CHAPTER 3. EXAMINATION AND DIAGNOSIS

Section 1. Periodontal Probing

The existence of a pocket implies a history of periodontal disease. While some visual signs of inflammation, such as redness and swelling, are helpful in detecting disease, they are not always present in conjunction with inflammation at the base of the pocket. Van der Velden (1980) noted that 4 to 5 weeks after scaling and root planing, most redness and swelling disappeared, although sites still bled when evaluated by the periodontal pocket bleeding index. Therefore, it is important to evaluate the bottom of the pocket as well as the visual signs of inflammation.

Listgarten (1993) emphasized correct terminology when describing periodontal probing in the literature and encouraged use of the terms proposed in the 1989 *Proceedings of the World Workshop in Clinical Periodontology* (American Academy of Periodontology, 1989). He discounted the term ''probing pocket depth,'' indicating that the true anatomic measurement of the pocket can only be accomplished histologically. ''Probing depth'' was suggested as a more correct term since it measures the depth of the pocket plus the inconsistent amount of connective tissue penetration. The term ''probing attachment level'' should be replaced by the more descriptive terms ''clinical attachment level" when the measurement is made from a fixed reference on the tooth (CEJ or restoration). ''Relative attachment level'' applies when the measurement is made from some other reference point (e.g., stent margin or occlusal tooth surface).

A number of variables exist that will affect probing depth measurements, and each must be considered when evaluating results. These variables include: probing reproducibility, probing force, probe angulation, status of gingival health, site location, local anatomy, and type of probe used.

PROBING REPRODUCIBILITY

Isidor et al. (1984) studied the reproducibility of measurements using a flexible splint, gentle pressure, and one examiner. Sixty percent (60%) of the measurements were in complete agreement between the first and second measurements before and after surgery. Ninety-five (95) of the surfaces differed by ≤ 1 mm or less and no measurement differed by ≥ 3 mm. Depth of the pocket and location of the probing site did not influence the measurements. Van der Velden and de Vries (1980), in a study involving 102 interproximal pockets in 7 periodontal patients, found no differences in reproducibility of measurements between a pressure-sensitive probe set at 0.75N and a Merritt B probe. Aeppli et al. (1985) examined inter- and intraexaminer reproducibility in terms of defining the effects of reproducibility on the sensitivity and specificity of different diagnostic thresholds for true change in probing depth. The mesio-facial surfaces of the Ramfjord teeth were measured in 15 patients by 3 examiners. With a threshold of probing depth increase > 1 mm, it was determined that an increase could be correctly diagnosed 91.3% of the time with a false-positive rate of 0.5%. A threshold of > 2 mm led to higher specificity, but with a great reduction in sensitivity.

Reproducibility and concomitant examiner error has been reduced with the advent of controlled force probes with computer interfaces such as the Florida probe (Magnusson et al., 1988) and Foster-Miller (Alabama) probe (Jeffcoat et al., 1986).

PROBING FORCE

Van der Velden and de Vries (1978) evaluated the effects of probing force on periodontal patients utilizing a pressure-sensitive probe with a tip diameter of 0.63 mm. The patients were free of clinical inflammation at the time of the measurements. Sites were probed at forces of 0.15N, 0.25N, 0.50N, and 0.75N. A positive relation between probing force and probing depth was observed. In a study using condemned teeth, Van der Velden (1979) evaluated the location of the tip of the probe with different probing forces. He reported that a force of 0.75N was in closest agreement with attachment level measurements. Chamberlain et al. (1985) also showed that forces of 0.75N were more reproducible, with the probe extending to the most coronal connective tissue (CT) attachment in health and disease. The authors suggested that one of the difficulties with understanding discrepancies with probing attachment levels in earlier studies may have been due to non-standardized probing forces. Mombelli et al. (1992) used a probe with a steel spring and strain gauges to provide a constant increase in probing force that could be diagrammed. The study indicated that higher probing forces will lead to more reproducible readings, but suggest that lighter forces could detect more subtle changes in attachment levels. Freed et al. (1983) studied different probing forces used by dental care providers based on levels of expertise (periodontists, general dentists, hygienists, and students). Probing forces ranged from 5 to 135 grams with no significant differences between any of the examiner groups, although periodontists and hygienists tended to probe with less force than general dentists and students. Probing force was found to be significantly greater in posterior segments than in anterior segments. In addition to large interexaminer differences, intraexaminer variability was also large, with a mean range of 44 grams.

PROBE ANGULATION

Persson (1991) compared line-angle measurements to midproximal measurements in untreated sites and found that the mean probing measurement was 1 mm greater with midproximal measurements than with line-angle measurements. This implies that clinical and epidemiological studies using line-angle measurements may underestimate pocket depth and the true level of disease.

The gingival sulcus is histologically or anatomically defined as the distance from the gingival margin to the coronal end of the junctional epithelium to the coronal end of the junctional epithelium (JE) (Listgarten, 1972). However, the ability of the periodontal probe to accurately measure this distance has been questioned by several studies in which the position of the probe tip was evaluated in healthy and diseased tissues. In a study of beagle dogs, Armitage et al. (1977) found that the probe failed to reach the apical termination of the JE in healthy specimens, but extended beyond the most apical cells of the junctional epithelium in periodontal specimens. Human studies such as that by Sivertson and Burgett (1976) indicated that the periodontal probe routinely penetrated to the coronal level of the connective tissue attachment of untreated periodontal pockets. Listgarten et al. (1976) observed that the most common position of the probe tip during routine measurements of periodontal pocket depth was at the coronal portion of the JE. Saglie et al. (1975) noted that probing depths measured in the laboratory were always less deep than those recorded clinically. The authors attributed this to the presence of a zone of completely and partially destructed periodontal fibers which allowed the probe to extend apically to the coronal level of connective tissue attachment. These studies have shown that periodontal probes do not precisely measure and often overestimate the true histologic sulcus, and that inflammation has a significant influence on the degree of probe penetration.

STATUS OF GINGIVAL HEALTH

Glavind and Löe (1967) observed that non-standardized forces in healthy tissue resulted in variations in probing depths of 1 mm compared to variations of over 2 mm in inflamed tissue. Robinson and Vitek (1979) showed a straight line correlation between GI scores and tissue penetration by the probe. Spray et al. (1978) suggested that the state of health of the underlying CT fibers influenced probing measurements, with the healthy fibers acting as a barrier and preventing apical movement of the instrument (the "hammock" effect). Caton et al. (1981) reported that inflamed CT offered less resistance to penetration and that with reduction of inflammation following initial therapy, a more accurate estimate of the sulcus depth resulted. Fowler et al. (1982) showed through histologic examination that in untreated teeth, the probe tip penetrated beyond the apical termination of the JE and into subjacent connective tissue by a mean of 0.45 mm, whereas in the treated specimens the probe tip stopped coronally to this landmark by a mean of 0.74 mm. These findings are in approximate agreement with earlier work (Magnusson and Listgarten, 1980) which reported 1.4 mm in probing attachment gain in treated sites.

Anderson et al. (1991) correlated the degree of clinical and histologic inflammation to probe tip penetration in dogs. A significant correlation was noted between probe tip penetration and amount of tissue inflammation adjacent to the probe. Correlations between gingival index and histologic inflammation and gingival index and, probe penetration were not significant. This suggests that probe penetration is more highly influenced by inflammation at the base of the pocket rather than marginal inflammation.

LOCAL ANATOMY

Crown contours, interproximal versus facial or lingual sites, narrow pockets, tipped or rotated teeth, heavy osseous ledges, and defective restorations and margins can affect probing accuracy. Moriarty et al. (1989) studied the vertical histologic probe position in untreated facial molar furcation sites. When vertical probing was carried out at the midfacial area of Class II and III furcations, the probe tip penetrated into interradicular connective tissue. The probe tip did not approximate tissue at the base of the pocket, but penetrated at various levels along the pocket wall. The authors suggest probing the root surface anterior to and posterior to the furcation entrance to more accurately reflect the true pocket depths at furcations.

TYPE OF PROBE USED

There are numerous types of probes with varying diameters. Some examples are: Michigan, Williams, Marquis (round probes); and Goldman-Fox, Dellich, and Nabers (flat probes). Errors in manufacturing of the probes can significantly affect measurements in clinical research settings. Van der Zee et al. (1991) evaluated the accuracy of probe markings in a variety of probes, noting that few probes coincided with the manufacturer's designated calibration. The tip diameters ranged from 0.28 mm for the Michigan "O" probe to 0.7 mm for Williams' probes. The widths of probe markings were important in that painted bands differed by as much as 0.7 mm. Etched bands had the most accurate width markings while etched grooves were nearly twice as inaccurate. Atassi et al. (1992) compared a parallel-sided probe to a tapered probe. The parallel-sided probe tended to yield deeper probing depths in deeper pockets suggesting that the tapered probe may tend to bind more within the pocket. However, the repeatability was similar for the tapered (81%) and parallel-sided (86%) probes. In addition, when the probe measurements were compared, 89% showed no difference in probing measurement.

STRENGTH OF THE EPITHELIAL ATTACHMENT

It is accepted that the probe cannot penetrate to the CT without damaging the epithelial attachment. However, the strength of the epithelial attachment and its ability to resist the probe is not known (De Waal et al., 1986).

RELATIONSHIP BETWEEN PROBING AND BONE LEVEL MEASUREMENTS

Isidor et al. (1984) evaluated transgingival probing measurements taken just prior to surgery and compared them to measurements taken immediately after flap reflection, utilizing a flexible stent to control probe angulation. Transgingival probing was identical to surgical measurements 60% of the time and within 1 mm of surgical measurements 90% of the time. Disagreement was never greater than 3 mm. Ursell (1989) studied the accuracy of probing with 30g or 60g force and vertical transgingival probing (> 100g force) as an estimate of open bone level measurements. Higher correlations were found with transgingival probing ($r = 0.98$) compared to measurements made at 30g ($r = 0.87$) and 60g ($r = 0.90$). A mean difference between measurements of 0.12 mm was found between transgingival probing and surgical measurements. Agreement between transgingival probing and surgical measurements was unaffected by tooth type, tooth surface, inflammation, or magnitude of bone loss. Correlations were higher for 30g and 60g measurements when inflammation was present. When sites with intrabony defects were considered, the correlation between transgingival probing and surgical measurements was $r = 0.79$ and the mean difference between measurements was 0.92 mm. Akesson et al. (1992) compared estimation of bone levels with bone sounding and periapical, bite-wing, and panoramic radiographs to open measurements. Bone sounding provided the best estimate of open bone level measurements. The percent underestimation was 5% for bone sounding, 13% (maxillary) to 14% (mandibular) for periapicals, 17% (maxillary) to 23% (mandibular) for bite-wings and 18% (maxillary) to 24% (mandibular) for panoramic radiographs. Percent image magnification was generally greater in the maxilla and was 8% for periapical films, 9% for bite-wings, and 25% for panoramic radiographs.

CRITICAL PROBING DEPTH

Lindhe et al. (1982) described the concept of critical probing depth (CPD), above which the result is gain of clinical attachment and below which a loss may occur. This CPD was shown to vary depending on the type of therapy used, with scaling and root planing having a CPD of 2.9 mm and modified Widman flap surgery having a CPD of 4.2 mm. Westfelt et al. (1983) evaluated the significance of frequently repeated recall appointments on CPD in 24 patients following modified Widman surgery. The CPD values after 6 months of maintenance every 2, 4, or 12 weeks were 4.4, 4.9, and 5.4 mm respectively. CPD values for plaque-free sites were lower than for plaque-containing areas and did not differ among the recall groups. Lingual surfaces had lower CPD values than other surfaces, and molar areas had higher CPD values than non-molar teeth. Another factor affecting the CPD may be the surrounding environment of the tooth. Leveling is a theory suggesting that a physiologic response takes place to maintain the same level of anatomical attachment throughout a given area. When healthy areas which are adjacent to pathologically deepened sites are disturbed, one may see leveling, or the loss of attachment in the "healthy" sites and gain of attachment in the deepened sites.

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Section 2. Tooth Mobility

DEFINITIONS

Fremitis: A palpable or visible movement of a tooth when subjected to occlusal forces.

Tooth Mobility: The degree of looseness of a tooth beyond physiologic movement.

MEASUREMENT OF TOOTH MOBILITY

The most commonly used clinical index for mobility is the Miller Index (Miller, 1950). Mobility is detected by using an instrument (e.g., mirror handle) on either side of the tooth and applying force. Using this index, mobility is scored as follows:

1 = first distinguishable sign of movement greater than "normal;"

2 = movement of the crown up to 1 mm in any direction; and

3 = movement of the crown more than 1 mm in any direction and/or vertical depression or rotation of the crown in its socket.

Instruments that have been used to measure and study tooth mobility include the macroperiodontometer, microperiodontometer, and the Periotest. The macroperiodontometer was developed by Muhlemann (1954); however, its application was limited to the anterior teeth and premolars.

The microperiodontometer was developed by O'Leary and Rudd (1963) and proved to be useful in measuring mobility in all of the teeth. Due to the time required to obtain mobility measurements with these instruments, use was essentially limited to research.

More recently, the Periotest has provided an objective means of assessing tooth mobility. The instrument is compact, resembling a dental handpiece, and has an electromagnetically retracting tapping head. The tapping head has a preset constant speed of 0.2 meters per second, and the contact time with the tooth varies from 0.3 to 0.2 milliseconds. Contact time upon impact is less in teeth whose damping by the periodontium is greater (more support), and is therefore less mobile. A strong association between the Periotest value and bone loss has been reported (Shulte et al., 1992). The Periotest has also been suggested as a means of objectively quantifying bone apposition around dental implants (Teerlinck et al., 1991).

DYNAMICS OF TOOTH MOBILITY

The periodontal ligament (PDL) surrounds the roots of the teeth and acts as a shock absorber to some extent. Collagen fibers constitute 50% to 75% of the PDL volume with the oblique fibers predominating (Weatherford, 1977). Tooth mobility seems to occur in two stages (See Weatherford, 1977, for review). First, there is an initial or intravascular stage where movement within the socket is associated with redistribution of the fluids, interstitial contents, and fibers. The second stage occurs gradually and includes elastic deformation of the alveolar bone proper in response to increased forces (Muhlemann, 1967).

TYPES OF MOBILITY

Physiologic mobility is movement that occurs with normal function (100 to 150g). It will vary from tooth-to-tooth and day-to-day and has been defined as movement up to 0.2 mm horizontally and 0.02 mm axially (Weatherford, 1977).

Pathologic mobility may be 10-fold that of "physiologic mobility" and is associated with damage to the PDL initiated by injury to the collagen fibers and associated loss of osseous support. Fremitus is a palpable or visible movement of a tooth when subjected to occlusal forces. Perlitsh (1980) described a "critical mass" of alveolar bone support. He speculates that if < 50% of the total root length remains surrounded by alveolar bone, zones of injury from excessive occlusal forces are irreversible and may involve the entire PDL space. Conversely, alveolar bone support greater than the "critical mass" provides healthy tissue for repair and changes are reversible. The critical mass for molars is located more coronal due to the complications of the furcations. This is an interesting concept and may be useful in assessing the prognosis of periodontally affected teeth.

CLINICAL IMPLICATIONS OF TOOTH MOBILITY

Ericsson and Lindhe (1984) subjected dogs to excessive jiggling forces (healthy periodontium) and found increased mobility due to loss of bone volume but no loss of CT attachment (physiologic adaptation). When an experimental periodontitis was initiated, no additional loss of attachment was seen compared to control sides. The authors concluded that the permanently increased mobility had no influence on the development of periodontitis.

Perrier and Polson (1982) induced an experimental periodontitis in squirrel monkeys; 10 weeks later, jiggling trauma was imposed for 10 weeks in the presence of good plaque control. Results showed that occlusal trauma in a reduced periodontium caused no additional attachment loss or bone height loss if inflammation was controlled by effective plaque control. However, additional loss of bone volume was seen.

Fleszar et al. (1980) examined the relationship between tooth mobility and clinical responses to periodontal therapy in the Michigan longitudinal studies. The authors reported that shallow sites lost attachment over time but that initially mobile teeth tended to lose more attachment. The 4 to 6 mm sites that were non-mobile initially gained attachment while the 4 to 6 mm sites with 2 and 3 degrees mobility lost some attachment by the second year. All teeth with deep pockets (7 to 12 mm) gained attachment following treatment but mobile teeth (2 and 3 degrees mobility) did not gain attachment.

Kerry et al. (1982) examined changes in mobility over time after 4 modes of periodontal therapy. The authors found that abnormal mobilities tended to decrease following the hygienic phase of therapy. Modified Widman flap therapy, scaling and root planing, and curettage had no influence on further mobility while pocket elimination therapy increased mobility after surgery, decreasing to presurgical levels after 1 year.

Muhlemann and Rateitschak (1957) examined changes in mobility patterns following selective grinding. Teeth in hypofunction were 30% more mobile than those in hyperfunction. Teeth in hypofunction had a decreased width of the PDL; the fibers become less well-arranged and are aligned more parallel to the root (non-functional arrangement). After selective grinding, teeth in both hypofunction and hyperfunction became less mobile; these observations were interpreted by the authors as improvement in periodontal health.

Gillespie and Chasens (1979) showed that supracrestal fibers do not provide support for a healthy premolar; however, as the amount of bone loss increases and the support decreases, the significance of the support offered by the supracrestal fibers increases.

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Section 3. Radiographic Interpretation

Limitations of Radiographs

Radiographs do not: 1) show periodontal pockets; 2) distinguish between successfully treated and untreated cases; 3) record morphology of bony defects; 4) show structures on buccal, lingual, and labial aspects of tooth; 5) show soft-to-hard tissue relationships; or 6) record tooth mobility (Prichard, 1983).

BENEFITS OF RADIOGRAPHS

Radiographs effectively accomplish the following: 1) record (with correct technique) position of septal bone on the tooth in one plane; 2) serve as an adjunct to the clinical exam but cannot offer conclusive evidence alone; 3) record the alveolar bone, alveolar process, and PDL on mesial, distal, and apical aspects of the root in a single plane; 4) document clinical-crown-to-clinical-root ratio; and 5) allow observation of dense deposits of calculus and metallic restorative margins on proximal tooth surfaces (Prichard, 1983).

INTREPRETATION OF RADIOGRAPHS

Interdental Septa

In the absence of periodontal disease, the configurations of the crests of the interdental septa are determined by relative positions of the cemento-enamel junction (CEJ). When periodontal disease is present, alterations in interdental septa are governed principally by specific pathologic processes. The shape and size of crowns of the teeth, state of eruption, and position of teeth can influence septal contour. If approximating tooth surfaces are relatively flat, septa will be more narrow and pointed. If mesial and distal tooth surfaces are extremely convex, interdental septa will be wide with flat crests. The greater the buccal-lingual dimension of the teeth, the greater the width of the interdental bone. If there is a difference in length of the crowns of adjoining teeth whose occlusal surfaces are in the same plane, the crest will slant upward from the CEJ of the long crown toward the CEJ of the short crown. Any inclination of long axis of the teeth results in a difference in the levels of the mesial and distal CEJs and produces oblique alveolar crests. Assuming mesial and distal contacts between the teeth, there is no correlation between occlusal disharmonies and the radiographic appearance of the crests (Ritchey and Orban, 1953).

Lamina Dura

Using 17 autopsy specimens, Manson (1963) found that the appearance of the lamina dura is determined as much by shape and position of the tooth root in relation to the x-ray beam as by the integrity of this plate of bone. Using microradiographs, he also noted that the bone comprising the socket wall (cribriform plate) has the same mineral content as adjacent bone. The author was able to produce a pseudo-lamina dura as an artifact and concluded that critical interpretation of the integrity of the lamina dura should be avoided. Greenstein et al. (1981) studied the relationship of the crestal lamina dura to clinical parameters in 90 subjects. They reported no correlation between clinical parameters of bleeding pockets or attachment loss and the presence or absence of crestal lamina dura. The authors recommended caution when using the integrity of the crestal lamina dura as an indicator for diagnosis of periodontal disease and predictor of therapeutic needs.

Osseous Defects

Bender and Seltzer (1961), using human mandibles obtained at autopsy, compared artificially-created periodontal and periapical lesions clinically and radiographically. They reported that lesions could not be observed on radiographs as long as they were confined in cancellous structures. However, if lesions encroached on the cancellous-cortical junctions, they were visible. If the inner surface of the cortex was eroded further, the area became even more discernible. Ramadan and Mitchell (1962) reported that: 1) minor destructive changes in the alveolar crest could not be detected by x-ray; 2) destruction of the buccal plate could not be distinguished from destruction of the lingual plate; 3) funnel-shaped defects with intact buccal and lingual plates could not be detected; 4) the long-cone paralleling technique is the most reliable for obtaining acceptable images; 5) removal of the entire buccal and lingual plate did not affect the trabecular pattern; 6) bone destruction caused by abscesses is not seen if it is superimposed by roots; and 7) both junctional and central core of trabecular bone must be removed to affect radiographic architecture.

Rees et al. (1971) examined the radiographic appearance of alveolar osseous defects in dry skulls to determine the predictability of diagnosing the defects on the basis of radiographic appearance. They found that proximal osseous defects and furcation defects on the facial and lingual surfaces of multi-rooted teeth can be identified with a high degree of accuracy based on their radiographic appearances. Conversely, lesions on the facial or lingual root surfaces are extremely difficult to recognize radiographically. These studies indicate that although radiographs are valuable adjuncts, clinical and radiographic findings must be correlated in order to facilitate a correct diagnosis.

Periodontal Ligament (PDL)

Using an artificial model, Van der Linden and Van Aken (1970) reported that the same width of the PDL can be interpreted as being different when the radius of circumference is different, exposure time is changed, or when kilovoltage is changed. The number of PDL projections depends upon the width and depth of root concavity and the thickness of the PDL projections depends upon the width and depth of root concavity and the thickness of the PDL, as well as horizontal angulation of the x-ray beam. The marginal aspect of the PDL in the radiograph varies significantly with the horizontal angulation of the x-ray beam and may lead to a subjective widening or complete loss of the PDL.

Healing

In periodontitis, increased radiolucency and cupped-out appearance of alveolar crests are noted on the radiograph. The cortical layer has been destroyed and underlying marrow spaces have been exposed and enlarged, decreasing the density. After treatment, the marrow spaces become smaller and new cortical bone is laid down, increasing the density. This increased density can lead to the misinterpretation of coronal bone regeneration when, in reality, it is only an increase in quality of bone (Friedman, 1958).

Normal level of crestal alveolar bone: Hausman et al. (1991) evaluated 13- to 14-year-old children to determine the average distance of the CEJ to alveolar bone. They found the average distance was 0.4 to 1.9 mm (mean 1.1

mm) and suggested that this distance increases with age as a result of continuous eruption. Goodson et al. (1984) examined the relationship between changes detected on radiographs and changes in clinical attachment levels using standardized radiographs. They examined 231 sites and observed that clinical attachment loss precedes visual radiographic changes by 6 to 8 months and, in all cases, clinical attachment changes were greater than observed radiographic changes. Radiographic change was not always detected in sites exhibiting clinical attachment change. The authors stated that radiographic changes may have been detected sooner if subtracted images had been used.

XERORADIOGRAPHY

Xeroradiography is a diagnostic x-ray imaging system which uses the xerographic copying process to record x-ray images. Xeroradiographic images (XIs) differ from conventional images, having greater exposure, latitude, and a property termed ''edge enhancement'' by which fine structures (bone, trabeculae, etc.) and areas of subtle density differences (gingiva, etc.) are visually enhanced. Conventional dental x-ray units can be used to produce high-quality dental XIs at significantly reduced radiation levels. In a human study with 96 patients, similar x-ray projections were made with conventional film and experimental dental xeroradiographs. Resultant images were compared visually and, in all categories (gingival soft tissues, calculus deposits, osseous tissues), information provided by XIs was equal to or greater than conventional radiographs. The authors found dental xeroradiographs to be a highly accurate, low in radiation, rapid, and convenient alternative to conventional intra-oral radiography. There have been, however, numerous technical difficulties with the processing equipment which have limited its use (Gratt et al., 1980).

SUBTRACTION RADIOGRAPHY

Subtraction radiography is a technique which uses computer-assisted imaging to convert different densities recorded on a conventional x-ray film into digitized gray level images. The gray level images of a second film are superimposed over the first and differences subtracted. Two identical films would result in all gray levels being subtracted, leaving a blank image. Differences in bone density over time (gain or loss) would be recorded as different digitized gray levels with subtracted images reflecting gains or losses of density. The rationale for its use is based on the fact with conventional radiographs, more than 30% of the bone mass at the alveolar crest has to be lost (or gained) before it can be recognized. Subtraction radiography can detect changes in bone density as small as 5%. The sensitivity of subtraction to accurately detect changes in bone depends on radiographs with standardized geometry, allowing precise superimposition. If the radiographic images cannot be completely aligned, areas of differing gray levels (structured noise) may appear on the subtracted image, making it difficult to distinguish from gray level variations due to actual bone changes. This has been a major disadvantage of the technique to this point (Hausmann et al., 1985). In a review of radiographic techniques for clinical trials, Reddy (1992) noted that subtraction radiography gives precise information, the technique is time consuming and labor intensive, and advances have been made in subtraction radiography with the digitalization of images.

DIGITAL IMAGING

New computer and video technology has led to the development of digital subtraction radiography (DSR). Light intensity transmitted through a radiograph is measured at each picture element (pixel) by a video camera and converted into gray-level values. The digitized image is stored on a computer and displayed on a TV screen as a positive image. A subsequent radiograph is displayed as a negative image on the screen and aligned to the structures of the baseline image revealing differences in density between baseline and subsequent radiographs. Numerous studies using artificially-created bone defects in dry skulls, cadavers, and animals have determined the diagnostic accuracy of DSR (Braegger, 1988A, 1988B). Few studies have dealt with the naturally-occurring lesion. Hausmann et al. (1986) were able to demonstrate bone changes in 9% of sites in 9 of 15 patients with untreated periodontitis over 6 months using DSR. Braegger (1988A, 1988B) found that bone density changes assessed with computer-assisted densitometric image analysis (CADIA) correlated well with actual calcium loss. Braegger et al. (1987) also detected surgically-induced bone loss (crown lengthening or flap osteoplasty) with a sensitivity of 82% and specificity of 88% by means of CADIA. DSR (i.e., CADIA) enables smaller changes in alveolar bone density, undetectable by conventional radiography, to be detected and quantified. Deas et al. (1991) used CADIA to determine if changes in bone density could be an indicator of progression of periodontitis; 38.3% of the sites investigated lost radiographic density and only 6.1% of sites showed loss of attachment. The authors suggested there was a complex relationship between loss of attachment and changing bone densities and that progression of disease cannot be based solely on loss of bone density.

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Section 4. Mucogingival Considerations

The question of whether or not to treat areas diagnosed as having little or no attached gingiva has been a matter of controversy in the past several years. Prior to the 1980s, preventive soft tissue grafting of areas with minimal attached gingiva was the accepted routine. This was prompted by such studies as that by Lang and Löe in 1972. Using Schiller's stain to identify the mucogingival junction in patients with optimal oral health, these authors reported a correlation between the width of keratinized tissue and attached gingiva and periodontal health. While over 80% of the surfaces with ≥ 2 mm of keratinized tissue and ≥1 mm of attached gingiva were clinically healthy (76% had no gingival exudate), all surfaces with < 2 mm of keratinized gingiva and < 1 mm or more of attached gingiva exhibited clinical inflammation and varying amounts of gingival exudate. These findings suggested that gingival inflammation results at least in part from a movable gingival margin which facilitates the introduction of microorganisms into the sulcus. It was concluded that a width of keratinized tissue of 2 mm (with at least 1 mm being attached) is adequate to maintain gingival health.

Other studies, however, have not supported routine grafting of sites with minimal or no keratinized or attached gingiva. Ten unilateral and 6 contralateral study pairs of premolar teeth, each with one tooth having minimal keratinized gingiva ≤ 1 mm with no attached gingiva and the other having appreciable keratinized tissue (≥ 2 mm) were evaluated for gingival health (Miyasato et al., 1977). The 6 contralateral study pairs were observed over a 25-day period of experimental gingivitis (no oral hygiene). Sites with plaque or high frenum insertions were excluded from the study. No differences in gingival health were observed between sites with or without keratinized tissue. In addition, sites with minimal keratinized gingiva and no attached gingiva were no more prone to develop plaque-induced inflammatory changes than areas with attached gingiva and a greater zone of keratinized tissue.

Using beagle dogs, Wennstrom and Lindhe (1983) studied the effect of plaque at sites with or without attached gingiva and with varying heights of the attachment apparatus, over a 40-day period of experimental gingivitis (no oral hygiene). The results indicated that the inflammatory response to bacterial plaque accumulation is unrelated to the presence or absence of attached gingiva, or to the height of the supporting attachment apparatus. The authors concluded that a free gingival unit which is supported by loosely attached alveolar mucosa is no more susceptible to an inflammation than a free gingival unit which is supported by a wide zone of attached gingiva.

In a 1983 human study, Wennstrom examined the clinical response following the surgical removal of the entire zone of attached gingiva. He reported that gingival recession occurred only during the first 3 post-operative months and remained stable over the next 6 months independent of the presence or absence of attached gingiva or the width of keratinized tissue. Regardless of the presence or absence of attached gingiva, gingival units were without clinical signs of inflammation over the 9-month period.

Kisch et al. (1986) studied canines and premolars with no attached gingiva and mobility of the gingival margin over a 5-year period. The mucogingival margin was identified using Lugol's iodine solution. They failed to demonstrate that unattached and mobile facial gingival surfaces are more susceptible to periodontal breakdown than attached surfaces in subjects with good oral hygiene and clinically healthy gingiva.

In a 5-year longitudinal study, Wennstrom (1987) confirmed the observations from his 1983 studies. In patients maintaining good oral hygiene, the lack of an "adequate" zone of attached gingiva did not result in an increased incidence of soft tissue recession. The author hypothesized that a narrow zone of gingiva apical to a localized recession is a consequence rather than a cause of the recession.

In another longitudinal study, Kennedy et al. (1985) examined 32 patients over a 6-year maintenance period who had insufficient attached gingiva on one side and a free soft tissue graft on the other. In addition, 10 patients who had not maintained recall appointments were re-examined. Results indicated that both treated and untreated sites of all patients remained stable over the 6-year period. It was concluded that the free gingival graft is a predictable means of enhancing the zone of attached gingiva and, in time, results in creeping attachment. However, if plaque control is adequate, minimal to zero attached gingiva can be maintained in a state of health. It must be noted that control sites with little or no attached gingiva in the unmaintained patients had a 20% frequency of further recession (mean recession = 0.5 mm). This suggests at least some risk of recession in sites with little attached gingiva, whereas no recession was noted on teeth with wide zones of attached gingiva.

A 10-year longitudinal study of sites with minimal keratinized gingiva (< 2 mm of keratinized, but ≥ 1 mm of attached gingiva) in 18 dental students with good oral hygiene, minimal inflammation, and no restorations in the area of observation was completed (Freedman et al., 1992). It was observed that the majority of sites remained unchanged or had a slight increase in keratinized gingiva. It was concluded that in the absence of inflammation, areas with minimal keratinized gingiva remain stable over a long period of time.

Mucogingival considerations in restorative dentistry were addressed in a 1987 study by Stetler and Bissada. They compared the tissue response (GI) around teeth with and without subgingival margins in association with narrow (≤ 2 mm) or wide (≥ 2 mm) zones of keratinized gingiva. Higher GI scores were observed when subgingival margins of restorations were present in areas with a narrow zone of keratinized gingiva. The authors concluded that in the presence of subgingival margins, a greater inflammatory gingival response is associated with a narrow band of keratinized gingiva, although no significant differences were found in attachment levels or bone height. They indicated that if subgingival restorations were to be placed in areas of minimal keratinized gingiva and less than optimal plaque control, augmentation to widen the zone of keratinized tissue may be warranted. It was also noted that in unrestored teeth there was no significant difference in the inflammatory status of sites with or without a wide zone of keratinized tissue.

Mucogingival problems in children were discussed by Maynard and Wilson in a 1980 article. They indicated they had never observed mucogingival problems in the deciduous dentition unless created by a factitial injury. Mucogingival problems tend to originate in the mixed and early permanent dentition resulting from developmental aberrations in eruption and deficiencies in the thickness of the periodontium. The authors indicated the following mucogingival problems may progress with age and should be treated with an autogenous gingival graft: 1) marginal tissue comprised of alveolar mucosa with frenum pull; 2) exposed root surface with minimal keratinized tissue and no attached tissue; 3) labial incisor eruption with minimal keratinized tissue, no attached gingiva, and no lingual movement of the tooth is planned; 4) tooth eruption into a rotated position and minimal keratinized tissue; 5) thin periodontium and labial tooth movement is planned; 6) root exposure during orthodontic movement; 7) maxillary incisor overbite stripping keratinized tissue on facial mandibular incisors. If orthodontic treatment is anticipated, the authors felt autogenous grafts should be placed prior to therapy when mucogingival problems exist.

Tenenbaum and Tenenbaum (1986) studied the width of facial gingiva in subjects aged 3 to 15 years (using a jiggling technique), noting that attached gingiva increases with age in both the primary and permanent dentitions. However, contrary to the findings of Bowers (1963), they reported it does not increase as a result of the transition from the primary to permanent dentition. Since sulcus depth decreased with age, it was concluded that the increase in width of attached gingiva results from decreased sulcus depth. Stated in another way, although sulcus depth decreases with age and results in increased attached gingiva, width of keratinized gingiva does not vary.

Andlin-Sobocki et al. (1991) completed a 3-year longitudinal study of 28 six to 13-year olds who initially presented with labial marginal recession associated with permanent central incisors. Over the 3-year period, an overall reduction in recession occurred with a gradual gain in clinical attachment levels. Since gingival recession on the facial of mandibular incisors often decreases or is totally eliminated over time (in children), the authors suggested that surgical treatment to correct the recession should be postponed until possible spontaneous improvement has been allowed to occur.

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