A Review of Longitudinal Studies That Compared Periodontal Therapies
Wayne B. Kaldahl,* Kenneth L. Kalkwarf,† and Kashinath D. Patil* 

There have been numerous longitudinal periodontal studies that have compared the effects of two or more therapies on various clinical parameters. These studies are reviewed and their results are compiled. Both surgical and non-surgical therapy produced improvement in periodontal health. Surgical therapy tended to create greater short-term probing depth reduction than non-surgical therapy; however, the advantage was lost in some studies over time. In shallow probing depths, surgery produced a greater loss of probing attachment than non-surgical therapy. In deeper probing sites, the short-term results comparing mean probing attachment change following non-surgical and surgical therapy were mixed. In most studies, no long-term differences in mean probing attachment level change were present between non-surgical and surgical therapy. There were no differences between surgical and non-surgical therapy in any of the gingival inflammatory indices. J Periodontol 1993; 64:243-253.

Key Words: Follow-up studies; periodontal diseases/surgery; periodontal diseases/therapy.

Longitudinal studies have documented not only the immediate, but also the long-term clinical results following several types of periodontal therapy. Treatment methods have been compared by their therapeutic effects on the clinical parameters traditionally utilized in periodontal evaluation. These parameters have included probing depth, probing attachment level, gingival recession, inflammatory indices (gingival index, Ramfjord periodontal index, bleeding upon probing, presence of suppuration), plaque accumulation, tooth mobility, and molar furcation involvement. Most studies have attempted to collect initial clinical measurements in a standardized method. The therapies to be evaluated have then been performed with subsequent supportive care of varying duration. Clinical data collection has occurred at varying periods post-therapy and during maintenance. This paper reviews the longitudinal studies that have compared two or more therapeutic approaches within their experimental design. For the sake of simplification, the studies are often identified by their geographic location. Also a compilation of the studies grouped by their reported therapeutic effects on each clinical parameter is included.

REVIEW
Ramfjord and coworkers1 were the first to prospectively compare and report the longitudinal clinical results following various periodontal therapy modalities on a large group of patients over an extended period of time. Their work began to focus the profession on the long-term rather than the short-term results of treatment. Two groups of patients were initially treated in their first study. One group received gingival curettage and the other received pocket elimination surgery (gingivectomy or flap with osseous resectional surgery). After 2 years, the study format changed to a split mouth design, with two or more therapies performed in different regions of each subject’s mouth. This approach reduced the biological variability inherent in other study designs. Most subsequent investigators have followed this split mouth format.

Michigan Studies
The Michigan Study I reported data from a subset of patients and compared the response following gingival curettage to that following pocket elimination surgery.1,2 Later, the Michigan Study II reported data from patients treated in a split mouth design with gingival curettage, pocket elimination surgery, and modified Widman surgery.3 This second report included some of the patients treated in the Michigan Study I. The final report of the Michigan Study II included 72 patients who had completed 5 years of maintenance care and 43 patients who had completed 8 years.4 Periodontal sites were grouped for analyses according to severity of periodontal involvement as defined by the initial probing depth. The results of therapy related to tooth types were also reported.5 The therapeutic impact of initial non-surgical instrumentation (Phase 1 therapy) on the clinical
parameters was not separated from that of the surgical phase of therapy in Michigan Studies I and II.

The Michigan Study III used a split mouth design to compare root planing, gingival curettage, modified Widman surgery, and pocket elimination or reduction surgery. Initial therapy was performed and its effect on the clinical parameters was analyzed prior to the initiation of the surgical and maintenance phases. The first paper from the Michigan Study III reported results from 90 patients who had completed 2 years of maintenance care. Subsequent papers documented results from 72 patients following completion of 5 years of maintenance.

Swedish Studies
A group of longitudinal studies from Sweden compared several types of periodontal therapy. The Sweden Study I compared apically positioned flap with osseous resection, apically positioned flap without osseous resection, Widman flap with osseous resection, Widman flap without osseous resection, and gingivectomy. Five parallel groups of 10 patients each received one of the therapeutic modalities. Clinical sites around single rooted teeth and the mesial aspects of mandibular molars were evaluated. The surgical phase was followed by frequent maintenance therapy. Sweden Study I first reported results 2 years post-therapy with a subsequent report following 6 years of maintenance care. A similar parallel study was conducted with each of five patients receiving one of the above therapies and a 24-month follow-up. No professional maintenance therapy was provided.

The Sweden Study II included 15 patients who received root planing alone and root planing with modified Widman surgery in a split mouth design. The first papers from Sweden Study II reported results 2 years post-therapy, with a subsequent paper reporting the results from 11 patients who completed 5 years of maintenance.

The Sweden Study III involved 15 patients who received root planing, modified Widman surgery, and modified Kirkland flap surgery in a split mouth design. The cases were observed for one year. The role of granulation tissue in the healing response was determined by leaving it intact at some surgical sites.

The Sweden Studies IV and V compared root planing, gingivectomy, apically positioned flap, apically positioned flap with bone recontouring, modified Widman, and modified Widman with bone recontouring in a split mouth design. Clinical results were reported following a duration of 6 months. The first paper included results from 16 patients, and the second reported findings from 39 patients.

Washington Study
The Washington Study compared apically positioned flap surgery with and without osseous recontouring in a split mouth design. The first report from this study included results from 12 patients after 6 months of follow-up. A subsequent paper included findings from eight patients after 5 years of maintenance. The Washington Study went into great detail to define the osseous resection surgical technique used, since questions had been raised regarding the actual osseous surgical techniques performed in prior studies.

Minnesota Study
The Minnesota Study compared root planing and modified Widman surgery in a split mouth design on 17 patients. The results were reported 4 years following the completion of periodontal therapy, with a subsequent report of 10 patients following 6½ years of maintenance care. The clinical differences between the responses of molar and nonmolar teeth from the same study were also published following 6½ years of maintenance.

Denmark Study
The Denmark Study compared root planing, modified Widman surgery, and reverse bevel apically positioned flap surgery in 17 patients utilizing a split mouth design. Molars were not included in the evaluation. The initial paper from this study discussed results 6 months after therapy. A follow-up paper reported on 16 patients completing 5 years of maintenance.

Loma Linda Study
Several therapeutic studies have been reported from the Loma Linda group. Two studies compared therapies performed on designated isolated defects in a split mouth design. The first study compared results 6 months following flap surgery with and without partial osseous resection of 26 defects in 16 patients. Citric acid root treatment was utilized in conjunction with both procedures. The second study compared the results following root planing to those following flap surgery with citric acid root treatment in 50 defects from 14 patients. Results were reported 6 months and 5 years following therapy.

Three other studies from Loma Linda assessed findings from patients who initially performed only plaque control for varying periods (i.e., 1 to 8 months) and subsequently received root planing. These studies involved 7 to 16 patients each, included no molars, and were 13 to 24 months in duration. The effects of plaque control alone and the subsequent root planing were compared.

Arizona Study
The Arizona Study was undertaken in a private practice setting in part to dispel concerns regarding the relevance of longitudinal studies to a private practice situation. Sixteen patients were treated with initial therapy followed by root planing, modified Widman surgery, and flap with osseous resectional surgery in a split mouth design. Clinical results were reported following one year of maintenance.

Nebraska Study
The Nebraska Study compared coronal scaling (no subgingival instrumentation), root planing, modified
Widman surgery, and flap with osseous resectional surgery performed in a split mouth design. Vertical and horizontal probing attachment level changes in the furcation region of molars were also evaluated. Results were initially reported following 2 years of maintenance care on 75 patients.33-37

Other Studies
Three studies of short duration were published in the late 1970s comparing various types of therapy. Zamek38 compared gingival curettage, replaced flap surgery, apically positioned flap with osseous resectional surgery, and initial therapy alone. Thirty-nine patients were treated in a split mouth design and then followed for 4 months. Waite39 compared root planing and gingivectomy in a split mouth study involving 28 patients followed for 48 weeks. Aeschlimann et al.40 compared apically positioned flap surgery with and without osseous recontouring in a split mouth design involving 10 patients treated and followed for 4 months.

Payot et al.41 compared root planing, modified Widman surgery, flap with “smoothed bone and odontoplasty,” and no treatment in 38 lower molar furcations from 16 patients. Some patients had two therapies on individual molars while others had one therapy. Results were reported for up to 1 year follow-up.

Schroer et al.42 compared root planing in 12 facial Class II molar furcations and open flap debridement in 13 similar furcations that involved 15 patients. Surgical therapy was performed after 4 months of initial therapy and followed by a 12-month maintenance period.

Two short-term studies compared only plaque control and plaque control coupled with root planing in split mouth designs. One involved 12 patients followed for 25 weeks post-therapy with six of the patients receiving tetracycline therapy.43,44 In addition to the usual periodontal clinical parameters, microbiological assessment of the crevice and histological evaluation of the gingiva were completed. The second study evaluated data obtained from three designated sites in each of 22 patients during a 2-month period.45 Sites were shallow suprabony pockets and were evaluated histologically.

Most recent studies have grouped data according to the severity of the initial probing depth (i.e., 1 to 3 mm, 4 to 6 mm, and ≥7 mm) at each site. This approach captures the effects of therapy on comparable periodontal situations and allows for more accurate therapeutic documentation. Therapies have been contrasted by comparing 1) the mean changes of clinical parameters; 2) the frequency distributions of sites for a clinical parameter; or 3) the prevalence of a parameter.

Numerous other studies have documented the successful effects of a particular periodontal therapy longitudinally but did not include comparison to other therapeutic approaches. These studies have not been included in this review.

RESULTS
The following is a summary of studies grouped according to the effects compared for each clinical parameter. Presentation is grouped by short-term (≤1 year post-therapy) or long-term (≥5 years post-therapy) results.

Probing Depth
Table 1 summarizes the studies that compared non-surgical and surgical therapies according to probing depth reduction. “Non-surgical therapy” usually consisted of root planing but in some instances also included gingival curettage1-9,38 “Surgical therapy” included flap with or without osseous resection (i.e., modified Widman, flap with osseous resection, pocket elimination surgery, apically positioned flap, etc.). Several studies2-4,7,13,21,24,27,32,33,38,39 demonstrated that surgical therapy produced greater probing depth reduction than non-surgical therapy over the short-term. Some of the early differences diminished during long-term follow-up; however, some studies2,4,8,22,28 showed that the surgically treated sites retained greater probing depth reduction than did non-surgical sites.

Table 2 presents studies which compared probing depth reduction following flap with osseous resectional surgery and flap without osseous resectional surgery. The flap without osseous resectional surgery grouping included several clinical procedures (modified Widman surgery, flap curettage, apically positioned flaps, etc.). Some studies4,7,10,17,19,32 showed no differences during short-term follow-up, while others4,7,26,33,38,40 demonstrated that regions treated with osseous resection had greater reduction of probing depth. Only one study20 reported a significant difference between therapy groups following 5 years.

All studies which compared the effects of plaque control alone to the effects of root planing and plaque control on probing depth reduction reported similar results. Plaque control alone produced a slight decrease in probing depth, however, the addition of root planing resulted in much greater reduction.29-31,33,43,45

Probing Attachment Level
The effects of non-surgical and surgical therapy on probing attachment levels were compared in shallow sites (≤3 mm) by several studies. All studies reported similar results. Non-surgical therapy produced either no change or a slight loss of probing attachment while surgical therapy produced greater loss. This was true for studies of short2-4,7,13,16,18,21,32 and long duration.4,8,22

Table 3 presents the studies that compared the effects of non-surgical and surgical therapy on probing attachment level gain in initially deeper sites (≥4 mm). A few studies13,17,27 reported that surgery produced a greater probing attachment level gain during short-term follow-up, while a larger number of studies4,7,16-18,21,24,32,33,38,39 demonstrated that non-surgical therapy either produced greater gain or that no differences could be discerned. In the studies that showed surgery producing greater gain, the surgical mo-
A REVIEW OF LONGITUDINAL PERIODONTAL THERAPY STUDIES

Table 1. Probing Depth Reduction: Non-Surgical Versus Surgical Therapy

<table>
<thead>
<tr>
<th>Study</th>
<th>≤ 1 Year Duration</th>
<th>≥ 5 Years Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Surgery→ Greater ↓</td>
<td>No Differences</td>
</tr>
<tr>
<td>Michigan I</td>
<td>Ramfjord et al.²</td>
<td>Knowles et al.²</td>
</tr>
<tr>
<td>Michigan II</td>
<td>Knowles et al.² (1-6 mm)*</td>
<td>Knowles et al.² (≥7 mm)</td>
</tr>
<tr>
<td></td>
<td>Zamet²⁶ (FO &gt; RP, C)</td>
<td>Zamat²⁶ (C = MW)</td>
</tr>
<tr>
<td>Michigan III</td>
<td>Hill et al.⁷</td>
<td>Ramfjord et al.²</td>
</tr>
<tr>
<td>Minnesota I</td>
<td>Pihlstrom et al.²³ (≥4 mm)</td>
<td>Pihlstrom et al.²³ (1-3 mm)</td>
</tr>
<tr>
<td>Sweden II</td>
<td>Lindhe et al.¹³</td>
<td>Lindhe et al.¹³</td>
</tr>
<tr>
<td>Denmark</td>
<td>Isidor et al.²⁴</td>
<td>Isidor et al.²⁴</td>
</tr>
<tr>
<td>Sweden III</td>
<td>Renvert et al.²⁷</td>
<td>Renvert et al.²⁷</td>
</tr>
<tr>
<td>Sweden IV</td>
<td>Westfelt et al.¹⁷</td>
<td>Westfelt et al.¹⁷</td>
</tr>
<tr>
<td>Sweden V</td>
<td>Lindhe et al.¹⁸</td>
<td>Lindhe et al.¹⁸</td>
</tr>
<tr>
<td>Arizona</td>
<td>Becker et al.²²</td>
<td>Becker et al.²²</td>
</tr>
<tr>
<td>Nebraska</td>
<td>Kaldahl et al.²³</td>
<td>Kaldahl et al.²³</td>
</tr>
</tbody>
</table>

* Special situations regarding certain therapies or severity categories.

FO = Flap and osseous surgery.
RP = Root planing.
C = Curettage.
MW = Modified Widman flaps.

Studies that compared the effects of flap surgery with and without osseous resection on the probing attachment level are presented in Table 4. Some studies reported that sites treated with flap surgery without osseous resection had more short-term probing attachment level gain than sites treated with osseous resection, while others reported no difference. Two long-term studies demonstrated that flap surgery without osseous resection produced greater probing attachment level gain than flap surgery with osseous resection.

Several studies, all of short duration, compared the effect of plaque control alone to the effect of root planing and plaque control on probing attachment levels. All except one reported that either no differences existed between study groups or root planing produced greater probing attachment gain. A mean loss of probing attachment occurred at sites treated by plaque control alone in one study.
Table 3. Probing Attachment Level Gain: Non-Surgical vs. Surgical Therapy (in deeper sites, ≥ 4mm)

<table>
<thead>
<tr>
<th>Study</th>
<th>≤ 1 Year Duration</th>
<th>≥ 5 Years Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Surgery→ Greater Gain</td>
<td>Non-surgical→ Greater Gain (Less Loss)</td>
</tr>
<tr>
<td>Michigan I</td>
<td>Ramfjord et al.²</td>
<td>Knowles et al.⁴</td>
</tr>
<tr>
<td>Michigan II</td>
<td>Zamek²⁶</td>
<td>Waite²⁶</td>
</tr>
<tr>
<td>Michigan III</td>
<td>Hill et al.⁷ (4-6 mm)</td>
<td>Hill et al.⁷ (≥7 mm)</td>
</tr>
<tr>
<td>Minnesota</td>
<td>Pihlstrom et al.²¹</td>
<td>Pihlstrom et al.²¹ (≥7 mm)</td>
</tr>
<tr>
<td>Sweden II</td>
<td>Lindhe et al.¹³</td>
<td>Lindhe et al.¹⁶</td>
</tr>
<tr>
<td>Denmark</td>
<td>Isidor et al.²⁴</td>
<td>Lindhe et al.¹⁶</td>
</tr>
<tr>
<td>Sweden III</td>
<td>Lindhe et al.¹⁶</td>
<td>No Differences</td>
</tr>
<tr>
<td>Loma Linda</td>
<td>Rosling et al.¹⁰</td>
<td>Zamek³⁴</td>
</tr>
<tr>
<td>Sweden IV</td>
<td>Westfelt et al.¹⁷ (MW, ≥7 mm)</td>
<td>Westfelt et al.¹⁷</td>
</tr>
<tr>
<td>Sweden V</td>
<td>Lindhe et al.¹⁸</td>
<td>Becker et al.³²</td>
</tr>
<tr>
<td>Arizona</td>
<td>Kaldahl et al.³³ (RP&gt;FO, 5-6 mm)</td>
<td>Kaldahl et al.³³</td>
</tr>
</tbody>
</table>

FO = Flap and osseous surgery.
RP = Root planing.
C = Curettage.
MW = Modified Widman Flap.

Table 4. Probing Attachment Level Gain: Flap Surgery With Versus Without Osseous

<table>
<thead>
<tr>
<th>Study</th>
<th>≤ 1 Year Duration</th>
<th>≥ 5 Years Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No Osseous→ Greater Gain (Less Loss)</td>
<td>No Differences</td>
</tr>
<tr>
<td>Michigan II</td>
<td>Knowles et al.⁴</td>
<td>No Differences</td>
</tr>
<tr>
<td>Sweden I</td>
<td>Rosling et al.¹⁰</td>
<td>No Differences</td>
</tr>
<tr>
<td>Washington</td>
<td>Smith et al.¹⁹</td>
<td>No Differences</td>
</tr>
<tr>
<td>Michigan III</td>
<td>Hill et al.⁷</td>
<td>No Differences</td>
</tr>
<tr>
<td>Loma Linda</td>
<td>Chamberlain et al.²⁶</td>
<td>No Differences</td>
</tr>
<tr>
<td>Sweden IV</td>
<td>Westfelt et al.¹⁷</td>
<td>No Differences</td>
</tr>
<tr>
<td>Sweden V</td>
<td>Lindhe et al.¹⁸</td>
<td>No Differences</td>
</tr>
<tr>
<td>Arizona</td>
<td>Becker et al.³²</td>
<td>No Differences</td>
</tr>
<tr>
<td>Nebraska</td>
<td>Kaldahl et al.³³ (1-6 mm)</td>
<td>No Differences</td>
</tr>
</tbody>
</table>

Clinical Inflammatory State

Many studies compared the effects of non-surgical and surgical therapy on a clinical index representing the gingival inflammatory condition, i.e., bleeding on probing, gingival index (GI), or periodontal index (PI). Two short-term studies demonstrated that surgically treated sites had a lower GI than non-surgically treated sites.³⁸,³⁹ The remainder of the studies reported no difference between the results following non-surgical and surgical therapy, either short-term or long-term.¹³,¹⁶-¹⁸,²¹,²²,²³,²⁴,²⁵,²⁷,²⁸,³²,³⁵

All but two studies reported no difference in inflammatory indices between sites treated by flap with osseous re-
sectional surgery and those treated by flap without osseous resection.\textsuperscript{10,11,17,18,19,20,32,35} One of the two studies demonstrated that sites treated with osseous resectional surgery had a lower GI\textsuperscript{30} while the other demonstrated that sites treated with osseous resection had a higher GI.\textsuperscript{38}

When plaque control alone was compared to plaque control coupled with root planing, all studies reported that plaque control alone either produced no change\textsuperscript{29,31,43} or a minimal reduction in clinical inflammation.\textsuperscript{30,35,44,45} Root planing with plaque control produced a much greater reduction in the inflammatory indices in all studies.

One study compared the effects of non-surgical therapy and surgical therapy on the presence of gingival suppuration and found no difference.\textsuperscript{37} The same study found no differences in the amount of suppuration between sites treated by modified Widman surgery and sites treated by flap with osseous resectional surgery. When effects of plaque control alone and plaque control with root planing were compared, root planed sites exhibited less suppuration.\textsuperscript{37}

**Supragingival Plaque**

The amount of post-therapy supragingival plaque accumulation in areas treated by non-surgical and surgical therapy has been compared in several studies.\textsuperscript{13,16-18,21,22,24,25,32,37-39} There was no difference in the amount of plaque accumulation at either short-term or long-term follow-ups. The effect of flap surgery with or without osseous resection on plaque accumulation also has been compared. No short or long-term difference in accumulation following either therapy has been reported.\textsuperscript{10,11,17,18,19,20,32,37,38,40}

**Response at Specific Dental Sites**

A few longitudinal studies evaluated differences in the response to therapy by various types of teeth or by various locations around a tooth. Some studies compared molar teeth to nonmolar teeth regarding response to therapy and reported that molars had a less favorable response.\textsuperscript{5,13,23,36,46} The furcation regions of molars responded less favorably to therapy than nonfurcation regions (i.e., flat surfaces of molars or single rooted teeth).\textsuperscript{36,47,48} Subgingival microbiological shifts following root planing and plaque control were compared between furcation and nonfurcation sites. Furcation sites had a less favorable microbiological response.\textsuperscript{49} No therapy modality demonstrated relative superiority over another in the molar furcation region.\textsuperscript{34,36,41,42,50}

**DISCUSSION**

Over the last 2 decades the scientific community has devoted considerable attention to the design, plan, and execution of clinical investigations in order to obtain inference of maximum durability or credibility.\textsuperscript{51} Although many important guidelines have been developed to improve specific types of studies, it is well accepted that the best way to obtain durability is through a study type commonly referred to as a clinical trial. Recognizing that this desirable instrument is expensive and that not all clinical questions can be answered by a clinical trial, researchers have also given thought to the assessment of the validity of clinical studies. One of the strategies suggested is to assign a numerical score (somewhat arbitrary) to each of a number of desirable attributes for a study type under consideration, and use the summative scores for validity and comparison of investigations.\textsuperscript{32,52} Similarly, work has been done in an attempt to test hypotheses and to obtain an estimate of a "net effect" from several studies, called the meta-analysis.\textsuperscript{54} These two approaches are appropriate for the assessment of multiple studies that address a single question and follow a reasonably similar protocol. Is mouthwash xxx effective in removal of plaque? Does smoking tobacco predispose a patient to periodontal disease? Is aspirin treatment effective in preventing mortality in post-myocardial infarction patients? Such a single question is not addressed by a standardized protocol in the periodontal studies reviewed in this paper and thus these approaches cannot be utilized fruitfully in their assessment. Therefore these studies were individually reviewed with a compilation of their results.

However the studies were examined in relation to the considerations that are important in the conduct and reporting of clinical trials. These are: 1) reliability of measurement; 2) method of obtaining a sample; 3) reduction of biases; 4) considerations in data analysis, particularly the unit used; 5) choice of a control or a comparison group; and 6) appropriate sample size to give adequate power. Table 5 indicates the studies that incorporated these attributes of a clinical trial. An elaboration of these details follow.

The primary measures used to estimate the effect produced by the periodontal therapies addressed in these studies were the clinical parameters detailed in the Results section. No amount of otherwise careful planning and conduct of a study can overcome the damage done by obtaining insensitive and inappropriate measurements. In the absence of precise evaluating tools for subclinical disease, the measures used seem quite pertinent and the researchers utilized the then up-to-date instrumentation. The inherent error in obtaining a measurement can be assessed and reduced by implementing examiner calibration and reproducibility trials. However the impact of this error becomes negligible when two or more modalities are compared under the same measuring protocol.

Of all scientific investigations, clinical studies have the most likelihood to be biased (because these are done by human beings on human beings). There are almost infinite ways in which a bias can enter a clinical investigation, but there are two broad stages at which an investigator attempts to control for bias. Obtaining the sampling units by randomization provides reasonable protection against an assembly bias and also legitimizes application of many statistical procedures. Secondly, blindness ensures that the investi-
Table 5. Study Attributes of Each Trial

<table>
<thead>
<tr>
<th>Study</th>
<th>Number Patients (First/ Subsequent Reports)</th>
<th>Statistical Unit of Analysis</th>
<th>Randomization Listed</th>
<th>Measurement Calibration/ Reproducibility</th>
<th>Length of Study Follow-Up (First/ Subsequent Reports)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Michigan F</td>
<td>10 Patient</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>6 Yrs.</td>
</tr>
<tr>
<td>Michigan II 4</td>
<td>43 Patient</td>
<td>Yes</td>
<td>Yes</td>
<td>Not stated</td>
<td>8 Yrs.</td>
</tr>
<tr>
<td>Michigan III 9</td>
<td>90/72 Patient</td>
<td>Yes</td>
<td>Not stated</td>
<td>2/5 Yrs.</td>
<td></td>
</tr>
<tr>
<td>Sweden II 10 1</td>
<td>10 per tx Site</td>
<td>Yes</td>
<td>Yes</td>
<td>2/6 Yrs.</td>
<td></td>
</tr>
<tr>
<td>Sweden II 11 15</td>
<td>15 Site</td>
<td>Yes</td>
<td>Not stated</td>
<td>2/5 Yrs.</td>
<td></td>
</tr>
<tr>
<td>Sweden III 16</td>
<td>16 Site and patient</td>
<td>Yes</td>
<td>Not stated</td>
<td>1 Yr.</td>
<td></td>
</tr>
<tr>
<td>Sweden IV 17</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6 Mos.</td>
</tr>
<tr>
<td>Sweden V 18</td>
<td>39 Site</td>
<td></td>
<td>Not stated</td>
<td>6 Mos.</td>
<td></td>
</tr>
<tr>
<td>Washington 19 20</td>
<td>12/8 Patient</td>
<td>Yes</td>
<td>Yes</td>
<td>6 Mos./5 Yrs.</td>
<td></td>
</tr>
<tr>
<td>Minnesota 21 22</td>
<td>17/10 Patient</td>
<td>Yes</td>
<td>Yes</td>
<td>4 Yrs./6.5 Yrs.</td>
<td></td>
</tr>
<tr>
<td>Denmark 26 25</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6 Mos./5 Yrs.</td>
</tr>
<tr>
<td>Chamberlain et al 26</td>
<td>12-14 sites per tx Site</td>
<td></td>
<td>Not stated</td>
<td>6 Mos.</td>
<td></td>
</tr>
<tr>
<td>Renvert et al 27 28</td>
<td>25 sites per tx Patient</td>
<td></td>
<td>Not stated</td>
<td>6 Mos./5 Yrs.</td>
<td></td>
</tr>
<tr>
<td>Arizona 29</td>
<td>16 Patient</td>
<td>Yes</td>
<td>Yes</td>
<td>1 Yr.</td>
<td></td>
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<tr>
<td>Nebraska 30 31</td>
<td>75 Patient</td>
<td>Yes</td>
<td>Yes</td>
<td>2 Yrs.</td>
<td></td>
</tr>
<tr>
<td>Zemet 32</td>
<td>39 Not stated</td>
<td>Yes</td>
<td>Yes</td>
<td>4 Mos.</td>
<td></td>
</tr>
<tr>
<td>Waite 33</td>
<td>28 Not stated</td>
<td>Yes</td>
<td>Yes</td>
<td>11 Mos.</td>
<td></td>
</tr>
<tr>
<td>Aeschliman et al 34</td>
<td>10 Site</td>
<td>No</td>
<td>Yes</td>
<td>4 Mos.</td>
<td></td>
</tr>
<tr>
<td>Payot et al 35</td>
<td>11-16 teeth per tx Site</td>
<td>Not stated</td>
<td>Not stated</td>
<td>&lt; 1 Yr.</td>
<td></td>
</tr>
<tr>
<td>Schroer et al 36</td>
<td>12-13 sites per tx Patient</td>
<td>Yes</td>
<td>Yes</td>
<td>1 Yr.</td>
<td></td>
</tr>
<tr>
<td>Listgarten et al 41</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Helleden et al 42</td>
<td>12 Unclear Patient</td>
<td></td>
<td>Yes</td>
<td>6 Mos.</td>
<td></td>
</tr>
<tr>
<td>Tagge et al 43</td>
<td>22 sites per tx Patient</td>
<td></td>
<td>Not stated</td>
<td>2 Mos.</td>
<td></td>
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</table>

It is important to distinguish between a sampling unit and an analysis unit in statistical analysis because it has important bearing on the validity of the results. In periodontal studies the sampling unit is a patient and the observation unit may be a tooth or a measurement site. It has been reiterated many times in the periodontal literature\(^{55-57}\) that using a site (or tooth) as a unit of analysis will underestimate the standard error of the estimate of an effect, its level of significance, and overestimate the power. It has been further pointed out that because the sites in a mouth cannot be reasonably expected to exhibit independent behavior, the application of statistical procedures requiring this independence is not correct and it is more appropriate for the patient to be used as the unit of analysis in interval data.\(^{56,58}\) The inference needs to be examined in relation to this detail.

In repeated determinations of a variable, there is a tendency for the subsequent determinations to regress toward the mean of distribution of that variable. Thus, if one obtains an unusually large value (far away from the mean of the population) at a given point, an observation obtained at a later time will likely be less extreme and more toward the mean. This further implies that a change from a large value at one time to the next is more likely to be larger than the change from a less extreme value. This phenomenon is known as the regression towards the mean (RTM). It is evident that in longitudinal studies of treatment effects where repeated follow-up determinations are made on the same observational unit, one must guard against potential bias produced by RTM. It has been pointed out that one way to prevent RTM is to include a control or comparison group to make possible adjustments for the bias caused by RTM. In the studies under review RTM bias was reduced by comparing between treatments (split-mouth or intergroup comparisons).\(^{39}\)

Finally, because of the obvious importance of the number of sampling units on the attendant inference, the studies were contrasted in relation to this attribute. This aspect has been appropriately addressed in the literature.\(^{60,61}\) The larger the sample size, the higher will be the power of analysis.

This review summarizes longitudinal periodontal studies and groups them by their therapeutic effects on various clinical parameters. The studies did not have the same experimental design, the therapeutic protocols were not standardized between studies, and the methods of data collection varied. There were technical differences between therapies that were grouped together (i.e., flap surgery included modified Widman and apically positioned flaps; non-surgical therapy included root planing and gingival curettage). Despite these limitations, the studies contain important information which justifies compilation and summary.

The relative aggressiveness of the osseous resection procedures may explain why some studies reported greater probing depth reduction than others (Table 2). Only two studies\(^{19-33}\) attempted to define osseous resectional surgery...
to the endpoint of “positive osseous architecture.” Osseous resectional surgery often resulted in greater short-term reduction of probing depth than surgery without osseous resection. Generally, this was at the expense of probing attachment in adjacent, more shallow, sites.

Data from all studies demonstrated that periodontal surgery was detrimental in shallow sites (i.e., ≤ 3 mm). Surgical design (i.e., vertical releasing incisions) should avoid these areas if possible.

The longitudinal studies demonstrated that furcation regions of molars responded less favorably to periodontal therapy than non-furcated sites. This is supported by retrospective clinical studies from private practices which demonstrated that molar teeth with furcation involvement had a higher tooth mortality than other teeth. Yet it must be emphasized that periodontally involved molars warrant therapy, can be successfully treated, and continue to function long-term. This has been shown by the longitudinal trials as well as retrospective clinical studies.

Therapeutic modalities have often been evaluated by comparing their effect on the mean change (all sites averaged together) of a clinical parameter. When mean change of a parameter is obtained by averaging a large number of sites, the few sites that change in the direction opposite the mean change go undetected. Therapies have also been evaluated by comparing frequency distributions between two examination points. A frequency distribution is the percentage of sites in each category of measurement for a clinical parameter. Frequency distributions compared between two examination points may reflect a larger percentage of sites in an improved category at the second period; indicating an overall improvement. Some sites however may have worsened, moved to a less favorable category and go undetected. In an attempt to counter this situation a few studies reported frequency of change. Frequency of change separates the percentages of sites that have undergone specific increments of change, either positive or negative, during a time period.

Ramfjord et al. compared the frequency of change in probing attachment level between sites treated with gingival curettage, root planing, modified Widman surgery, and pocket reduction surgery. Two time periods were reported: 1) initial examination through fifth year of maintenance, including the net change during active therapy plus maintenance care; and 2) year 1 through year 5 of maintenance, including only change during the maintenance period. There was no appreciable difference between the percentages of sites losing probing attachment in any of the therapy groups during either time period. Isidor and Karring reported the percentages of sites that lost probing attachment following root planing, modified Widman surgery and reverse bevel apically positioned flap surgery through 5 years of maintenance. They found no difference between therapy groups. Lindhe et al. reported the frequency of change in probing attachment level for sites treated by root planing and sites treated with modified Widman surgery. The patients were also grouped according to plaque control status. No difference could be discerned between the percentages of sites losing probing attachment in either treatment group. In patients with poor plaque control, a higher percentage of sites treated by modified Widman lost probing attachment than sites treated with root planing.

Comparisons between the mean results of two or more therapeutic procedures demonstrate the probability that one therapy is superior to another. When there is no difference in the comparison of mean data, the probability is that one therapy will not produce a greater change than another. When the first therapy demonstrates a greater mean change than a second therapy, there is a probability that the first will create a greater change than the second. However, in specific individuals or at specific sites, the response may be different than expected for a given technique. The frequency of change provides the clinician with criteria to determine the incidence of sites that respond or fail to respond from that which is expected, based on the mean data.

There may be changes in clinical parameters: 1) following the initial, non-surgical phase of therapy; 2) following the surgical phase of therapy; and/or 3) during the maintenance phase. Sites may also improve during the first and/ or second phase of therapy and deteriorate during the maintenance phase. The question is whether a therapeutic approach produces an environment superior to another for long-term maintenance of probing attachment level. A review of the long-term studies indicates that no therapeutic modality resulted in an increased ability to maintain probing attachment during the maintenance period. However, to depict differences in probing attachment loss during maintenance between therapy groups is inherently difficult. The incidence of sites losing probing attachment in untreated periodontal disease is relatively small. Therefore, in order to discern differences between therapies, longitudinal studies need to be of sufficient duration to detect enough sites losing attachment.

In some studies, sites treated by the therapeutic approaches which produced greater mean probing attachment gain during the active phases also demonstrated greater loss during the earlier periods (1 to 2 years) of maintenance when compared to sites treated by therapies that produced less initial gain. However, later in maintenance, the rate of subsequent loss was the same. General loss of mean probing attachment occurred in other studies during the maintenance phase with no difference between therapy groups. This loss of probing attachment often did not totally eliminate the gain produced by active therapy. A few studies reported no mean loss during maintenance therapy.

The severity of periodontal destruction varied within the subjects in the longitudinal studies, not unlike patients in a private practice. With the recognition that sites with shallow probing depths respond differently to therapy than deeper sites, several studies analyzed sites by
grouping them according to their initial probing depth (i.e., 1 to 3 mm, 4 to 6 mm, ≥ 7 mm). Usually a larger number of sites were in the shallower categories. In studies that did not subdivide data by initial probing depth, the magnitude of response may have been affected by the more numerous shallow sites, therapy underestimating or diluting the response actually occurring in the deeper sites. In studies that did categorize by initial depth, the same concern applies to the deeper category (≥ 7 mm). Is the therapeutic effect observed in the more numerous 7 or 8 mm sites diluting that of the fewer ≥ 9 mm sites? A question remains as to the most appropriate therapy for deeper regions.

Therapeutic results and comparisons changed over time as evidenced by comparing the short- and long-term data in the few long-term studies. More clinical studies monitoring long-term results are needed.

When all the results of the periodontal longitudinal studies are considered, the logical therapeutic approach for a patient with periodontitis is: 1) non-surgical periodontal therapy; 2) evaluation after adequate time for patient’s plaque control improvement and potential resolution of the inflammatory response; 3) periodontal surgery to obtain access to remaining sites with an “active disease process” or to correct (regenerate) existing deep defects; and 4) supportive periodontal therapy (maintenance). This approach essentially agrees with the World Workshop observations. It must be recognized that some sites do not respond like the average. A clinical therapeutic procedure should be performed and reevaluated against an expected response. A response that is less than expected requires evaluation of other potential variables to determine the direction for future therapy.

SUMMARY
The following composite summary can be made of the longitudinal studies that have compared modes of periodontal therapy:

1. Surgical and non-surgical periodontal therapy produced general improvement in the periodontal clinical parameters.

2. Surgical therapy generally created greater short-term reduction of probing depth. Long-term results were mixed, with some studies reporting greater probing depth reduction following surgery and others reporting no differences.

3. Effects of flap surgery with and without osseous resection on probing depth showed mixed short-term results. Some studies reported that osseous resection produced greater probing depth reduction while others showed no difference. One long-term study reported that osseous resection produced greater probing reduction while the others showed no difference.

4. Surgery produced a greater loss of probing attachment in shallow sites, both short- and long-term. In sites with initially deeper probing depths, short-term results were mixed with a few studies reporting greater gain following surgery, others reporting greater gain following non-surgical therapy, and still others reporting no difference. Most long-term studies reported no difference in probing attachment change between non-surgical and surgical therapy.

5. When probing attachment levels following surgery with and without osseous resection were compared, either no difference was found between therapies or flap surgery without osseous resection produced greater gain both short and long-term.

6. There was no difference in the longitudinal maintenance of probing attachment level between sites treated nonsurgically and those treated surgically, with or without osseous resection.

7. There was no difference in inflammatory indices between sites treated with non-surgical therapy and any type of surgical therapy.

8. There was no difference in post-treatment supragingival plaque accumulation between sites treated with any of the therapeutic approaches reported.

9. When the effects of plaque control alone and plaque control with root planing were compared, root planing produced a superior response in the clinical parameters.

Acknowledgments
The authors wish to thank Penny Gardner, Dr. Robert Krejci, and Dr. Jeffrey Payne for help in the manuscript preparation.

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A REVIEW OF LONGITUDINAL PERIODONTAL THERAPY STUDIES


Send reprint requests to: Dr. Wayne B. Kaldahl, UNMC College of Dentistry, 40th and Holdrege, Lincoln, NE 68583-0740. Accepted for publication October 15, 1992.