression of caries in enamel is well documented.[1-3] However, early lesion formation in dentin and cementum remains incompletely understood. There have been too few representative longitudina[14-10] epidemiological studies of root surface caries to define its natural history and its distribution in the population. The studies of Hand et al. (1988)[9,10] are the only ones with incidence data of a representative population, which were a group of rural Iowans aged 65 years or older living in two counties. During the three years of the study the mean annualized root caries attack rate was 1.8 surfaces per 100 surfaces at risk. Of the 338 persons in the study 44 percent (148) had new caries.

Apart from age and gingival recession the other associated risk factors have not been adequately determined. Banting et al. (1985)[6] found that new lesions were associated with higher gingival index scores. In the Iowa study,[11] several medical and social variables were associated with root caries prevalence. Refined carbohydrate intake,[4,5,12] potential xerostomic medications13 and less frequent tooth brushing[14,15] have also been correlated with root surface lesion formation.

ROOT SURFACE CARIES AND FLUORIDE

Fluoridated drinking water has been shown to reduce the incidence of new caries in children.[16] Only recently have population studies been published which evaluate the effect of caries in adults. In 1980 Banting and Stamm[17] showed that life-long residents of a naturally-fluoridated city in Canada (1.6 mgF/L) had 0.64 root lesion per person compared to 1.36 lesions per person for a non-fluoridated city. The residents in the fluoride area also had a higher fluoride content in their cementum.[18]

In 1986 Burt *et al*.[19] reported on two similar communities in New Mexico, one having an optimal level of fluoride (0.7 mgF/L), the other five times optimal (3.5 mgF/L) for that climate zone. They found caries rates similar to those reported by Banting and Stamm for the optimally fluoridated city but a much lower rate for the high fluoride city. Hunt *et al* (1989)[20] found the incidence rate for coronal and root caries to be considerably higher for rural residents of non-fluoridated communities. The caries rate in fact, was related to length of residence in a fluoridated community.

THE PROBLEM

When we began our *in vitro* investigations in 1982, studies of dentin and cemental caries had examined existing lesions in extracted teeth. The problem with this methodology was that it was difficult to obtain a sufficient number of different specimens which accurately simulated the sequential stages of caries formation. Also, if teeth with natural lesions were used it was impossible to compare the reaction of various sites on the same tooth to a carious attack. Thus, an *in vitro* root caries model system needed to be developed which could simulate natural root caries. Such a model system could then be used to test the efficacy of various caries preventive regimens.

Using an acidified gel system it was possible to produce artificial lesions in root surfaces, however, these lesions were similar but not identical to naturally occuring root surface lesions (Paper No. 1). Because of the much higher organic content of dentin and cementum it was not possible to use a variety of imbibing media with polarized light microscopy to quantify the amount of demineralization within the lesion. However, it was possible to characterize the various zones within the root surface lesion and evaluate the process of initial lesion formation.

This in vitro model system was then used to evaluate difference in depth of penetration of the root surface lesions in anterior and premolar teeth by varying the time of exposure. The depth of penetration of lesions on the root surface was also compared with those in enamel and at the cemento-enamel junction (Paper No. 2).

On most overdenture abutment teeth, dental caries has been found adjacent to restorations sealing the root canal orifice. The vulnerability of the margin of the tooth-restoration interface to acid attack is not surprising as numerous investigators[21-28] have studied the problem of microleakage and dental caries around different restorative materials. However, no investigators have studied these problems in overdenture abutments. Thus, the in vitro system was used to evaluate the development of caries-like lesions adjacent to restorations sealing the root canal orifice in overdenture abutments (Paper No. 3).

Fejerskov et al. (1981)[29] have suggested that topical fluoride may be the most efficient way of treating initial root caries lesions. However, in 1982 Nyvad and Fejerskov[30] also reported "No human clinical studies have as yet documented the relative importance of fluoride in root caries treatment." Swango (1983)[31] in reviewing the existing literature stated that there are no adequate existing studies on the effects of topical fluoride procedures in

inhibiting the development of caries, especially root-surface caries in older adults.

Toolson and Smith (1978)[32] have shown that brushing by itself was not sufficient to prevent caries in persons wearing overdentures. Thus, prevention has relied on a combination of home care and topical fluorides. Derkson and MacEntee (1988)[33] had 17 patients use a 0.4 percent Stannous fluoride gel on their overdenture abutments or a non-fluoridated placebo gel. A double-blind crossover experimental design was used for 6 months. The plaque index was altered very little by either gel and no differences in the caries rate were detected. Feagin (1984)[34] suggested that fluoride may react differently with root surfaces. He developed a remineralizing gel39 which he had shown to reduce mineral loss in root surfaces. Using a cyclic design, root fragments were treated with either a high fluoride gel, the Feagin solution or a placebo and challenged with a demineralizing gel to evaluate the effectiveness of the fluoride on overdenture abutments (Paper No. 4).

Although the use of topical fluorides on overdenture abutments seems to improve their resistance to caries, it is still not entirely clear how fluoride acts on cut dentin and root surfaces. Furthermore, most commercial topical fluorides have been developed for the protection of enamel surfaces rather than root surfaces. Thus, various concentrations of topical fluoride applications on dentin and cementum were used in a cyclic acid challenge to determine the most effective formulation for the protection of overdenture abutments (Paper No. 5). We have not as yet determined the ideal concentration or formula for fluoride and further studies are being carried out.

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SECTION B

IN-VITRO STUDIES

PUBLICATION

No. 1 Phankosol, P., **Ettinger, R.L.**, Hicks, J.M., and Wefel, J.S. Histopathology of the initial lesion of the root surface: An *in vitro* study. J. Dent. Res. 64:804-809, 1985.

This study was initiated and designed by the applicant. Dr. Phankosol, a Masters candidate in the Prosthodontic Department used these studies as his thesis project, therefore he carried out the work. Dr. Hicks was a member of the thesis committee and helped Dr. Phankosol with some of the histological techniques, while Dr. Wefel (also a member of the committee) helped especially with the microradiography. Dr. Phankosol helped write the first draft of the paper which was essentially written by the applicant with editorial comment from Dr. Hicks and Dr. Wefel.

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Publication 1

Histopathology of the Initial Lesion of the Root Surface: an *in vitro* Study

P. PHANKOSOL[1], R. L. ETTINGER[1,2], M. J. HICKS[3], and J. S. WEFEL[2]

[1]Department of Removable Prosthodontics and [2]Dows Institute for Dental Research, College of Dentistry, The University of Iowa, Iowa City, Iowa 52242; [3]Dental Research Unit & Department of Growth and Development, School of Dentistry, University of Colorado, Health Sciences Center, Denver, Colorado 80262

An acidified gel system was used to produce artificial caries lesions in root surfaces. Radiopaque surface layers were found with 47% of the lesions. Demineralized bodies of the lesion and mineralized zones of banding were seen in all lesions when examined by microradiography. Cementum and dentin seemed to respond to the acid attack in a similar manner. Although artificial root lesions did not simulate natural root caries entirely, the acidified gel system resulted in a reproducible method that might give insight into initial lesion formation on root surfaces. This technique may be used for studying the physico-chemical process involved in the demineralization of root surfaces and for testing the effects of various agents in the prevention of root caries.

J Dent Res 64(5):804-809, May, 1985

Introduction.

The incidence and prevalence of root caries are not well-documented (Hazen *et al.,* 1973; Sumney *et al.,* 1973; Jordan and Sumney, 1973; Banting and Courtright, 1975; Lohse *et al.,* 1977; Katz *et al.,* 1982). Katz *et al.* (1982) estimated that the prevalence of root caries in the population ranges from 21.7% to 55.9%. Root caries has been reported to be prevalent in specific population groups (Hecht and Friedman, 1949; Gustaffson *et al.,* 1954; Lowenthal, 1967; Chilton *et al.,* 1972), where there is gingival recession (Ravald and Hamp, 1981), and tends to increase with advancing age (Banting *et al.,* 1980).

The histopathology of root caries has not been investigated thoroughly and is poorly understood. An electron microscopic investigation of carious cementum found that early lesions had a rough, porous surface and were markedly deficient in mineral components. Characteristic cross-striations of collagen fibers in sound cemental matrix were observed to be partially or completely lost in cemental lesions (Awazawa, 1961). Another electron microscopic and chemical study (Johansen, 1965) of the organic phase of caries lesions suggested that the breakdown of the major portion of the collagen occurred late or was the final step in the destructive phase of the carious process. Ultrastructural observation (Furseth and Johansen, 1970) of the highly mineralized surface layer of the carious cementum revealed masses of bacteria attached to the surface and also present within lacuna-like spaces in the cementum.

Microradiographic studies have reported a radiopaque surface layer on cementum from periodontally diseased human teeth (Selvig and Zander, 1962; Selvig, 1969; Yamamoto *et al.,* 1962, 1966; Yamada, 1968), exposed sound cementum, and carious cementum (Furseth and Johansen, 1968; Furseth, 1971). The radiopaque surface layer which overlies the demineralized zone of carious cementum was reported to be wider than that observed for exposed sound cementum.

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From studies of natural lesions in extracted teeth, it has been difficult to establish the sequential stages of root caries formation; that is, whether demineralization of the inorganic substance precedes degradation of the organic matrix by bacterial enzymes. The purposes of this study were: (1) to develop an *in vitro* system which could simulate natural root caries and (2) to describe the histopathology of the initial *in vitro* lesions of root caries. The development of such a system would also provide a basis for the testing of various preventive agents to remineralize existing lesions, as well as for preventing and retarding the formation of new lesions.

Materials and methods.

Twenty-four anterior and 26 bicuspid teeth were collected from patients who were 50-70 years of age. All teeth were stored at 0°C in distilled water, with 1% thymol added to prevent growth of micro-organisms. All teeth had at least 4 mm of cementum exposed to the oral environment prior to extraction. Each tooth was examined under a stereomicroscope at 10x magnification to eliminate those with root caries or cavitation. The teeth were cleaned using a rotary handpiece and a rubber cup with pure aluminum oxide slurry alone or with hand scaling. Four windows (1.5 x 3 mm) on the approximal surfaces of each tooth at the middle third and gingival third of the anatomical crown, at the cemento-enamel junction, and on the exposed root surface were selected for study (Fig. 1). Two layers of an acid-resistant varnish were painted on the tooth surfaces except in the area of the windows. Ten percent acidified gelatin gel was prepared and adjusted to a final pH of 4.5 with 0.1N lactic acid. All teeth were suspended in the acidified gel at room temperature. Twelve anterior teeth and 13 bicuspid teeth in each group were removed from the gel following exposure periods of two and four weeks. Each tooth was cut longitudinally with a diamond disc so that all four windows located in the approximal surfaces were present in the same section. The histopathology of artificial root caries was studied using three methods: (1) transmitted light microscopy, (2) polarized light microscopy, and (3) microradiography.

Results.

On gross examination with a stereomicroscope at 10x magnification, none of the specimens showed any evidence of macroscopic cavitation following exposure to the acidified gel after two- and four-week time periods. The enamel windows with caries-like lesions appeared rough and chalky white. There was no brownish discoloration on any of the tooth surfaces exposed to the artificial lesion system.

The root surface lesion at the cemento-enamel junction. — Because of the anatomical differences, the cementum which covered the root surface at the cemento-enamel junction (C.E.J.) was either lost or was thinner than cementum toward the apical area, and the artificial lesions at the C.E.J. involved primarily root dentin.

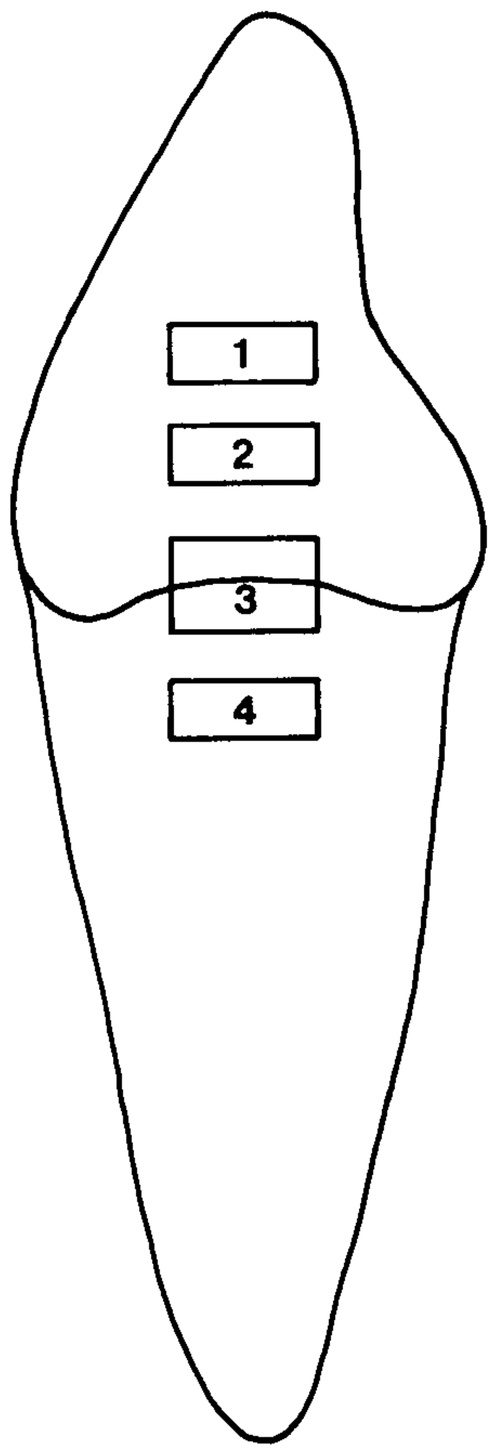

Fig. 1 – Locations of the window areas on the proximal surfaces of the teeth: (1) middle 1/3 of the clinical crown, (2) cervical 1/3 of the clinical crown, (3) enamel of cemento-enamel junction, and the root surface of the cemento-enamel junction, and (4) exposed root surface.

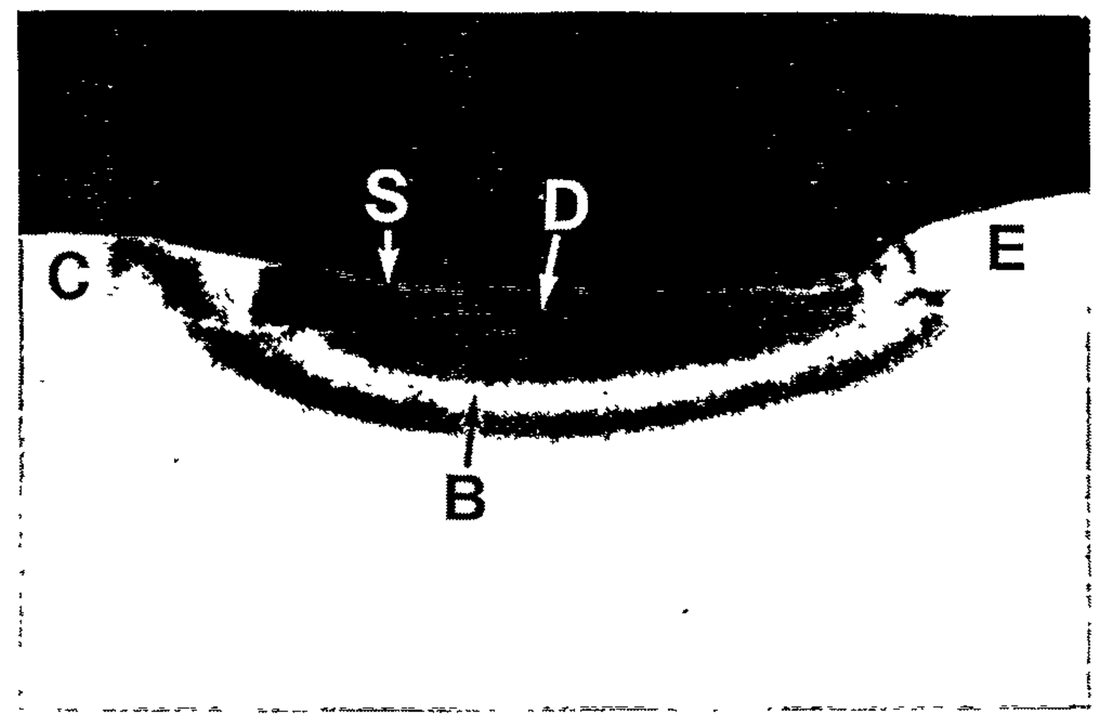

Fig. 2 – Microradiograph of an undecalcified ground section showing the cemento-enamel junction of a bicuspid which exhibits contraction of the surface and vertical fractures. E = Enamel, S = Radiopaque surface layer, D = demineralized body of the lesion, and B = Mineralized band in the body of the lesion (magnification x 40).

Microradiographically, all teeth showed a saucer-shaped artificial lesion. All lesions exhibited a similar appearance, with both demineralization of the bodies of the lesions and bands of mineralization within the bodies of these lesions. The body of the lesion was seen as a radiolucent zone, while the mineralized bands were seen as radiopaque zones. At the coronal and the apical extremities of the lesion, the bands became thicker and curved toward the enamel and root surfaces, respectively. All artificial lesions showed contraction of their surfaces when allowed to desiccate in preparation for microradiography. This resulted in the lesions having concave outer surfaces (Fig. 2). Radiopaque surface layers were found in 48% of the lesions, while 46% of the lesions had radiopaque lines along their cemento-dentinal junctions. Because of the contraction of the lesions, 72% of the lesions had vertical fractures along their surfaces that involved either cementum alone or both cementum and dentin (Table 1).

With transmitted light, the lesions were saucer-shaped and showed bodies of the lesions with bands corresponding to the mineralized bands seen with microradiography. The bands seemed to be more translucent than the rest of the lesion and the sound root surface. The appearance of the body of the lesion and the bands in the cementum seemed to be similar to that in dentin. The advancing front of the dentinal lesion could be identified as a darkened line. This front seemed to be rounded and parallel to the root surface. However, at higher magnification, 80% of the teeth showed small finger-like projections which seemed to extend into the dentinal tubules for some distance (Table 2). The characteristic structural markings of sound cementum and dentin could still be identified within the lesion areas. Incremental lines were seen with 32% of the cemental lesions, while 64% of the dentinal lesions showed some traces of the dentinal tubules.

With polarized light, the lesions were similar to but more defined than those seen with transmitted light. The body of the lesion in the dentin had a higher degree of positive birefringence than did sound dentin. The zone of banding in the cementum and in the dentin had a degree of birefringence similar to or higher than that in sound cementum and dentin. Although surface zones were not observed with polarized light microscopy, surface layers were observed when microradiographic techniques were used. However, traces of dentinal tubules and finger-like projections seen with transmitted light could still be seen with polarized light.

Lesions on the exposed root surfaces. – The cementum at this location was intact for the majority of specimens and was generally thicker than at the cemento-enamel junction. In only four of the 24 anterior teeth were lesions confined to cementum. For the other 44 teeth, the lesions extended through the cementum into the dentin.

Microradiographically, all lesions were saucer-shaped (Fig. 3). These lesions exhibited a pattern similar to that for lesions located at the cemento-enamel junction. Radiopaque surface layers were seen in 46% of the lesions, while in 32% of the lesions radiopaque lines were found at the cemento-dentinal junction. Vertical fractures extending from the lesion surfaces could be seen in 72% of the lesions (Table 3).

With transmitted light (Fig. 4), the bodies of the lesions and zones of banding could be seen in all lesions. Forty-four percent of the lesions showed loss of incremental lines within lesions located only in cementum. The dentinal tubules were not seen within 54% of the lesions, while 78% of the lesions exhibited finger-like projections along the advancing front of the lesions (Table 4).

With polarized light (Fig. 5), the appearance of the lesions in the exposed root surface was similar to that of the lesions located at the cemento-enamel junction and corresponded to that seen with transmitted light. There

TABLE 1
MICRORADIOGRAPHIC CHARACTERISTICS OF ARTIFICIAL LESIONS LOCATED AT THE CEMENTO-ENAMEL JUNCTION

Tooth Type	N	Body of the Lesion (%)	Zone of Banding (%)	Radiopaque Surface Zone (%)	C.D.J.* Radiopaque (%)	Vertical Fractures (%)
Two-week Exposure Period						
Anterior	12	100	100	41.7	50.0	91.7
Posterior	13	100	100	53.8	46.2	58.8
Total	25	100	100	48.0	48.0	72.0
Four-week Exposure Period						
Anterior	12	100	100	75.0	50.0	83.3
Posterior	13	100	100	23.1	38.5	61.5
Total	25	100	100	48.0	44.0	72.0
All Teeth	50	100	100	48.0	46.0	72.0

*C.D.J. = Cemento Dentinal Junction.

TABLE 2
HISTOLOGIC CHARACTERISTICS OF ARTIFICIAL LESIONS LOCATED AT THE CEMENTO-ENAMEL JUNCTION

Tooth Type	N	Partial Loss of Cementum (%)	Lesions Confined to C^1 (%)	Lesions Confined to $C + D^2$ (%)	Finger-like Projections (%)	Loss of Dentinal Tubules (%)
Two-week Exposure Period						
Anterior	12	33.3	0	66.7	83.3	58.3
Posterior	13	30.8	0	53.8	61.5	38.5
Total	25	32.0	0	60.0	72.0	48.0
Four-week Exposure Period						
Anterior	12	8.3	8.3	83.3	83.3	33.3
Posterior	13	23.1	0	92.3	92.3	15.4
Total	25	16.0	4	88.0	88.0	24.0
All Teeth	50	24.0	2	74.0	80.0	36.0

C^1 = cementum only.
$C + D^2$ = cementum and dentin.

TABLE 3
MICRORADIOGRAPHIC CHARACTERISTICS OF ARTIFICIAL LESIONS IN ROOT SURFACES

Tooth Type	N	Body of the Lesion (%)	Zone of Banding (%)	Radiopaque Surface Zone (%)	C.D.J.* Radiopaque (%)	Vertical Fractures (%)
Two-week Exposure Period						
Anterior	12	100	100	41.7	25.0	58.3
Posterior	13	100	100	69.2	61.5	61.5
Total	25	100	100	56.0	44.0	60.0
Four-week Exposure Period						
Anterior	12	100	100	33.3	33.3	91.7
Posterior	13	100	100	38.5	7.7	76.9
Total	25	100	100	36.0	20.0	84.0
All Teeth	50	100	100	46.0	32.0	72.0

C.D.J.* = Cemento Dentinal Junction.

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were very few measurable histopathologic differences between the anterior and pre-molar teeth at either the two-week or the four-week time period.

Discussion.

It is well accepted that bacterial enzymes, as well as organic acids, play an important role in the development of root surface caries. Acid primarily causes demineralization, while the enzymes are believed to destroy the collagen matrix of cementum and dentin. In an *in vitro* acidified gel system, there are no bacterial organisms invading the tissue as in a naturally occurring lesion. There is less destruction of the collagen matrix in the *in vitro* lesion than in the natural lesion due to the absence of these bacterial enzymes. The acidified gel system, therefore, simulates only the physico-chemical dissolution process involving the mineral component of the root surface. Since this system is a pure chemical dissolution system, one may postulate that the collagen matrix in the cementum or dentin may remain intact for the most part, while the hydroxyapatite crystals are dissolved. Without proteolytic enzymes, collagen would not be destroyed by an acid, but would be simply left unsupported and would collapse. The cross-banding of the collagen fibers may also be decreased or lost. When mineral is released from the advancing front of the lesion, the various mineral phases may re-precipitate loosely along the previously demineralized collagen matrix, resulting in remineralization of an area with decreased mineral content. The crystal shapes may be changed, enlarged, or elongated by this remineralization phenomenon. In this *in vitro* system, remineralization, as suggested by Furseth and Johansen (1970), seemed to occur in the zones of banding and in the surface layers, as evidenced by their radiopaque appearances.

The surface layers of the artificial root lesions remained intact even though very little mineral remained. This was evident when we compared the polarizing light micrographs and microradiographic appearance of the same lesions. With hydration, no change in the surface morphology was observed, but when allowed to desiccate, the demineralized collagen matrix was seen to shrink and thus produce a con-

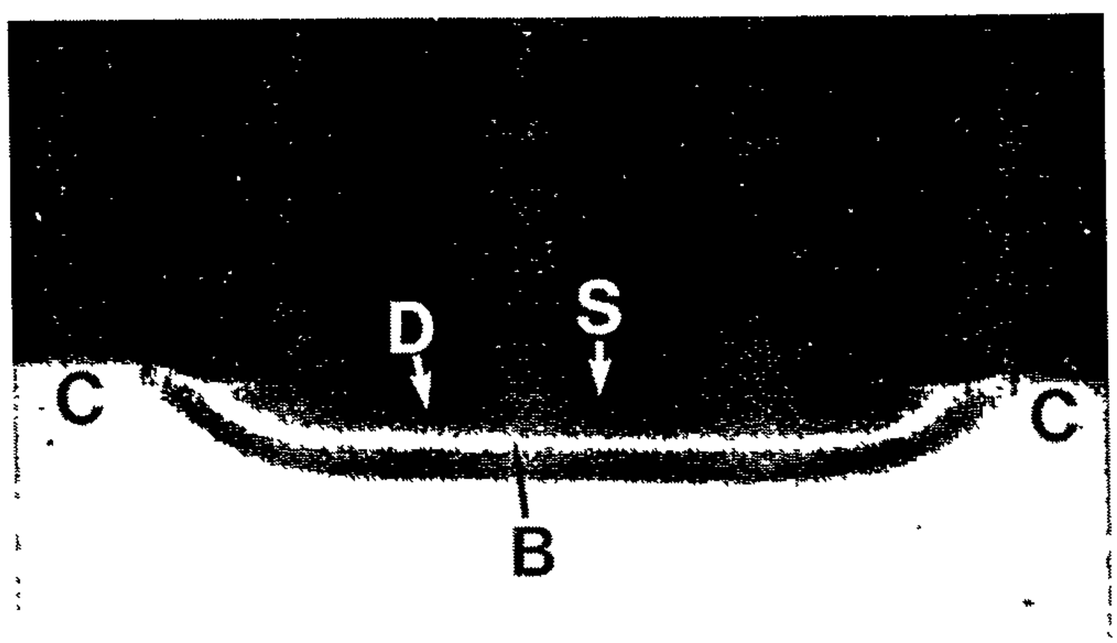

Fig. 3 – Microradiograph of an undecalcified ground section of a lesion on the root surface showing contraction of the surface. C = cementum, S = radiopaque surface layer, D = demineralized body of the lesion, and B = mineralized band in the body of the lesion (magnification x 40).

Fig. 4 – Photomicrograph taken with transmitted light of a lesion showing the extent of the lesion involving cementum (C) and dentin (D). Neither the surface layer nor the mineralized band can be clearly visualized (magnification x 40).

TABLE 4
HISTOLOGIC CHARACTERISTICS OF ARTIFICIAL LESIONS IN ROOT SURFACES

Teeth	N	Partial Loss of Cementum (%)	Lesions Confined to C^1 (%)	Lesions Confined to $C + D^2$ (%)	Finger-like Projections (%)	Trace Detection of Dentinal Tubules (%)
Two-week Exposure Period						
Anterior	12	33.3	25	75.0	58.3	16.7
Posterior	13	46.2	0	94.3	76.9	38.5
Total	25	40.0	12	84.0	68.0	28.0
Four-week Exposure Period						
Anterior	12	8.3	8.3	83.3	75.0	58.3
Posterior	13	7.7	0	100.0	100.0	69.2
Total	25	8.0	4	92.0	88.0	64.0
All Teeth	50	24	8	88.0	78.0	45.4

C^1 = cementum only.
$C + D^2$ = cementum and dentin.

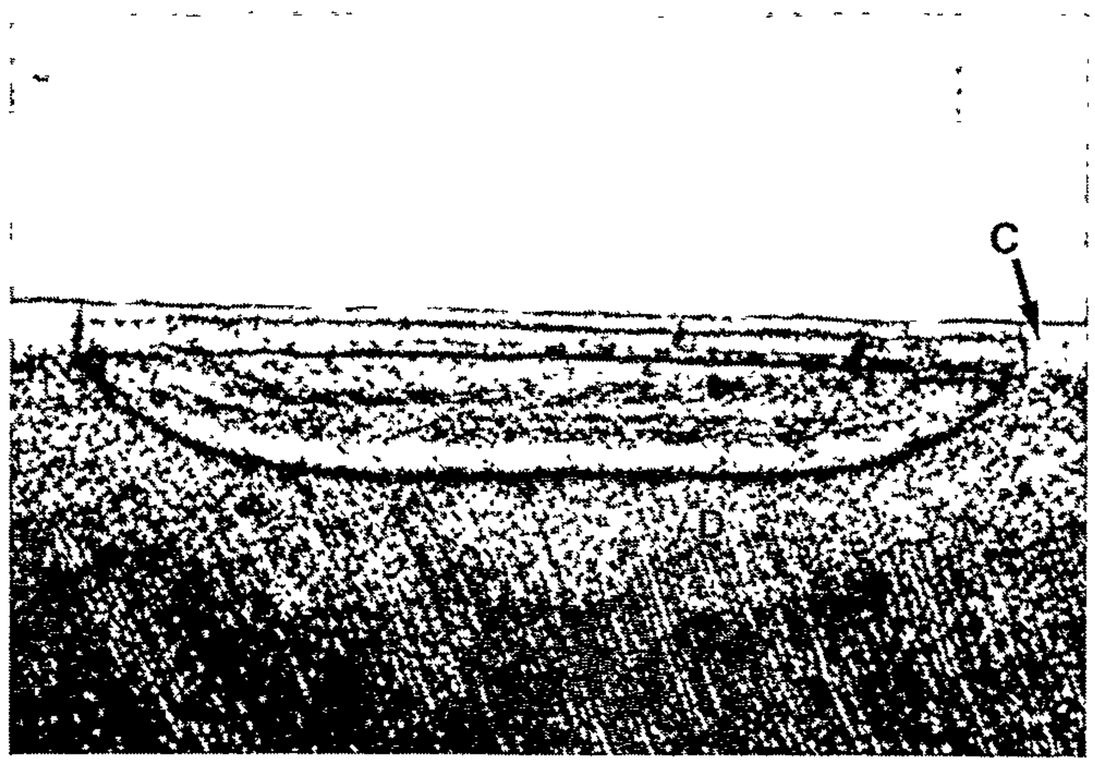

Fig. 5 – Photomicrograph of a lesion after imbibition in water and taken in polarized light. The appearance of the lesion is similar to that seen in transmitted light; however, it is possible to determine more clearly cementum (C) from dentin (D) (magnification x 40). Nevertheless, the greatest detail is seen with microradiography (Fig. 3).

cave surface. This was particularly noticeable with microradiographs, since the technique requires drying of the sections before exposure to the nickel-filtered copper Kα x-rays.

The zone of banding may be similar to the radiodense lines present in the body of a natural lesion, as reported by Levine (1974). It may also correspond either to the zone of penetration reported by Johnson *et al.* (1969) or to the hypermineralized surface layer described for the naturally occurring lesions. In the oral environment, mechanical forces such as tooth-brushing or mastication may be responsible for the loss of the superficial demineralized portion of the lesion, leaving behind the zone of banding as the radiopaque surface layer.

A consistent finding at the advancing fronts of most of the dentinal lesions was the existence of finger-like projections. A possible explanation for this finding may be related to the differences in mineral content of the peritubular and intertubular dentin. Peritubular dentin is more highly calcified than intertubular dentin and would be more resistant to acid dissolution (Weber, 1974). The *in vitro* system acts primarily as a physicochemical dissolution system. The advancing front of the lesion could progress selectively along the path of least acid resistance, and thus the finger-like projections may represent the dissolution of intertubular dentin around the dentinal tubules.

Radiopaque surface layers were found in 47% of the *in vitro* root lesions in this study but were not observed with either transmitted or polarized light microscopy. The question must be raised as to whether this surface layer in fact exists. The surface radiopacity may be an edge effect due to the microradiographic technique alone producing a thin radiopaque appearance along the edge of the specimen. However, when radiopaque surface layers in this study were evaluated, any thin or questionable radiopacities on the lesion surfaces were not identified as surface layers. Hals and Selvig (1977) reported high concentrations of Ca, P, F, and S in the surface layer. They found that the radiopaque surface layer had a relatively high fluoride content and might absorb foreign heavy elements such as Sn and Zn from the oral cavity. They reported that the high Ca and P concentrations in the surface layer could not explain the marked increase in the radiopacity of the surface layer observed with microradiography. Clarkson and Miller (1982) used two different *in vitro* root caries models to create lesions in unexposed root surfaces: a viable bacterial system and an acidified gel system. They concluded that *in vitro* root caries lesions showed histologic features similar to those present *in vivo*, especially when the lesion involved only the superficial portion of the dentin. Their microradiographs showed radiopaque bands in the root surfaces which were less distinct than the bands described for *in vivo* lesions. These results are similar to the findings in this study, although the root surfaces used in this study had been exposed to the oral environment for some time prior to the extraction of the teeth. The presence of radiopaque surface layers in these two studies tends to suggest that mineral phases released from the advancing front of the lesion may re-precipitate into the lesion surface and may be responsible for the radiopaque appearance of the surface layer.

The acidified gel system can produce artificial lesions in root surfaces that are similar but not identical to naturally occurring root surface caries. The physicochemical dissolution of hydroxyapatite from the tissue, which is the basis for the *in vitro* system, is believed to be only one of the processes occurring in natural lesion formation. However, dissolution of the mineral component of cementum and dentin may represent the initial process involved in formation of root caries. The advantages of using an *in vitro* system are that it produces consistent results, is well controlled, and is a relatively simple technique. This system is helpful in understanding some phases of the carious process and may aid in finding appropriate agents that could prevent or retard the progress of root caries. The acidified gelatin gel system has been used for testing the effects of various preventive agents (Clarkson and Silverstone, 1974; Wefel and Harless, 1982) on lesion formation in enamel. Various preventive agents could also be tested for their effect on lesion formation in root surfaces using similar methodologies.

Acknowledgment.

The authors wish to thank Dr. Brian Clarkson for his help and advice in carrying out the study and in the preparation of the manuscript.

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SECTION B

IN-VITRO STUDIES

PUBLICATION

No. 2 Phankosol, P., **Ettinger, R.L.**, Hicks, J.M., and Wefel, J.S. Depth of penetration of in vitro root surface lesions. J. Dent. Res. 64:897-899, 1985.

This study was initiated and designed by the applicant. Dr. Phankosol, a Masters candidate in the Prosthodontic Department used these studies as his thesis project, therefore he carried out the work. Dr. Hicks was a member of the thesis committee and helped Dr. Phankosol with some of the histological techniques, while Dr. Wefel (also a member of the committee) helped especially with the microradiography. Dr. Phankosol helped write the first draft of the paper which was essentially written by the applicant with editorial comment from Dr. Hicks and Dr. Wefel.

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Publicatiion 2

Depth of Penetration of *in vitro* Root Surface Lesions

P. PHANKOSOL[1], R. L. ETTINGER[2], M. J. HICKS[3], and J. S. WEFEL[2]

[1]*Department of Removable Prosthodontics,* [2]*Dows Institute for Dental Research, College of Dentistry, The University of Iowa, Iowa City, Iowa 52242; and* [3]*Dental Research Unit & Department of Growth and Development, School of Dentistry, University of Colorado, Health Sciences Center, Denver, Colorado 80262*

An acidified gel system was used to produce artificial caries lesions in root surfaces and in enamel. The teeth were exposed to the gel system for two weeks and four weeks, after which the lesions were examined by polarized light microscopy and photographed by standardized techniques. The depths of penetration of the lesions were measured from these standardized photomicrographs.

The lesions in root surfaces were deeper than those in enamel for all teeth. After two but not four weeks of exposure in the gel system, the lesions in the root surfaces of anterior teeth were deeper than those in pre-molars.

J Dent Res 64(6):897-899, June, 1985

Introduction.

Root surface caries has been reported to occur following exposure of cementum to the oral environment (Sumney *et al.,* 1973; Ravald and Hamp, 1981; Katz *et al.,* 1982). Since there are no adequate longitudinal studies, the true incidence of root surface caries is unknown. It has been suggested that the rate of progression of caries on root surfaces may be different from that on coronal surfaces (Katz *et al.,* 1982).

When natural caries lesions in extracted teeth are examined, one cannot evaluate how long it has taken for the degree of destruction to occur, nor can one compare the resistance of various sites on the same tooth to a caries challenge.

In a previous paper (Phankosol *et al.,* 1985), we described the development of an *in vitro* system capable of producing root surface lesions. Although this system did not entirely simulate natural root caries, it was a reproducible method of developing early lesion formation on root surfaces. The purposes of this study were: (1) to measure the depth of penetration of the artificial lesion in anterior and pre-molar teeth by varying the time of exposure, and (2) to compare the depth of penetration of lesions on root surfaces with those in enamel.

Materials and methods.

Twenty-four anterior teeth and 26 pre-molar teeth were collected from patients ranging in age from 50 to 70. Anterior and posterior teeth were not collected from the same patients. All teeth were stored at 0°C in distilled water, with 1% thymol added to prevent growth of micro-organisms. All teeth had at least 4 mm of cementum exposed to the oral environment prior to extraction. Each tooth was examined under a stereomicroscope at 10x magnification to eliminate those with visible root caries or cavitation. The teeth were cleaned by using a rotary handpiece and a rubber cup with pure aluminum oxide slurry, alone or with hand-scaling. Four windows (1.5 x 3 mm each) were marked on the approximal surfaces at the middle third and gingival third of the clinical crown, at the cemento-enamel junction and on the exposed root surface. Two layers of an acid-resistant varnish were painted on the tooth surfaces except in the area of the windows. Ten percent acidified gelatin gel was prepared with 0.1 N lactic acid to produce a final pH of 4.5. All teeth were suspended in the acidified gel at room temperature (25°C). Twelve anterior teeth and 13 pre-molar teeth in each group were removed from the gel following exposure periods of two and four weeks. Each tooth was sectioned longitudinally with a diamond disc so that all four windows located in the approximal surfaces were in the same section.

Each section was ground with an aluminum oxide abrasive slurry (9.50 μm grit) on a tufnal* lapping base (Bakelite) until the thickness measured with a micrometer was 100 ± 10 μm. The sections were examined under polarized light after imbibition in water, and standard photomicrographs were taken for measurement purposes. The photographic slide of each specimen was projected onto a screen with a projector at a 5-m distance. For each specimen, the distance from the surface to the deepest portion of the lesion was measured (Fig.) with a millimeter ruler and calibrated to a standard scale. With this technique, repeated measures of the same lesion at varying times resulted in measuring errors for the lesion depths which were not more than ± 3 μm. Differences among the depths were evaluated using analysis of variance (ANOVA) and Duncan's multiple range test.

Results.

With polarized light, all the lesions were saucer-shaped, and the body of the lesion in dentin had a higher degree of positive birefringence than did sound dentin. In the body of the lesions, there was a band which became thicker at the coronal and apical extremities. The zone of banding in the cementum and dentin had a similar or a higher degree of birefringence than that of sound cementum and dentin. No surface zones could be observed with polarized light microscopy (Fig.).

At the two-week time period, the mean depths of the lesions in the anterior teeth were significantly greater than those in pre-molars at all four locations (Table). After four weeks of exposure to the gel, these differences no longer existed. However, the mean depths of the lesions on the root surfaces were significantly deeper than those in enamel in all teeth and at all time periods when the differences were evaluated by Duncan's multiple range test with an alpha level of 0.05.

The p values for the mean depths of lesions on anterior teeth by exposure time to the gel and site of lesion location are also presented in the Table. Statistical analysis showed that the mean depths of the lesions at location 1, which is in enamel, and those on the root surface in locations 3b and 4 were significantly deeper at four weeks than at two

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*McMaster Carr Supply Co., P.O. Box 4355, Chicago, IL 60680

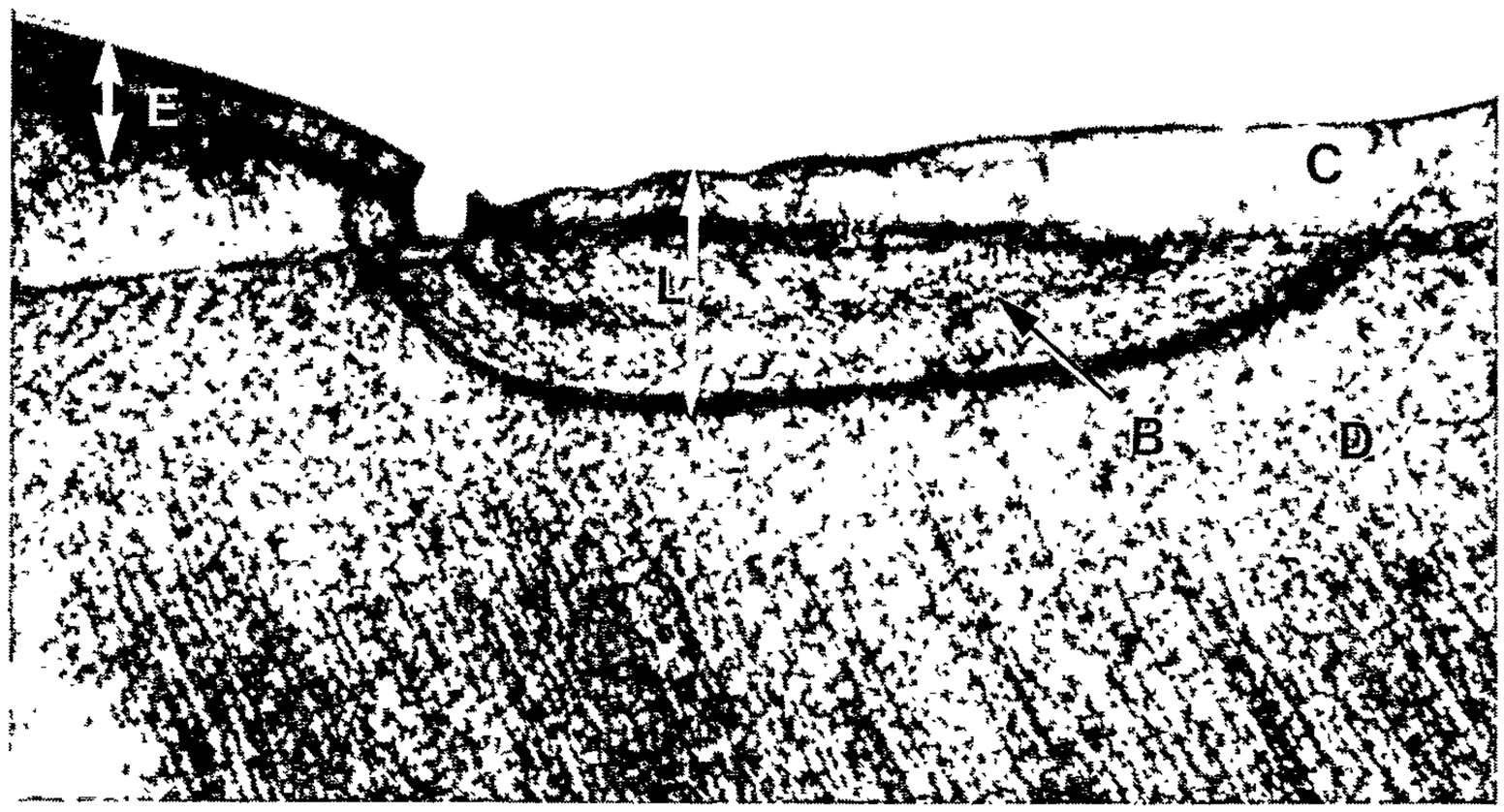

Fig. – Photomicrograph taken in polarized light of an undecalcified ground section of a lesion at the cemento-enamel junction after imbibition in water after two weeks in the gel system. The lesion shows cementum (C), dentin (D), a body of the lesion (L), and a band in the body of the lesion (B). The deeper penetration of the lesion into the cementum and dentin as compared with that into enamel can be seen (arrows). Magnification 40x.

TABLE
DEPTHS ($\bar{x}$ ± S.D.) OF *IN VITRO* LESIONS FOLLOWING A TWO-WEEK AND FOUR-WEEK EXPOSURE PERIOD TO THE ARTIFICIAL CARIES SYSTEM: EFFECT OF TOOTH TYPE, LESION LOCATION, AND EXPOSURE TIME

	Anterior Teeth			Pre-molar Teeth			p Values	
	After Two Weeks (n=12)	After Four Weeks (n=12)	p	After Two Weeks (n=13)	After Four Weeks (n=13)	p	Effect of Tooth Type, Lesion Location After Two Weeks	Effect of Tooth Type, Lesion Location After Four Weeks
Location 1 Middle third of clinical crown	88.9 ± 13.9	104.4 ± 21.2	<0.05	55.8 ± 21.6	100.1 ± 23.5	<0.001	<0.001	>0.05
Location 2 Cervical third of clinical crown	83.8 ± 13.8	92.8 ± 21.3	>0.05	50.7 ± 15.2	93.5 ± 23.6	<0.001	<0.001	>0.05
Location 3a Enamel at CEJ	81.4 ± 16.9	79.4 ± 27.7	>0.05	59.3 ± 19.6	102.5 ± 31.1	<0.003	<0.003	>0.05
Location 3b Root at CEJ	145.8 ± 12.0	188.9 ± 22.8	<0.001	120.6 ± 21.6	190.8 ± 25.8	<0.001	<0.001	>0.05
Location 4 Exposed root surface	152.2 ± 15.9	195.5 ± 9.4	<0.001	128.4 ± 14.6	197.5 ± 14.7	<0.001	<0.001	>0.05

*All depths were measured in micrometers.

weeks. In pre-molar teeth, all the lesions at four weeks were significantly deeper than those at two weeks, regardless of the lesion site.

Discussion.

The mean depths of the lesions in anterior teeth were significantly greater than those for pre-molar teeth at all locations after two weeks in the gel system. However, when the teeth were left for a four-week time period, the depths of the lesions in both types of teeth were not statistically different. Analysis of these data seems to suggest that the artificial lesions developed similarly in anterior and pre-molar teeth. At the present time, there is insufficient information to explain why the depths of the lesions in anterior and pre-molar teeth were different at the two-week time period. A possible explanation may be related to biological variation of the teeth examined and the relatively small sample sizes. Another explanation of the increased lesion depth in anterior teeth after two weeks in the gel may be related to the condition of the teeth prior to exposure to the demineralizing challenge. It is possible for demineralization and structural damage to exist at the ultrastructural level on what would appear to be sound teeth when examined at 10x magnification. If these defects existed in some of the teeth, then the rate of lesion progression may have been different in the affected teeth. In addition, it must be remembered that the anterior and the pre-molar teeth used in this study were not from the same mouth. To evaluate whether there was a true difference between anterior and posterior teeth would require repeating this study with a series of paired teeth from the same mouths of at least ten persons.

The lesion depths were similar for both anterior and pre-molar teeth after four weeks of exposure in the gel. Such similarity of lesion depths may imply that remineralization (or less demineralization) of the surface zone and of certain areas within the body of the lesion in root surfaces occurs in the *in vitro* system and affects lesion progression. It has been shown (Phankosol *et al.*, 1985) that in the *in vitro*

gel system the body of the lesion possesses bands composed of increased mineral content when compared with adjacent areas. Hypermineralized areas deep to the active lesion have also been described in natural root caries by Westbrook *et al.* (1974). This suggests that the remineralization phenomenon, known to play a significant role in the progression and reversal of enamel caries, may be of some importance in root surface lesions as well.

This study showed that the depths of the lesions in the root surfaces were approximately twice as deep as the lesions created in enamel, for both types of teeth. Since enamel contains a higher degree of inorganic substances than do both cementum and dentin, it may be more resistant to *in vitro* caries formation (Westbrook *et al.,* 1974). Moreover, a scanning electron microscopic and microbiological investigation of early plaque formation has shown that bacteria seemed to colonize cementum earlier than they do enamel (Nyvad *et al.,* 1981; Nyvad and Fejerskov, 1983). In older populations, where gingival recession results in increased areas of tooth and root surfaces to clean, and where eyesight and manual dexterity may be impaired, this may result in compromised oral hygiene skills and lead to root surface caries. The caries susceptibility of exposed root surfaces *in vivo* may be associated with the decreased ability of the aging population to remove plaque.

Acknowledgment.

The authors wish to thank Dr. Brian Clarkson for his help and advice in carrying out the study and in preparing the manuscript.

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SECTION B

IN-VITRO STUDIES

PUBLICATION

No. 3 Kambhu, P.P. , **Ettinger, R.L.**, and Wefel, J.S. An *in vitro* evaluation of artifical caries-like lesions on restored overdenture abutments. J. Dent. Res. 67:582-584, 1988.

This study was initiated and designed by the applicant. Dr. Kambhu, a Masters candidate in the Prosthodontic Department used this study as his thesis project and therefore he carried out the work. Dr. Wefel, a member of the committee helped especially with the microradiography. Dr. Kambhu helped write the paper with editorial comment from Dr. Wefel.

Reprinted from *Journal of Dental Research,* March 1988

Publication 3

An *in vitro* Evaluation of Artificial Caries-like Lesions on Restored Overdenture Abutments

P.P. KAMBHU, R.L. ETTINGER[1,2], and J.S. WEFEL[2,3]

Department of Preventive and Community Dentistry, [1]Department of Removable Prosthodontics, [2]Dows Institute for Dental Research, and [3]Department of Pediatric Dentistry, The University of Iowa, Iowa City, Iowa 52242

An acidified dialyzed gelatin gel system was used to determine the caries resistance of a variety of restorative materials used to obturate the canal orifice of overdenture abutment teeth. The restorative materials used were Tytin, Tytin + Copalite, P_{30} + Scotchbond, Fuji Ionomer-Type II, and Miracle Mix. Polarized light microscopy and microradiography were used to examine the caries-like lesions adjacent to the restorations. The lesions formed in the Fuji Ionomer-Type II and Miracle Mix groups appeared arrested at the wall adjacent to the restoration, and did not penetrate apically down the wall as did those associated with the other restorative materials. The mean depths of lesions adjacent to Fuji Ionomer-Type II and Miracle Mix restorations were significantly less than those of Tytin, Tytin + Copalite, or P_{30} + Scotchbond.

J Dent Res 67(3):582–584, March, 1988

Introduction.

Reports on the advantages of preserving teeth as overdenture abutments are numerous (Miller, 1958; Crum and Rooney, 1978; Rissin *et al.,* 1978; Toolson and Smith, 1983). However, the popularity of overdentures has been limited, partially due to the susceptibility of the abutment teeth to dental caries (Toolson and Smith, 1978; Reitz *et al.,* 1980; Toolson *et al.,* 1982; Toolson and Smith, 1983; Ettinger *et al.,* 1984). Dental caries has usually been found adjacent to the restoration sealing the canal orifice of the abutment teeth. The lesion site may be due to the vulnerability of the margin and tooth-restoration interface to acid attack.

Numerous investigators (Pickard and Gayford, 1965; Andrews and Hembree, 1975; Asmussen, 1976; Kidd, 1978; Hembree, 1984; Derand and Johansson, 1984) have studied the problem of microleakage and dental caries around different restorative materials. However, no previous study has reported on the development of artificially-induced lesions in dentin around restorations sealing the canal orifices of overdenture abutment teeth.

Materials and methods.

A large pool of extracted maxillary anterior teeth from patients between 50 and 70 years of age was collected. Immediately after extraction, the teeth were washed and stored in distilled/de-ionized water containing thymol. Sixty teeth which were caries-free at the cemento-enamel junction area were randomly selected from the pool. Each tooth was prepared in a fashion similar to that used for an abutment tooth for an overdenture. The teeth were sectioned and domed immediately below the cemento-enamel junction with a straight fissure carbide bur on a high-speed dental handpiece with water spray. Light sweeping strokes were used. The pulpal tissue was removed and the root canal mechanically instrumented with root canal reamers and files. The root canal was then filled with gutta-percha cones and Grossman root canal cement. Cavit (Premier Dental Products Co., PA 19401) was placed in the orifice and the teeth stored for one week in distilled/de-ionized water containing thymol. Cavity preparation of the canal orifice was to a depth of approximately 3 mm with smooth parallel lateral walls. A straight fissure carbide bur on a high-speed dental handpiece with water spray was used for cavity preparation.

The 60 teeth were then randomly assigned to five groups. The occlusal cavities of each group of 12 teeth were restored with the assigned restorative material, carefully following the manufacturer's instructions. The restorative materials used were:

Group I: dental amalgam. Tytin (S.S. White Dental Products International, PA 19102).

Group II: dental amalgam after the application of two coats of cavity varnish. Tytin (S.S. White Dental Products International, PA 19102). Copalite (Harry J. Bosworth Co., IL 60076).

Group III: composite resin and a bonding agent. P_{30} and Scotchbond (3M Co., MN 55101).

Group IV: glass-ionomer cement. Fuji Ionomer-Type II (G.C. International Corp., AZ 85260).

Group V: a mixture of glass-ionomer and alloy. Miracle Mix-Fuji Ionomer-Type II and Lumi Alloy (G.C. International Corp., AZ 85260).

All the restored teeth were subjected to thermocycling. The thermocycling system consisted of two water baths maintained at 60°C and 12°C ± 2°C. The cycle rate was one cycle every two minutes, with a 30-second dwell time in each bath. One thousand five hundred cycles were completed. After being thermocycled, each tooth was painted with two layers of an inert, acid-resistant varnish covering all surfaces except for the buccal half of the cut surface.

Twelve percent by weight acidified dialyzed gelatin gel was prepared and adjusted with lactic acid to make a 0.1 mol/L solution at pH 4.3. The prepared teeth were suspended in the acidified dialyzed gel at room temperature with one group of 12 teeth *per* container. As a precautionary measure against the lesions becoming too extensive, one specimen *per* group was removed from the gel at the end of two weeks and again at three weeks. These teeth were sectioned and viewed under polarized light but were not included in the statistical evaluation. The remaining teeth were left exposed to the acidified dialyzed gel for four weeks. After removal from the gel, each tooth was sectioned longitudinally on a hard-tissue microtome in a bucco-lingual direction. Each section was ground with a progressive series of aluminum oxide abrasive slurries (9.50 – 6.00 – 3.00 μm grit) on a Tufnal (McMaster Carr Supply Co., IL 60680) lapping base until the thickness was about 110 ± 10 μm.

Polarized light microscopy, with distilled water and quinoline used as the imbibition media, and microradiography were used for lesion examination. Standardized photomicrographs were made for all examination methods. For qualitative comparison, the slides from each section were projected.

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A sonic digitizer was used to make quantitative comparisons of the lesions from slides of the sections after imbibition in distilled water and quinoline. Lesion depth was measured at three points: adjacent to the restoration, at the midpoint or halfway from the restoration wall to the most distal point of the lesion, and at the three-fourths point or halfway between the midpoint and the most distal point of the lesion. All slides were projected onto the digitizer screen at the same magnification (140X) and focal distance. The data were evaluated for statistical significance using Duncan's multiple-range test.

Results.

Statistical analysis of the specimens after imbibition in distilled water showed that the mean depths of the lesions adjacent to Fuji Ionomer-Type II (273 μm) and Miracle Mix (355 μm) were significantly less than those of Tytin (478 μm), Tytin + Copalite (456 μm), and P_{30} + Scotchbond (444 μm) (Table). At the midpoint and three-fourths point, the mean depths of the lesions of all five groups were not significantly different from one another.

For specimens after imbibition in quinoline, statistical analysis showed that the mean depths of the lesions adjacent to Fuji Ionomer-Type II (286 μm) and Miracle Mix (288 μm) were significantly less than those of Tytin (413 μm), Tytin + Copalite (388 μm), and P_{30} + Scotchbond (406 μm) (Table). However, at the midpoint and three-fourths point, the mean depths of the lesions of all five groups, again, were not significantly different from one another.

Qualitative comparison of the lesions as seen in specimens after imbibition in distilled water and quinoline showed a clear distinction in the shape of the lesion fronts adjacent to Fuji Ionomer-Type II and Miracle Mix as compared with the shape of the lesion fronts adjacent to the other restorative materials. In the area adjacent to the amalgam, amalgam + cavity varnish, and composite resin restorations, all lesion fronts turned apically before intersecting the restoration wall (Fig. 1). Two unique lesion shapes adjacent to Fuji Ionomer-Type II and Miracle Mix were observed. In the first group, the lesion fronts either ran parallel to the surface of the lesion (Fig. 2) or turned slightly coronally toward the restoration wall, intersecting it at approximately a right angle. This variation in lesion shape was seen in 30% of lesions adjacent to Fuji Ionomer-type II and 50% of lesions adjacent to Miracle Mix. In the second group, the lesion fronts turned abruptly coronally and ran parallel to the restoration wall before turning to intersect it (Fig. 3). This lesion shape was seen in 40% of lesions adjacent to Fuji Ionomer-Type II and 40% of lesions adjacent to Miracle Mix. For the remaining 30% of lesions adjacent to Fuji Ionomer-Type II and 10% adjacent to Miracle Mix, the lesion fronts turned apically before intersecting the restoration wall.

Subjective qualitative changes observed from the microradiographs suggested a relatively even degree of radiolucency in the body of the lesion in the Tytin, Tytin + Copalite, and P_{30}+ Scotchbond group. In the Fuji Ionomer-Type II and Miracle Mix group, a radiolucent band was observed at the lesion front beneath a more radiopaque lesion.

All specimens showed a degree of contraction when observed in quinoline and by microradiography. The contraction was observed in the lesion area only and not in normal dentin.

TABLE

DUNCAN'S MULTIPLE RANGE TEST FOR THE DEPTH OF THE LESION ADJACENT TO THE RESTORATION WALL. SPECIMENS AFTER IMBIBITION IN DISTILLED WATER AND QUINOLINE. MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

Grouping		Mean and S.D. (μm)		
Water	Quinoline	Water	Quinoline	Restoration
A	A	478 ± 46	413 ± 38	Tytin
A	A	456 ± 102	388 ± 74	Tytin + Copalite
A	A	444 ± 69	406 ± 71	P_{30} + Scotchbond
B	B	273 ± 109	286 ± 131	Fuji Ionomer Type II
B	B	355 ± 119	288 ± 102	Miracle Mix

Alpha Level = 0.05.
DF = 45.
MS = 8674 (water).
MS = 7902 (quinoline).

Fig. 1 — Photomicrograph of an undecalcified ground section after imbibition in distilled water. This lesion is adjacent to Tytin and shows the lesion front turning apically and intersecting the restoration wall (to the right of the photomicrograph). The restoration has been lost in this section. (Magnification X 40)

Fig. 2 — Photomicrograph of an undecalcified ground section after imbibition in distilled water. This lesion is adjacent to Fuji Ionomer-Type II and shows the lesion front running parallel to the surface of the lesion and intersecting the restoration wall (to the right of the photomicrograph) at approximately a right angle. (Magnification X 40)

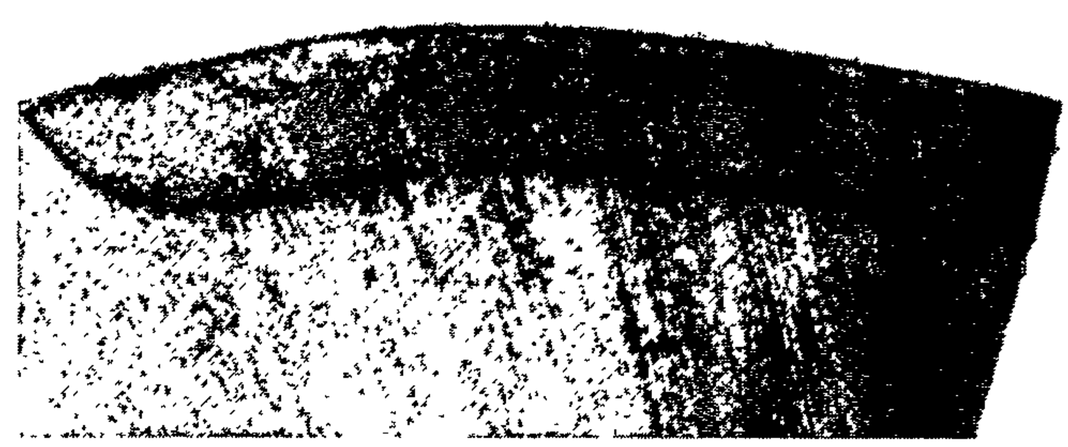

Fig. 3 — Photomicrograph of an undecalcified ground section after imbibition in distilled water. This lesion is adjacent to Miracle Mix and shows the lesion front turning abruptly coronally and running parallel to the restoration wall (to the right of the photomicrograph) before turning to intersect it. (Magnification X 40)

Distortion was apparent at the surface of the lesion but not at the lesion front. Statistical analysis, using a dependent *t* test, showed that the differences between lesion depths measured after imbibition in distilled water and quinoline from the same specimens were significantly different at the 0.0001 probability level.

Discussion.

The acidified gels used to create lesions in this study were dialyzed for elimination of ionically active calcium, phosphate, and fluoride. Therefore, any differences between the lesions created can be attributed directly to the restorative materials and not to free ions in the gel.

The measurements of lesion depths adjacent to the restorations (Table) showed that the mean depths of the lesions were significantly less, adjacent to Fuji Ionomer-Type II and Miracle Mix. The reported anticariogenic property of glass-ionomer cement resulting from the release of fluoride (Kidd, 1978; Wesenburg and Hals, 1980; Swartz *et al.,* 1984) can be supported by this study.

The fluoride in Fuji Ionomer-Type II and Miracle Mix may have affected the lesion development in two ways: First, the fluoride in the restorative materials may have crossed the tooth-restoration interface and thus inhibited the demineralization process in the area adjacent to the cavity wall. This hypothesis appears to be supported by the smaller lesion depths seen adjacent to Fuji Ionomer-Type II and Miracle Mix. Second, the fluoride from the restorative materials may have leached out into the acidified dialyzed gelatin gel and inhibited the degree of demineralization in the body of the lesion. This hypothesis may be supported by the fact that lesions in the specimens restored with Fuji Ionomer-Type II and Miracle Mix appeared to be less radiolucent in the microradiographs than the lesions associated with the other restorative materials. Nevertheless, the differences in lesion depth between the five groups at the midpoint and three-fourths point were not statistically significant. However, the subjective findings from the microradiographs suggest that even though the depths of penetration in these areas were comparable, the degree of demineralization within the lesion may have been less with Fuji Ionomer-Type II and Miracle Mix. Densitometric studies are required to confirm these observations.

The mean depth of the lesions adjacent to the amalgam restoration decreased when the cavity walls were coated with cavity varnish (Table). This is in agreement with the reports of Andrew and Hembree (1975). However, in this investigation the differences between lesions with and without varnish use were not statistically significant.

The adhesion of composite resin to dentin by chemical coupling agents, as reported by McCabe (1984), was not effective in inhibiting the penetration of acid along the cavity wall in this study. The depth of penetration of the lesions adjacent to the composite resin group was similar to that of the amalgam and amalgam + cavity varnish group (Table).

An interesting observation was that 70% of the P_{30} + Scotchbond restorations were still attached to the sections after being sectioned with the microtome. Only 10% of the Tytin and Tytin + Copalite restorations remained attached, and 40% of the Fuji Ionomer-Type II restorations and 60% of the Miracle Mix restorations remained attached. If the ability of the restoration to remain attached to the section after being subjected to the mechanical forces generated by the cutting action of the microtome can be translated into ability to bond to dentin, then it can be said that the composite restoration had the strongest bond. It can be seen, however, that the mean lesion depths adjacent to the composite resin group were not statistically different from those of the amalgam and amalgam + cavity varnish group. This suggests that there may be no correlation between the ability of composite resin to bond to dentin and its ability to protect the tooth from acid attack.

Although contraction of all specimens was observed when quinoline was used as the imbibition medium, the lesion depths at all three points showed the same trend whether distilled water or quinoline was used as the imbibition medium. Thus, the statistical analysis of the lesion depths measured within groups using either of the two imbibition media showed the same results. However, one should be aware of the shrinkage factor associated with quinoline. Specimens after imbibition in distilled water should not be compared with those after imbibition in quinoline. Although specimens after imbibition in distilled water gave a less distorted appearance, it was often easier to measure lesion depths in specimens after imbibition in quinoline because of the ease in determining the lesion front which appeared as a purple band. Therefore, both techniques are of value when used in the same study.

The results of this investigation showed that the fluoride-containing restorative materials, Fuji Ionomer-Type II and Miracle Mix, had an inhibiting effect on the demineralization process *in vitro.* The use of these restorative materials as overdenture abutment restorations may help reduce the caries incidence associated with this prosthesis.

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SECTION B

IN-VITRO STUDIES

PUBLICATION

No. 4 **Ettinger, R.L.**, Manderson, D., Wefel, J.S. and Jensen, M.E. An *in vitro* Evaluation of the prevention of caries on overdenture abutments. J. Dent. Res. 67:1338-1341, 1988.

This study was initiated and designed by the applicant. Ms. Manderson was a final-year dental student working on a summer extramural fellowship from the University of Cardiff in Wales. Dr. Wefel helped with advice especially with the microradiography while Dr. Jensen supplied some of the funds to help with the study. The paper was written by the applicant with editorial comment from Dr. Wefel.

Reprinted from *Journal of Dental Research,* October 1988

Publication 4

An *in vitro* Evaluation of the Prevention of Caries on Overdenture Abutments

R.L. ETTINGER[1], D. MANDERSON[2], J.S. WEFEL[3], and M.E. JENSEN[3]

[1]*Department of Removable Prosthodontics, and Dows Institute for Dental Research;* [3]*Department of Pediatric Dentistry, and Dows Institute for Dental Research, College of Dentistry, The University of Iowa, Iowa City, Iowa 52242; and* [2]*University of Wales, Cardiff, Wales, United Kingdom*

Teeth prepared as overdenture abutments are susceptible to caries, and it has been shown that brushing by itself is not sufficient to prevent this process. This study evaluated the preventive effect of a remineralization gel which has a low fluoride concentration and compared its effects with those of a phosphate fluoride gel (Karigel), which has a much higher concentration of fluoride. Twenty extracted anterior teeth from patients aged 50 to 70 years were prepared as for overdenture abutments. Each tooth was sectioned into three fragments. An acidified gel system was used to produce artificial caries lesions on the occlusal and root surfaces of each fragment. One fragment of each tooth was treated with the remineralizing gel, the second fragment with a high-fluoride gel, and the third fragment served as the control. Ten teeth were removed at two weeks and again at four weeks, and were sectioned and prepared for histological examination. The depth of the lesions was measured from standardized photomicrographs by means of a sonic digitizer. The conclusions were: (1) Lesions on the occlusal tended to be deeper than those on the root surfaces at four weeks but not at two weeks; and (2) the high-fluoride gel was more protective than the low-fluoride remineralizing solution at both time periods on the occlusal but not on the root surface.

J Dent Res 67(10):1338–1341, October, 1988

Introduction.

Overdentures have only recently become an accepted treatment modality. Their popularity increased after Crum and Rooney (1978) reported a significant reduction in mandibular bone loss after five years (0.6 mm compared with 5.2 mm) in persons wearing overdentures, as compared with subjects using conventional complete dentures. However, the usefulness of overdentures has been limited by the susceptibility of the abutment teeth to dental caries. Toolson and Smith (1978) have shown that brushing, by itself, was not sufficient to prevent caries. Thus, prevention has relied on the combination of good home care and the use of topical fluorides (Fenton and Hahn, 1978).

Although the use of topical fluoride on overdenture abutments seems to improve their resistance to caries, it is not entirely clear how fluoride acts on the root surface. Most of the fluoride preparations have been developed for the protection of enamel surfaces in young populations (Silverstone *et al.*, 1981), while what is needed for overdentures is protection of the cut dentin and root surfaces. There is a paucity of data concerning the degree to which dentin surfaces can be protected by any of the fluoride compounds. Also, the chemical compositions of enamel and dentin are so different that it is impossible to extrapolate to dentin from the results of fluoride protection of enamel. In fact, Swango (1983) stated that there are no adequate existing studies on the effects of topical fluoride procedures in inhibiting the development of caries, especially root-surface caries in older adults.

When fluoride is added to demineralizing (acid) gels interfaced with enamel, it has been shown that a 40–50% reduction in dissolved mineral results (Feagin *et al.*, 1985). When a similar experiment was performed with root surfaces, only a 25% reduction in mineral dissolution was observed. Feagin (1984) has suggested that fluoride may react differently with root surfaces.

Fluoride added to a remineralizing gel and used topically on a root surface resulted in a reduction in mineral loss upon challenge in a demineralizing environment. The recrystallization gel developed by Feagin (1986) was saturated with respect to apatite so that no root-surface mineral was dissolved, and when fluoride was added, the gel became supersaturated with respect to fluorapatite. The aim of this study was to evaluate *in vitro* the effectiveness of Feagin's remineralizing gel (containing 20 mmol/L calcium, 10 mmol/L phosphate, and 0.75 mmol/L F^- at pH 5) on root surfaces and on the dentin of root fragments prepared for overdentures.

Materials and methods.

A large pool of extracted anterior teeth from patients aged 50–70 years was collected. Immediately after extraction, the teeth were washed and stored in double-de-ionized/distilled water containing thymol. Twenty caries-free teeth were randomly selected from the pool. All calculus, bone, and attached soft tissue was removed by means of a hand scaler. Bacterial stains and plaque were removed with a rotary handpiece and a rubber cup with aluminum-oxide abrasive slurry containing no fluoride. Each tooth was prepared in a fashion similar to that used for an abutment tooth for an overdenture. The teeth were sectioned and domed immediately below the cemento-enamel junction with a straight-fissure carbide bur on a high-speed dental handpiece with water spray. Light sweeping strokes were used. The pulpal tissue was removed and the root canal mechanically instrumented with root canal reamers and files to No. 30. Each tooth was sectioned longitudinally into thirds to provide two experimental portions and a control portion (Fig. 1). Two layers of an acid-resistant nail polish were painted on all surfaces except for two windows (2 mm × 4 mm) on each of the tooth fragments. One window was placed approximately 2 mm below the cemento-enamel junction and the other on the superior prepared dentin surface. Dental floss tied to a hole drilled in the root tip was used to suspend the tooth in the acidified gel.

All tooth fragments were dried thoroughly. On the fragments in Group No. 1, the windows were painted with the remineralizing gel (prepared by the University of Iowa's College of Pharmacy) which was left on for four min. Fragments in Group No. 2 were painted with Karigel (Lorvic Corporation, St. Louis, MO 63134), a commercially-available acidulated-phosphate fluoride for four minutes. Fragments in Group No. 3 were used as the control and were not pre-treated. All sites were thoroughly washed with distilled H_2O for 60 sec. This was an arbitrary time chosen for the sake of uniformity in the *in vitro* experiments.

The demineralizing gel was dialyzed to remove fluoride, calcium, and phosphate contaminants and evaporated to a concentration of 10% (w/v). The pH was adjusted to 5.0 by the

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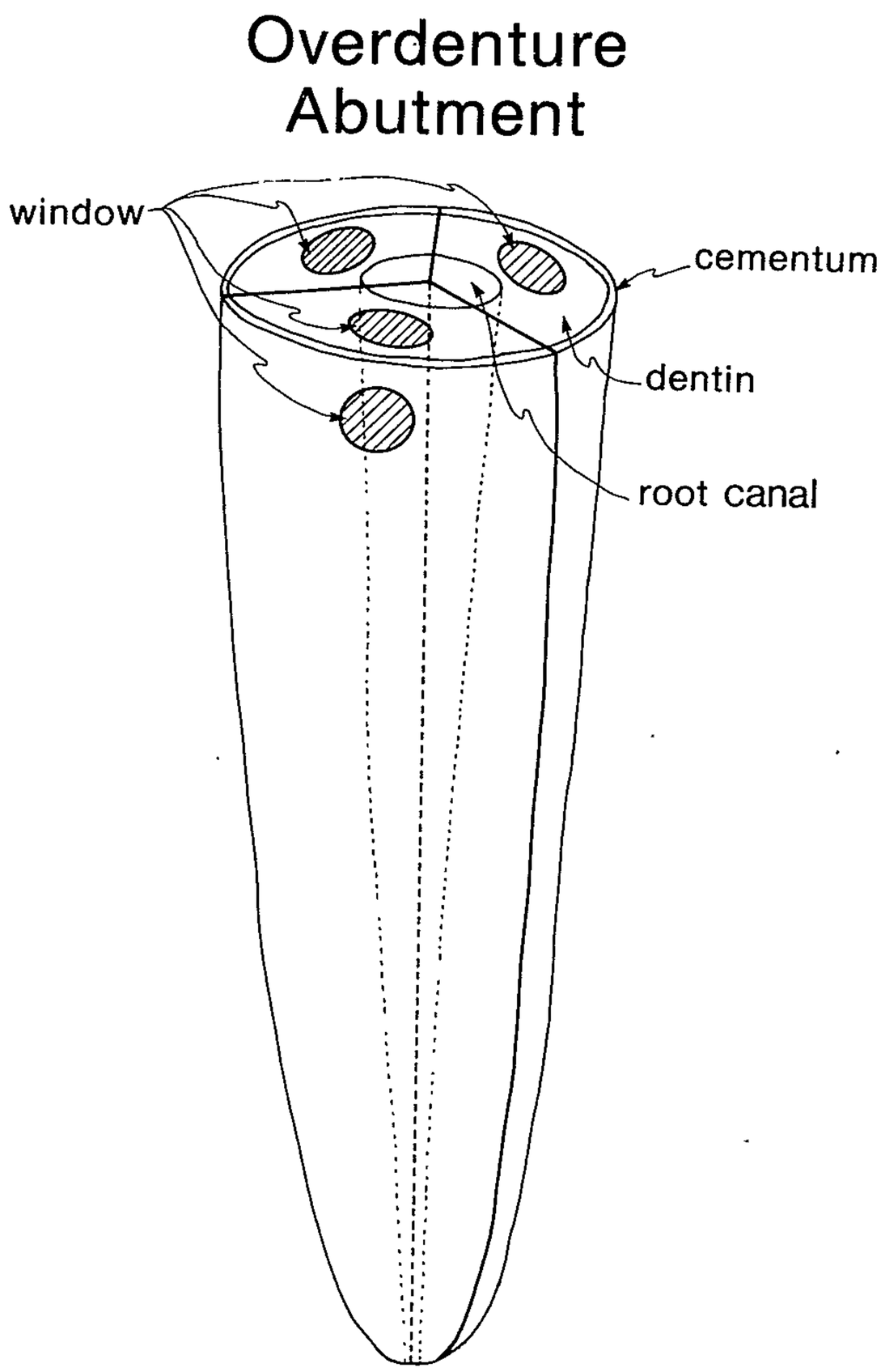

Fig. 1—Schematic of tooth prepared as for an overdenture abutment, showing locations of the windows on the occlusal and the root surfaces.

addition of 0.1 mol/L lactic acid, and thymol was used as a preservative.

The prepared tooth fragments were then suspended in the acidified gel solution. The solution was left to gel at room temperature and sealed. All tooth fragments were removed once every third day, washed, re-treated with the remineralizing gel for four min, washed for 60 sec, and placed back in the acidified gel. Ten sets of tooth fragments were removed from the gel, rinsed, and stored in distilled water at the end of two weeks and at the end of four weeks.

Each tooth fragment was sectioned longitudinally on a hard-tissue microtome in a bucco-lingual direction. A representative section was ground with a progressive series of aluminum-oxide abrasive slurries (9.50-, 6.00-, 3.00-μm grit) on a tufnal lapping base to a thickness of 100 ± 10 μm. The ground sections were stored in distilled water at 4°C.

Polarized light microscopy, with distilled water used as the imbibition medium, and microradiography were used for lesion examination. Standardized photomicrographs were made of all sections. All photomicrographs were projected onto a digitizer screen at the same magnification and focal distance. Lesion depth was recorded by measurement of the lesion at its deepest portion by means of a sonic digitizer. The intra-examiner reliability was measured at 98%. Wefel and Harless (1987) have calculated the error inherent to the digitizer hardware to be less than 1%. The data were evaluated for statistical significance by use of Duncan's multiple range test.

Results.

Lesions on the occlusal surface.—Histologically, all dentinal lesions on the occlusal surfaces appeared as shallow, broad, and saucer-shaped and showed no visible surface zone (Fig. 2). The body of the lesion had a higher degree of positive birefringence than did sound dentin, and the advancing front was seen as a darkened line. At two weeks, no histological differences could be seen between lesions treated by the fluoride gels and the untreated controls. At four weeks, all the lesions were at least 55% deeper ($p < 0.05$) than at two weeks, and they appeared to be similar.

However, when the lesions were examined by microradiography, some differences could be detected (Table 1). After two weeks of exposure in the demineralizing gel, all the occlusal lesions showed a radiolucent body with absence of banding in the body. In some lesions, there was a difference in radiodensity between the body of the lesion and the lower one-third. The increased density of this lower one-third gave the area a "foggy" look (Fig. 3a) and was more often associated with the use of the high-fluoride gel. At four weeks, diffuse bands and an increased density of the lower 1/3 of the lesions were seen more frequently in specimens treated with the high-fluoride gel when compared with the control or with specimens which were treated with the remineralizing gel.

Lesions on the root surface.—The demarcation between cementum and dentin could easily be seen with polarized light, since the cementum was negatively birefringent after imbibition in water. The lesions were broad, flat, and saucer-shaped, with no visible surface zone when viewed in polarized light.

After two weeks of exposure in the acidified gel, the root-surface lesions were mainly in cementum. The only difference between the lesions treated with fluoride and the control lesions was an increase in partial banding in the fluoride groups, when the sections were examined microradiographically (Table 1).

The root-surface lesions after four weeks' exposure in the acidified gel showed distinctive bands within the body of the lesion. The bands seen with polarized light were confirmed by microradiography as multiple radiodense bands (Fig. 3b) and were seen more frequently in the group treated with the high-fluoride gel than in the control group or in the group in which

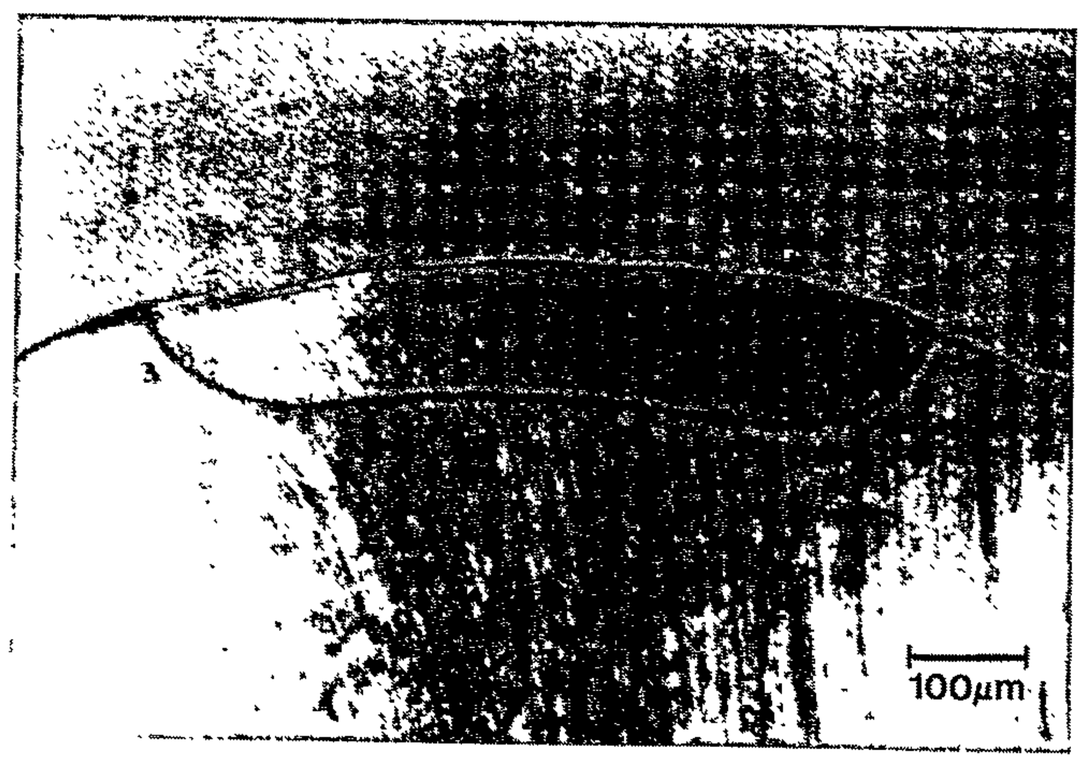

Fig. 2—Photomicrograph of an undecalcified ground section after imbibition in distilled water, showing a lesion on the occlusal surface of the teeth after four weeks in the acid gel.

TABLE 1
MICRORADIOGRAPHIC EVALUATION OF ARTIFICIAL LESIONS OF DENTIN (O) AND THE ROOT SURFACE (R) (CHARACTERISTICS OF THE LESIONS EXPRESSED AS A PERCENTAGE OF THE TOTAL SPECIMENS EXAMINED)

	Remineralizing Gel		High-fluoride Gel		Control Gel	
	At Two Weeks					
	O	*R*	*O*	*R*	*O*	*R*
Less Radiolucent Surface Zone	—	44	22	44	22	44
Partial Banding	22	22	11	44	—	11
Increased Density of the Lower 1/3 Lesion	44	66	88	55	77	66
	At Four Weeks					
	O	*R*	*O*	*R*	*O*	*R*
Less Radiolucent Surface Zone	—	20	—	30	10	20
Surface Zone	—	60	—	70	—	50
Diffuse Bands	50	80	80	100	30	90
Multiple Bands	—	20	—	50	—	20
Increased Density of Lower 1/3 Lesions	10	10	60	10	30	—

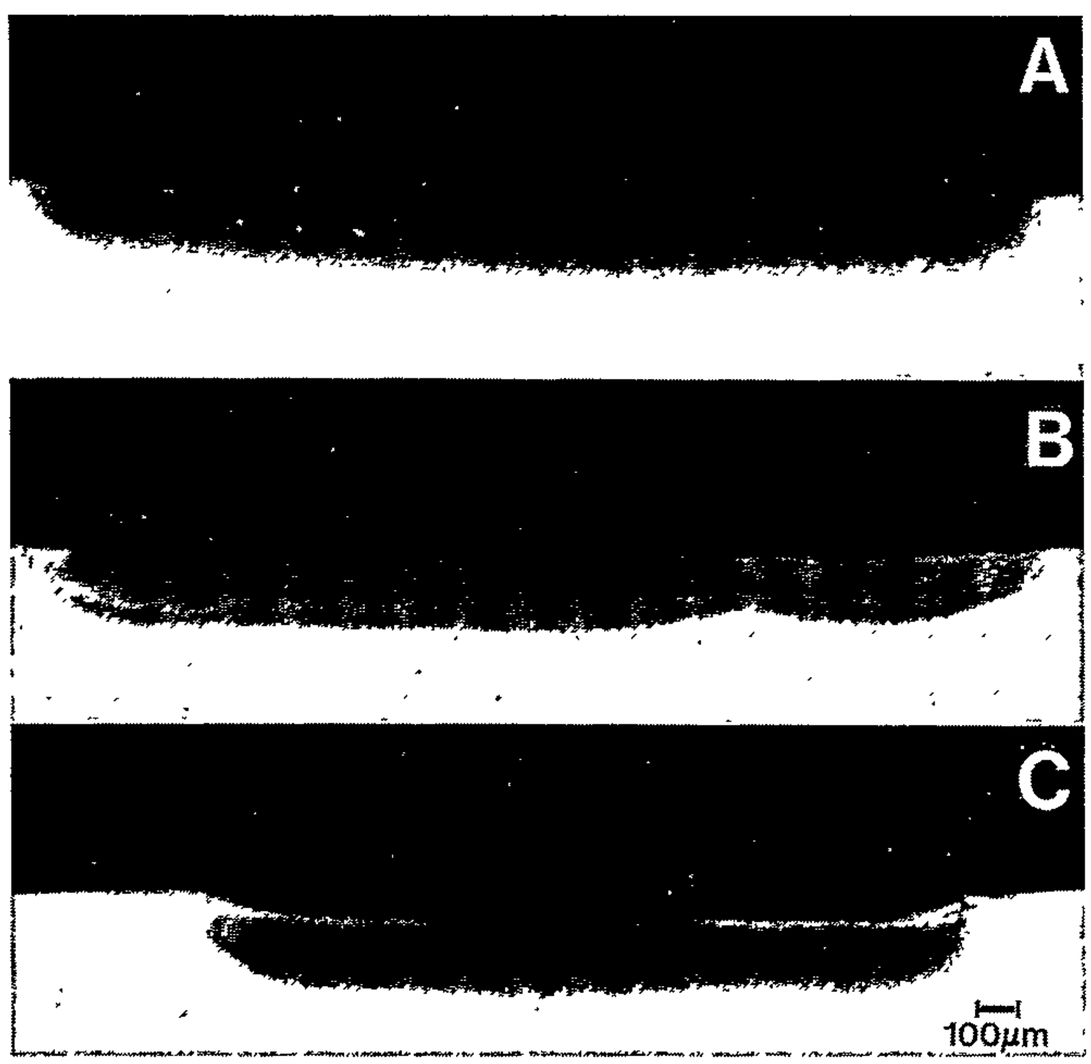

Fig. 3 (a)—Microradiograph of an undecalcified ground section showing a lesion on the occlusal surface of the tooth after two weeks in the acid gel. Note the increased density of the lower one-third of this lesion—"foggy" look.

(b) Microradiograph of an undecalcified ground section showing a lesion on the root surface after four weeks in the acid gel. A partially radiopaque surface zone can be seen, as can multiple bands in the body of the lesion.

(c) Microradiograph of an undecalcified ground section showing a lesion on the root surface after four weeks in the acid gel. This lesion shows a radiopaque surface zone and increased density of the lower one-third of the lesion.

the remineralizing gel was used. Microradiographically, surface zones were seen (Fig. 3c) more frequently in this four-week group than in the group which had two weeks of exposure in the acidified gel.

Depth of the lesions.—After two weeks of exposure in the acidified gel (Table 2), the control fragments had the deepest occlusal lesions when the depths were measured with a sonic digitizer. However, there were no significant differences in depth between the control lesions and the teeth treated with the remineralizing gel. The occlusal lesions in tooth fragments treated with the high-fluoride gel were significantly shallower than those in the control but not different from the fragments treated with the remineralized gel.

When the depths of root-surface lesions were examined in the three groups after two weeks of exposure in an acidified gel, there were no significant differences. After four weeks of exposure in the acidified gel, there was a statistically significant lower depth in the tooth fragments treated with the high-fluoride gel in both the occlusal and root-surface lesions (Table 2).

Discussion.

The acidified gels used in this study were dialyzed for removal of calcium, phosphate, and fluoride. Any differences observed in the induced caries-like lesions may therefore be attributed to the treatment of the tooth specimens during lesion formation and are not due to extraneous ions in the gel.

Lesions which were created on the cut dentin surface had a different appearance than did those on root surfaces. The root-surface lesions were more likely than were the occlusal lesions to have either a less radiolucent surface zone at two weeks or a distinctive surface zone at four weeks. No multiple banding was seen in the occlusal lesions.

The banding found within the body of the artificial lesions, as described by Phankosol *et al.* (1985), seemed to be associated with the presence of calcium, phosphate, and fluoride ions. When undialyzed gels are used, these free ions may precipitate along the previously demineralized matrix in the body of the lesion or on the surface. These remineralized areas are seen as surface zones of various radiodensities or as bands within the body of the lesions. In the current experiments, dialyzed gels were used, and the free ions could only have come from the treatment regimens and/or dissolving tissue. After two weeks of treatment (that is, five applications of fluoride gels), there were some signs of banding, mainly in the root-surface lesions treated with the high-fluoride gels. After four weeks, bands were seen in a majority of the lesions treated with fluoride gels (Table 1). Remineralization is known to be enhanced by the presence of fluoride, and therefore the increased prevalence of banding with increased fluoride application is not unexpected. Al-Joburi and Koulourides (1984) have also noted radio-dense banding after fluoride treatment of root surfaces during *in vitro* demineralization.

The source of ions for banding in the control specimens is not clear, since dialyzed gels were used, and the specimens were washed with de-ionized distilled water. Presumably, calcium and phosphate released during demineralization were reprecipitated within the body of the lesion.

The gel containing Ca, P, and F [developed by Feagin (1986)] was effective in his studies in reducing demineralization and in increasing the fluoride content of the root surface when in continuous contact. To simulate the clinical situation, we implemented a four-minute exposure every third day in this study. This short exposure failed to reduce demineralization significantly in this experiment. However, the high-fluoride gel (1000 times more concentrated) was effective in reducing demineralization, even during the short period of application. Thus, a 15-ppm-F gel with calcium and phosphorus applied for four minutes every third day was *not* effective in a constant acid challenge, but the 12,300-ppm-F in the high-fluoride gel was effective. It therefore appears important for us to establish the

TABLE 2
DUNCAN'S MULTIPLE RANGE TEST: DEPTH OF *IN VITRO* LESIONS FOLLOWING A TWO- OR FOUR-WEEK EXPOSURE PERIOD TO THE ARTIFICIAL CARIES SYSTEM (mean depth in μm)

			Occlusal	
		2 Weeks		4 Weeks
Control	A*	130 ± 5.1	A	202 ± 10.3
Remineralizing Gel	B, A	117 ± 6.9	A	202 ± 10.3
High-fluoride Gel	B	107 ± 4.9	B	163 ± 12.0
		MSE = 296.5 DF = 24	ALPHA = 0.05	MSE = 1183.1 DF = 27
			Root Surface	
		2 Weeks		4 Weeks
Control	A	127 ± 11.1	A	180 ± 4.5
Remineralizing Gel	A	112 ± 2.9	A	176 ± 6.1
High-fluoride Gel	A	112 ± 8.2	B	147 ± 4.8
		MSE = 597.2 DF = 24	ALPHA = 0.05	MSE = 266.5 DF = 27

*Means with the same letter are not significantly different from one another.

concentration, frequency, and modality of fluoride application which will give the optimal protection to dentin and cementum. Future studies will attempt to define these conditions under simulated clinical situations.

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SECTION B

IN-VITRO STUDIES

PUBLICATION

No. 5 **Ettinger, R.L.**, Ahmad, R., and Wefel, J.S. An *in vitro* evaluation of the effect of fluoride concentrations on overdenture abutments. Submitted J. Dent Res.

This study was initiated and designed by the applicant.

Dr. Ahmad was a visiting faculty member from the Prosthodontic Department, University of Malaya who spent her sabbatical at Iowa. Dr. Wefel again helped with advice, especially with the microradiography. The paper was written by the applicant with editorial comment from Dr. Wefel.

AN *IN VITRO* EVALUATION OF THE EFFECT OF FLUORIDE CONCENTRATIONS ON OVERDENTURE ABUTMENTS

R. L. Ettinger[1]

R. Ahmad[2]

J. S. Wefel[3]

1. Department of Prosthodontics, and
   Dows Institute for Dental Research
   College of Dentistry
   The University of Iowa
   Iowa City, IA 52242

2. Department of Prosthetic Dentistry
   University of Malaysia

3. Department of Pediatric Dentistry and
   Dows Institute for Dental Research
   College of Dentistry
   The University of Iowa
   Iowa City, IA 52242

Short Title: Effect of fluoride on overdenture abutments.

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ABSTRACT

Teeth prepared and used as overdenture abutments are susceptible to caries. Since brushing by itself has been shown not sufficient to prevent caries in overdenture abutment teeth, epidemiological and clinical studies have indicated that fluoride may be a useful preventive agent in adult populations. This study evaluated the preventive effect of four concentrations of fluoride. Twenty-five extracted caries-free anterior teeth from patients aged 50-70 were prepared as overdenture abutments. The teeth were sectioned mesiodistally into two halves. The teeth were covered with a protective varnish, leaving a window on the root surface and one on the cut dentin of the occlusal. The root halves were randomly divided into 5 groups of 10 specimens and each group received a different five minute topical treatment prior to being placed in the demineralizing solution. The treatments were: Group I - distilled H_2O only; Group II - 100 ppm F^-, Group III - 250 ppm F^-; Group IV - 500 ppm F^-; and Group V - 1000 ppm F^-. The cycle was maintained for 10 days. The teeth were cycled for 6 hours in a demineralizing solution and for 17 hours in a fluoride-free remineralizing solution. The root halves were sectioned and prepared for histologic examination. The depth of the lesions were measured from standardized photomicrographs by means of a sonic digitizer. The conclusions were: (1) the lesions on the root surface were so small as not to be measurable, (2) the lesions on dentin were all of similar depth, and (3) the lesions had bands within them and the width of these bands showed a dose response to fluoride concentration after the topical application.

INTRODUCTION

In the past two decades a number of longitudinal clinical studies (Crum and Rooney 1978, Toolson and Smith 1978, Davis et al. 1981, Toolson et al. 1982, Toolson and Smith 1983, Ettinger et al. 1984, Renner et al. 1984, Toolson and Taylor 1989) have been published describing overdenture populations. The primary problems associated with overdenture use have been caries and periodontal disease of the abutment teeth. In 1978 Toolson and Smith showed that brushing the abutment teeth by itself was not sufficient to prevent caries. Thus, successful therapy has relied on a combination of good home care and the use of topical fluorides (Toolson and Smith 1983).

Stamm et al. (1990) have demonstrated that life-long consumption of fluoridated water significantly reduced the prevalence of root caries when compared to similar individuals living in a non-fluoridated community. Burt et al. (1986) confirmed these findings when investigating two communities in New Mexico and stated that their results "confirm that root caries experience is directly related to the fluoride concentration in drinking water." Although the use of topical fluorides on overdenture abutments seems to improve their resistance to caries, it is not entirely clear how fluorides act on root surfaces. In fact, most of the commercial fluorides have been developed for the protection of enamel surfaces in young populations (Silverstone et al. 1981). The chemical composition of enamel and dentine is so different that it is inadvisable to extrapolate from the results of fluoride protection of enamel to dentine.

The aim of this study was to evaluate the effect of various concentrations of topical fluoride applications on dentin and cementum associated with cyclic acid challenge to the tooth structure.

METHODS AND MATERIALS

Sound extracted caries free anterior teeth from patients aged 50-70 years were collected, cleaned of all soft tissue, washed and stored in deionized/distilled water containing thymol. Twenty five caries-free teeth were randomly selected from the pool. All calculus and bone were removed by means of a hand scaler, and bacterial stains and plaque were removed with a rotary handpiece and a rubber cup with aluminum-oxide abrasive slurry containing no fluoride. Each tooth was prepared in a fashion similar to that used for an abutment tooth for an overdenture. The teeth were sectioned and domed immediately below the cemento-enamel junction with a long tapered diamond bur on a high-speed dental handpiece with a water spray. Light sweeping strokes were used. The pulpal tissue was removed and the root canal mechanically instrumented with root canal reamers and files to No. 30 but the root canal was not filled. Each tooth was sectioned mesodistally to give a lingual and buccal half. Two layers of an acid resistant nail polish were painted on all surfaces except for two windows (2mm x 4mm) on each tooth fragment. One window was placed approximately 2mm below the cemento-enamel junction and the other on the superior prepared dentin surface of the overdenture abutment. Orthodontic wire was tied to a hole drilled in the root tip to suspend the tooth in the demineralizing and remineralizing solutions.

Test solutions of sodium fluoride were prepared from stock by diluting with distilled/de-ionized water so that they contained either:

1,000 ppm	fluoride which is equivalent to a standard toothpaste
500 ppm	fluoride which is equivalent to a prescription home fluoride rinse.
250 ppm	fluoride which is equivalent to a standard mouth rinse.
100 ppm	fluoride which is equivalent to a low concentration of mouth rinse.

The concentration of fluoride ion was verified by a fluoride electrode* at the start of the experiment and again at the end of the experiment. There was a decrease in fluoride concentration over time of not more than 10% in each of the solutions.

A demineralizing solution was prepared based on Ten Cate and Duijsters (1982) formula. The solution consisted of 2.0mM $CaCl_2$:2 H_2O, 2.0 mM KH_2 PO_4 and 75 mM acetic acid. The ph was adjusted to 4.3.

The 50 root halves were randomly divided into 5 groups of 10 specimens. All specimens except the control were treated topically with one of the fluoride concentrations for 5 minutes while the control was treated with de-ionized/distilled water. The specimens were then washed for 2 minutes with de-ionized/distilled water and placed in the demineralizing solution for 6 hours at 37°C. At the end of 6 hours the specimens were retrieved, washed for 2 minutes in de-ionized/distilled water, and placed in a fluoride-free remineralizing system for 17 hours. The remineralizing solution contained 1.5mM $CaCl_2$:2 H_2O, 0.9mM KH_2 PO_4 and 150 mM KCl. The ph was adjusted to 7.0. This cycle was used to mimic intraoral pH changes and was maintained continuously for 10 days.

Polarized light microscopy (PLM)

At the end of the experimental period each tooth fragment was sectioned longitudinally on a hard tissue microtome in a bucco-lingual direction. A representative section was ground with a progressive series of aluminum oxide abrasives slurries (9.50, 6.00, 3.00μm grit) on a tufnal base to a thickness of 100 + 10 μm. The ground sections were stored in distilled water at 4°C.

* Combination fluoride electrode
N096-09-00, Orion Research SA 270.

Polarized light microscopy, using distilled water as the imbibing medium, and microradiography were used to examine the lesions. Standardized photomicrographs were made of all sections. All photocmicrographs were projected onto a digitizer screen at the same magnification and focal distance. Lesion depth was recorded by measuring the lesion at its midpoint using a sonic digitizer. The intra-examiner reliability was measured at 98%. Wefel and Harless (1987) have calculated the error inherent to the digitizer hardware to be less than 1%. The data were evaluated for statistical significance using Duncan's multiple range test.

Microradiography (MRG)

The same sections used in the polarized light, histological evaluation were used for contact microradiography. The sections and an aluminum step wedge were fixed to Kodak high resolution film and mounted in a specially designed camera for exposure. A GE x-ray generator operated at 40 kV and 16mA in conjunction with a nickel filter was used to produce Cu ($K\alpha$) radiation. After exposure, the films were processed and mounted on glass slides and the lesions photographed at the same magnification as used with polarized light. The photomicrographs of these microradiographs were projected onto a digitizer screen at the same magnification and focal length as those made with polarized light. Changes in depth in the body of the lesion were measured at the midpoint of the lesion with a sonic digitizer. Mineral density profiles of the microradiographs were made with a bioquant image analyzer and used to confirm the banding observed qualitatively in the polarized light and MRG photomicroradiographs. The bioquant system consists of a high resolution television camera mounted on a microscope where the image of the sample is displayed on a CRT and a pixel density record of the image can be stored on a computer for future evaluation.

RESULTS

Occlusal Surface Lesions

Histologically all the dentinal lesions on the occlusal surface appeared as shallow, broad and saucer shaped with no visible surface zone. The body of the lesion had a higher degree of positive birefringence than sound dentin and the advancing front was seen as a darkened line (Figure 1a). The depths of the lesions at their midpoint was measured on the occlusal surface (Table 1). No particular pattern could be seen. Teeth treated with 100ppm F had the deepest lesions. No statistical differences were found between the control teeth and the fluoride treated teeth with regard to depth of the artificial caries-like lesions.

Histologically the body of the lesion had areas of increased density within the lesion (Figure 2a, 3a). It was presumed that these were bands of remineralization within the lesion. The width of these bands was measured and are shown in Table 2. The width of the bands seem to show a dose response to the fluoride concentrations with the smallest band in the control lesion and the widest bands in the lesion of the teeth which were treated with 1000 ppm. Statistically, the bands in the lesions of the control teeth were narrower than in all the other teeth and those teeth treated with 1000 ppm F were also significantly different from all the rest of the teeth except those treated with 500 ppm F.

The width of the bands were also measured in the MRG's (Figure 1b, 2b, 3b) and the results are shown in Table 3. The results are very similar to those measured in the standardized photographs taken with polarized light. The same dose response to fluoride concentration was found in the MRG evaluations.

Selected microradiographs were evaluated using the bioquant system. The densiometric recordings confirmed that the bands were zones of mineralization and that bands existed within the lesions.

Root Surface Lesions

The demarcation between cementum and dentin could easily be seen with polarized light on the root surface of those teeth which still retained some cementum. The root surface lesions were broad and flat and saucer shaped with no visible surface zone when viewed with polarized light. The depth of the lesion was quite shallow and difficult to measure so no data for root surfaces are presented in this paper.

DISCUSSION

The studies of Stamm et al. 1990 have shown that fluoride does play a significant role in protecting the root surface from caries in adults. These studies were carried out on adult lifelong residents of naturally fluoridated communities. The question we are asking in this study is what concentration of fluoride is the most effective for topical use on overdenture abutments.

It was interesting that in 10 days the lesions seen on the occlusal were well developed, whereas those on the root surfaces were very shallow. An explanation for this finding could be that the root surface has some natural protection from being exposed to the oral environment, whereas the cut dentin on the occlusal has open tubules which allow acid penetration. Previous studies in our laboratory (Ettinger et al. 1988) have shown that lesions on the occlusal surface tended to be deeper than those on the root surface. It also has been shown that gels with a high concentration of fluoride were more protective on the occlusal surface than on the root surface when used in an in vitro system. The clinical consequences of this finding may be that the treatment/preventive modality for the cut dentin surface may need to be different to that for exposed root surfaces as the root surfaces seem to be less susceptible to acid penetration.

It was found that the lesion depths were not significantly different from one another after 10 days of cycling. An explanation for this result could be that lesion depth appears to be controlled by the acidity of the demineralizing solution. In a future study we plan to vary the ph of the demineralizing solution to evaluate this hypothesis.

Although the lesions did not vary significantly in depth, the width of the bands within the body of the lesions did show significant change (Table 2, 3). This banding which has been described by Phankosol et al. (1985) seems to be associated with the presence of calcium, phosphate, and fluoride ions. The width of the bands within the artifical lesions in this study were dependent on the concentration of fluoride used topically. The densiometric measurements verified that these bands were in fact multiple bands of mineralized tissue.

The results of this study suggest that the higher concentrations of fluoride were more effective in remineralizing lesions in dentin. The best regimen for the use of fluoride still needs to be determined as well as the optimum concentration. The mechanism of delivery clinically also needs to be determined.

CONCLUSIONS

1. The lesions on the root surface after 10 days were so small that it was difficult to measure their depth.
2. The mean depth of the lesions on the occlusal surface were similar to one another, however, the lesions treated with 100 ppm were the deepest.
3. Bands were seen within the body of the lesions
   a. The width of the remineralized bands within these lesions showed a dose response sensitivity to Fluoride concentrations.
   b. A significant increase in width of the bands in all groups was found when compared to the control specimens.

TABLE 1

MEAN DEPTH OF LESIONS ON THE OCCLUSAL SURFACE
OF THE OVERDENTURE ABUTMENTS AT THE MIDPOINT

DUNCAN'S MULTIPLE RANGE TEST

ALPHA = 0.05 DF = 45 MSE = 333.2

Grouping	$\bar{x} \pm SD$ μm	N	Treatment
A*	101 ± 13	10	100 ppm F^-
A	100 ± 30	10	1000 ppm F^-
A	93 ± 19	10	250 ppm F^-
A	89 ± 8	10	Control
A	88 ± 14	10	500 ppm F^-

*Means with the same letter are not significantly different from one another.

TABLE 2

MEAN WIDTH OF THE BANDS IN THE OCCLUSAL SURFACE LESIONS from the PLM

DUNCAN'S MULTIPLE RANGE TEST

ALPHA = 0.05 DF = 45 MSE = 116.5

Grouping	$\bar{x} \pm SD$ μ m	N	Treatment
A*	49 ± 22	10	1000 ppm F^-
B	41 ± 4	10	500 ppm F^-
B	38 ± 7	10	100 ppm F^-
B	35 ± 4	10	250 ppm F^-
C	19 ± 4	10	Control

*Mean with the same letter are significantly different from one another.

TABLE 3

MEAN WIDTH OF BANDS IN THE OCCLUSAL SURFACE LESIONS FROM THE MRG

DUNCAN'S MULTIPLE RANGE TEST

ALPHA = 0.05 DF = 43 MSE = 63.6

Grouping	$\bar{x} \pm SD$ μ m	N	Treatment
A*	52 ± 14	10	1000 ppm F^-
B	42 ± 7	10	500 ppm F^-
B	36 ± 6	10	250 ppm F^-
B	34 ± 4	8	100 ppm F^-
C	14 ± 3	10	Control

*Means with the same letter are not significantly different from one another.

FIGURE LEGENDS

Figure 1a — Photomicrograph of an undecalcified ground section after imbibition in disitilled water showing a lesion in the occlusal dentin after 10 days of cycling in a de and remineralizing solution. This was a control specimen photographed on a polarizing microscope. In the body of the lesion a thin band of increased density can be seen.

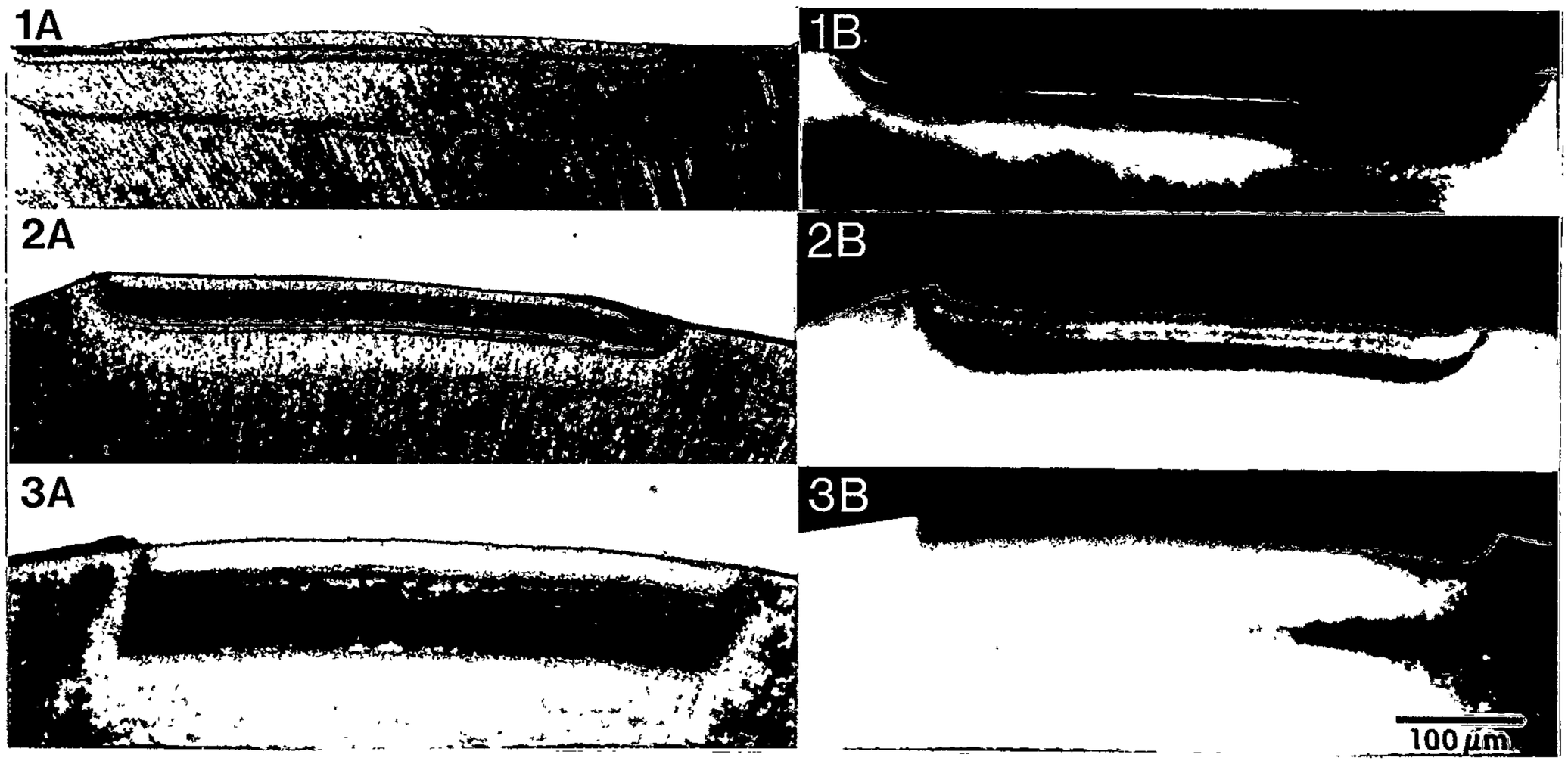
Figure 1b — Microradiograph of the same undecalcified ground section showing a thin band of increased density within the body of the lesion.

Figure 2a — Photomicrograph of an undecalcified ground section showing a lesion in the occlusal dentin. This specimen has been treated topically with 100 ppm F daily during 10 days of cycling.

Figure 2b — Microradiograph of the same undecalcified ground section showing the bands of increased density within the body of lesion.

Figure 3a — Photomicrograph of an undecalcified ground section showing a lesion in the occlusal dentin. This specimen has been treated with 1,000 ppmF daily during 10 days of cycling.

Figure 3b — Microradiograph of the same undecalcified ground section showing the thick band of increased density within the body of the lesion.


1A
1B
2A
2B
3A
3B
100 µm

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THE UNIVERSITY OF SYDNEY

DEPARTMENT OF PROSTHETIC DENTISTRY

2 CHALMERS STREET
SYDNEY
NSW 2010
AUSTRALIA

Tel : (02) 282-0490
Fax : (02) 211-5912

Sybille K Lechner, MDS, FRACDS
Senior Lecturer and Associate Dean
(Curriculum)

Professor R. L. Ettinger
College of Dentistry
Dows Institute for Dental Research
University of Iowa
Iowa City,
Iowa 52242
USA
Fax 0011-1-319-335-~~7385~~ 8895

15.3.93

Dear Ron,

I was absolutely delighted to get the copy of your thesis. I am well aware of just how precious such a tome is. I shall treasure it (and its very flattering inscription) in a befitting manner. It also, of course, makes highly interesting reading. I begin to understand what the examiners were on about when they praised it so highly. Thank you very much.

The partial denture manual is on its way. After a small hiccup, it seems that it will, after all, be Lechner and Mac Gregor. Thank you for firming my back on that subject, and also for your sound advice re "saddles". We now refer exclusively to distal extension bases or edentulous areas. I got into a terrible mess with my computer over that. I told it to change all the DES into DEB. But I forgot to space before and after, and ended up with a text full of shadeb, sideb and other such weird words. Obviously, with computers, as with everything else, a little knowledge is a huge hassle!

All the best to you, Sonya and your gorgeous kids. Come back for another visit soon,

Lots of love

Syb