Interrelationship between periodontal parameters for the evaluation of clinically stable dental implants

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I. Introduction

Dental implants do not decay and do not have dental pulps that may give indications of symptoms or disease. But, the mere presence of an implant in site is not acceptable as the single criterion for "success," because potentially critical peri-implant pathology is not considered. Therefore, detailed criteria for what constitutes success are necessary.

Albrektsson et al[1] described the criteria necessary for implant success: Dental implants should be immobile, and radiographs of implants should not demonstrate any evidence of peri-implant radiolucencies. Bone loss should not exceed 0.2mm annually after the first year, and there should be an absence of pain, infection, paresthesia, an other implant-related neuropathies.

Whereas earlier studies included mostly radiographic assessments of bone height changes and implant mobility to characterize the peri-implant conditions[1-7], later reports also emphasized the importance of the use of modified periodontal indices[2, 4, 8-14].

For the natural dentition, examinations such as for bleeding on probing, probing depth have been found to be important periodontal parameters, so their usefulness in the assessment of implants has been reported previously by many researchers[3, 4, 9, 15]. The interface of implant surface and connective tissues was different from natural teeth due to the absence of periodontal ligament. It may, therefore, be expected that periodontal parameters around natural teeth and around implant fixtures are not the same. From a histological point of view, the per-implant marginal cuff shows a different structure than natural teeth. Fibers inserting directly on the surface of the implants, as they do in the cementum of root, are not found. Therefore, the question may be raised as to whether periodontal parameters are reliable criteria for monitoring implant and whether there is a biological similarity between implants and teeth[16]. However, similar to the periodontal evaluation, modified clinical indices are also applied for the assessment of peri-implant tissues.

Plaque is the primary etiologic factor in long-term peri-implant tissue destruction as with the natural dentition. It would therefore seem appropriate to monitor oral hygiene through plaque indices or some other related method[17, 18].

Bleeding from the junctional epithelium of the implant has been considered an early symptom of peri-implantitis. Sulcus bleeding in well-controlled natural dentition has been reported to be less than 10%[19]. It was reported that the higher sulcus bleeding index was recorded from the healthy implant sites compared with the heathy natural dentition in the dog[20]. These authors also revealed that the resistance offered by the gingiva to probing was greater than that offered by the peri-implant mucosa. The slightly higher sulcus bleeding index indicated also suggested that the juctional epithelium around implants might be more fragile than that of natural teeth.

Pocket probing depth is a commonly accepted measurement in monitoring periodontitis patients and is often applied in implants. In stable implants the pocket probing depth ranges between 1.3 and 3.8 mm[15, 21-23]. Increased pocket depth may be correlated with a higher degree of inflammation of the peri-implant mucosa[15, 24]. Unsuccessful implant sites were characterized by probing depths 6mm or greater, suppuration, bone loss, and microbiota consisting primarily of Gram negative anaerobic rods[9, 24].

Implant mobility is regarded not only as an important indicator of implant success or failure, but also as an important clinical parameter that warrants continual assessment during the maintenance period[1, 2, 6, 25]. To date, peri-implant bone loss and implant mobility have gained wide acceptance as measures of osseointegration and therefore as criteria for implant success[26, 27]. An electronic device, the Periotest®(Siemens, Bensheim, Germany), which has been reported to be able to measure the damping characteristics of the periodontium in a very reproducible way, could permit the objective discrimination between an implant that has a close bone apposition and one that is fibrously encapsulated[28, 29].

It is considered that the long-term success of dental implant treatment depends on periodical maintenance and precise follow-up examinations, among other factors. Presently, a few long-term controlled follow-up studies on the use of periodontal parameters for implants in patients have been reported[2, 4, 10, 11, 25]. In this study, we measured periodontal parameters for evaluating dental implants in a periodical recall program.

This study focused on 5 modified periodontal parameters applied for implant that would allow for objective evaluation of clinically stable dental implants. The goal of this study was to define the interrelationship between these periodontal parameters in peri-implant tissues.

II. Materials and Methods

Between January 1991 and April 1996, a total of 178 of implants, 51 Bråemark(Nobel Biocare, Göeborg, Sweden) dental implants, 109 IMZ(Interpore International, Irvine, CA, USA) titanium plasma flame-sprayed type implant, and 18 ITI(Bonefit® Straumann, Waldenburg, Switzerland) solid screw type implants, were placed in 43 patients(18 males and 25 females) with a mean age of 44.7 years(range of 26 to 65 years). The patient selection from the patient pool included candidates with a good oral hygiene status and without systemic and/or local contra-indications. All patients had at least a 1-year follow-up of prosthesis function(mean 670 days ranging from 373 to 2265 days), and there was no evidence of continual peri-implant radiolucency.

The details of preoperative patient education, surgical technique, and postoperative care were performed according to the manual of each dental implant. The patients were recalled every 3 months for prophylaxis. After removal of the superstructure, the modified periodontal parameters of each implant were taken. The clinical status of all 178 implants showed no detectable mobility or sign of peri-implant infection. All measurements were performed by one periodontist(DHK) using identical methods on all patients.

1) The Modified Plaque Index(M-PI)[3] was determined on all 4 surfaces(buccal, lingual, mesial, distal) of each implant. : score 0=no detection of plaque, score 1 =plaque only recognized by running a probe across the smooth marginal surface of the implant. Implants covered by plasma spray in this area always score 1, score 2=Plaque can be seen by the naked eye, score 3=Abundance of soft matter.
2) The Modified Sulcus Bleeding Index (M-SBI)[3] was assessed at the same surfaces by checking for the occurrence of bleeding from the implant sulcus in response to pressure applied using a Plastic Perio Probe(Implant Innovations® West Palm Beach, FL, USA). : score 0 =no bleeding when a periodontal probe is passed along the gingival margin adjacent to the implant, score 1=isolated bleeding spots visible, score 2=Blood forms a confluent red line on margin, score 3=heavy or profuse bleeding.
3) Keratinized Mucosa Index(KMI)[13] was assessed at the same surfaces. : score 0 =no keratinized mucosa, score 1=1mm or less of keratinized mucosa present, score 2=between 1 and 2mm of keratinized mucosa, score 3=greater than 2mm of keratinized mucosa.
4) Probing Depth(PD)[10] was assessed at the same surfaces to the nearest mm using a Plastic Perio Probe(Implant Innovations® West Palm Beach, FL, USA), attention being given to maintaining parallelism between the probe tip and the long axis of the implant. The PD was determined by measuring the distance from the gingival margin to the bottom of the pocket.
5) Periotest Values(PTVs) was measured with the Periotest® device(Siemens, Bensheim, Germany) as used by Teerlinck et al[29]. The tip of the handpiece was applied perpendicularly to the surface of the abutment, at 3 mm from the implant shoulder and with the patient seated in a vertical position. The measurements were repeated until the same score was obtained 3 times.

Data Analysis

ANOVA using the SAS system with General Linear Models procedure was used to analyze the clinical parameters. Frequency distribution graphs were constructed of all periodontal parameters. Correlation analysis between variables was done using the Pearson Correlation Coefficient. Student t-test was used to compare of PTVs between maxilla and mandible.

III. Results

1. Peri-implant parameters

The measured parameters were analyzed in terms of overall distribution. The maximum, minimum and mean values for each parameter were summarized in Table 1.

(1) Modified Plaque Index(M-PI)

The patients have demonstrated excellent oral hygiene. Approximately 80% of the sites showed a M-PI of≤1. The overall mean value and standard deviation of M-PI was 0.83±0.82, indicating good oral hygiene practices(Fig. 1, Table 1).

(2) Modified Sulcus Bleeding Index(M-SBI)

The M-SBI 0 was assessed in 33% of the evaluated sites. The overall mean value and standard deviation of M-SBI was 1.04±0.86(Fig. 2, Table 1).

(3) Keratinized Mucosa Index(KMI)

The peri-implant tissue has demonstrated adequate keratinized tissue. The KMI 3 was assessed in 72% of the evaluated sites. The overall mean value and standard deviation of M-SBI was 2.47±0.95(Fig. 3, Table 1).

Table 1 Results of 178 implants

Parameters	Sites	Mean	Min	Max
M-PI	712	0.83±0.82	0	3
M-SBI	712	1.04±0.86	0	3
KMI	712	2.47±0.95	0	3
PD	712	3.12±1.14	1	7
PTVs	178	-0.66±4.28	-7	9

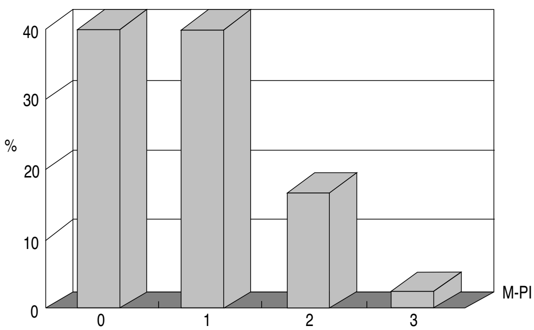

Fig 1 Distribution of Modified Plaque Index

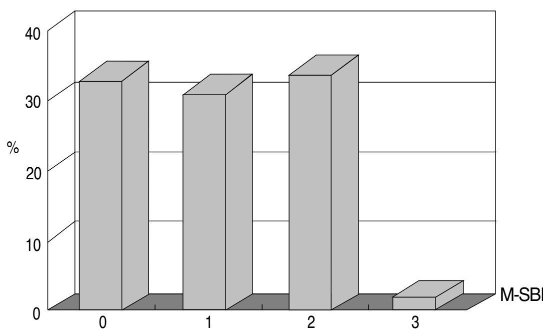

Fig 2 Distribution of Modified Sulcus Bleeding Index

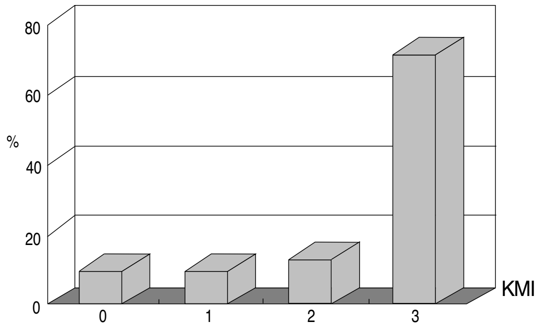

Fig 3 Distribution of Keratinized Mucosa Index

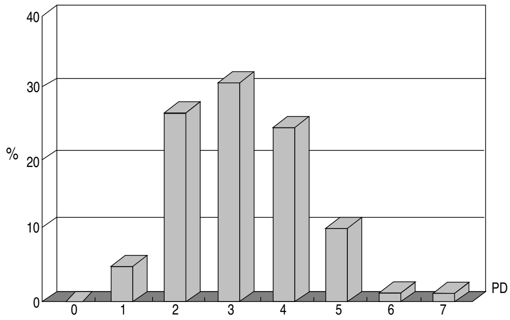

Fig 4 Distribution of Probing Depth

(4) Probing Depth(PD)

The PD ranged between 1 and 7 mm. The overall mean value and standard deviation of PD was 3.12±1.14 mm. In 88 % of total probed sites, PD were 4 mm or less(Fig. 4, Table 1).

(5) Periotest Values(PTVs)

None of the implants exhibited mobility on manual examination. The Periotest measurements produced values ranging from -7 to +9. Over 60% of the implants showed PTV of±0. The overall mean value and standard deviation of PTVs was -0.66±4.28, indicating clinically stable implants(Fig. 5, Table 1).

2. Interrelationship between peri-implant parameters

It was summarized in Fig. 6-13.

M-SBI showed a significant increase in higher M-PI(R^2=0.170, $P<0.01$, Fig. 6). Therefore, the presence of supragingival plaque seemed to affect the peri-implant tissue health. Peri-implant sulcus bleeding also correlated with deeper pocket depth. The presence of subgingival plaque may have been the reason for the positive correlation (R^2=0.170, $P<0.01$, Fig. 7). Peri-implant sulcus bleeding was inversely correlated with the width of keratinized mucosa(R^2=-0.140, $P<0.01$, Fig. 8).

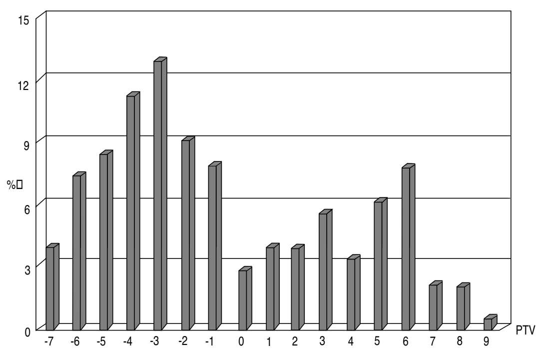

Fig 5 Distribution of Periotest Values(PTVS)

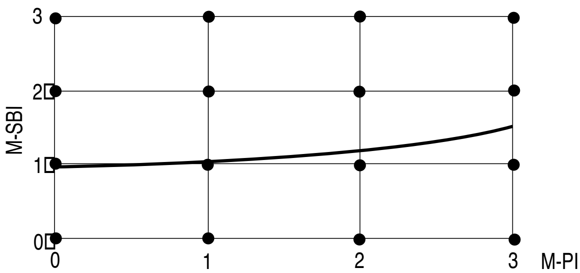

Fig 6 Relationship between Modified Plaque Index and Modified Sulcus Bleeding Index (R2= 0.170)

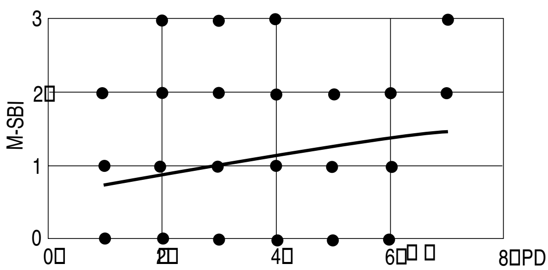

Fig 7 Relationship between Pocket Depth and Modified Sulcus Bleeding Index(R^2=0.170)

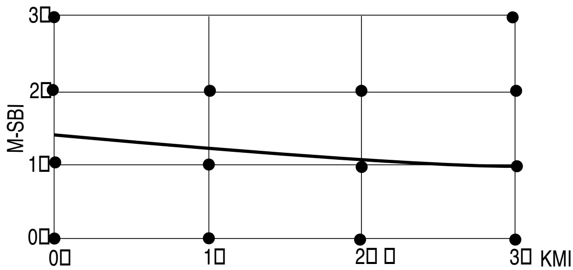

Fig 8 Relationship between Keratinized Mucosa Index and Modified Sulcus Bleeding Index(R^2=-0.140)

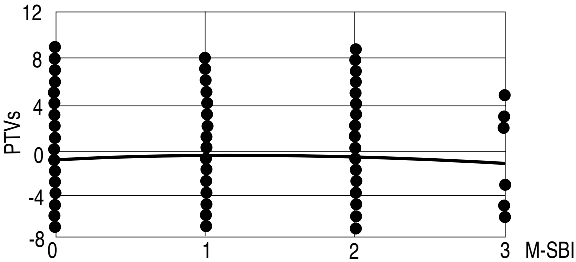

Fig 9 Relationship between Modified Sulcus Bleeding Index and Periotest Values(PTVS)(R^2=-0.001)

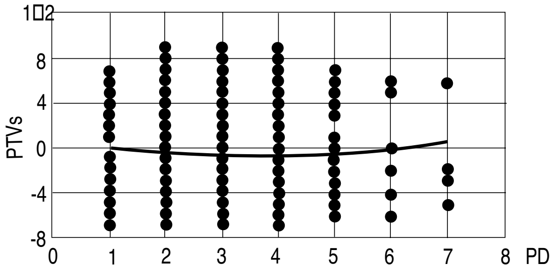

Fig 10 Relationship between Probing Depth and Periotest Values(PTVS)(R^2= -0.004)

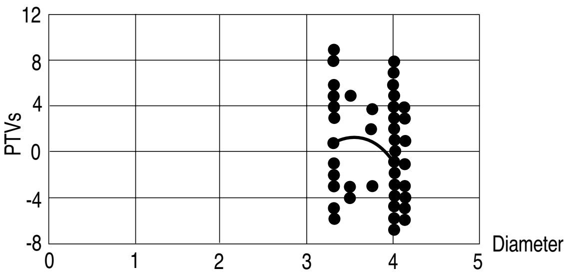

Fig 11 Relationship between diameter of fixture and Periotest Values(PTVS)(R^2= -0.120)

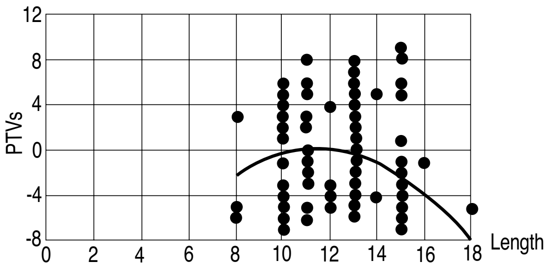

Fig 12 Relationship between length of fixture and Periotest Values(PTVS)(R^2=-0.154).

The correlation analysis performed on the present data showed no link between M-SBI and PTVs($P>0.05$, Fig. 9). Furthermore, there was no correlation between PD and PTVs ($P>0.05$, Fig. 10). These results may be due to absence of periodontal ligament around an implant body.

There was an inverse correlation between the diameter of implant fixture and PTVs ($R^2=-0.120$, $P<0.01$, Fig. 11). The length of implant fixture also inversely correlated with PTVs($R^2=-0.154$, $P<0.01$, Fig. 12).

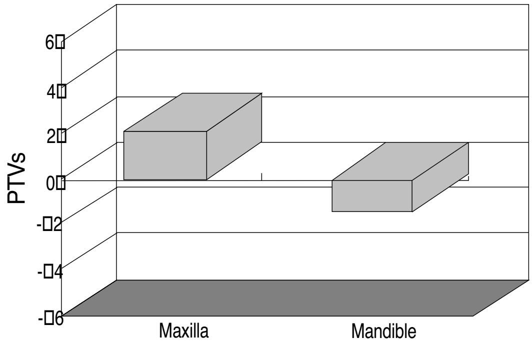

Fig 13 Comparison of Periotest Values(PTVS) between maxilla and mandible

The mean PTVs in maxilla was +2.14, and the mean PTVs in mandible was -1.38. In the present study, Periotest® values(PTVs) demonstrated significantly high values in the maxilla compared to the mandible, which may be due to difference of bone quality(Fig. 13).

IV. Discussion

Periodontal parameters were frequently used as criteria for the peri-implant tissues[24, 30]. Increased indices for plaque accumulation, marginal inflammation and increased probing depths values are associated with the development of peri-implant lesions in experimental animals[31-33].

Modified plaque and sulcus bleeding indices can be used to evaluate the standard of oral hygiene and degree of inflammation in peri-implant mucosa[34]. A modified plaque index in the present study was well controlled, showing mean values of 0.83, and similar results were reported in other studies[3, 4, 5].

High plaque index scores are positive correlated with high gingival index scores[3, 15, 23]. In animal studies, it could be demonstrated that ligature-induced peri-implantitis including bone loss, could be caused by placing ligatures around the implant[35, 36]. A correlation between higher bone loss around implants and increased plaque formation was also found in humans[5]. The bone loss occurred slowly and to a lesser extent in the implants compared with the natural teeth controls.

A sulcus bleeding index has been routinely used as a clinical parameter for assessment of the peri-implant tissue health. Since this parameter is an important sign of periodontal disease, its use may be of great value in assessing peri-implant health. The most common sulcus bleeding gingival index used for implants is suggested by Mombelli et al[9]. But, implant success is not so related to gingival health as in the natural tooth. The inflammation may be limited to above the bone, because there is less fibrous tissue between the implant and bone interface.

An analysis of the clinical data obtained from successful implant throughout this observation period indicated that healthy peri-implant soft tissues with little bleeding tendency were found. There were no remarkable signs of gingival inflammation in any patient. The mean M-SBI values obtained was 1.04, comparable to results from other reported studies[3, 4, 15]. The excellent home care performed by the patients was certainly the major contributing factor for the health of the peri-implant soft tissues.

Poor oral hygiene is the primary cause of sulcus bleeding on probing. When the sulcus depth is less than 5 mm and the bleeding index increases, chlorhexidine often is indicated, along with other professional and home care methods. However, bleeding on probing with sulcus depths in excess of 5 to 6 mm is more common and may require reentry surgery. Radiographic bone loss and increased pocket depth have been correlated with sulcus bleeding[37].

More often, bleeding sites were found with either increased plaque accumulation or increased probing depths in natural dentition. Absence of bleeding on probing has been demonstrated to be a reliable parameter to indicate healthy periodontal tissues[37]. Bleeding on probing has been also reported as a typical sign of peri-implant infection[9, 38], but it has been shown that bleeding on probing may be influenced by probing pressure[37]. Therefore, it is still open to debate that absence of bleeding on probing should be used as a goal for successful maintenance. However, the results of the present study seem to indicate that low bleeding prevalences were associated with maintenance of peri-implant tissues.

In recent years the discussion has been focused on the necessity of the presence of keratinized mucosa around dental implants. It has repeatedly been postulated that the establishment of a circumferential sealing effect by a dense connective tissue collar at the site of implant penetration into the contaminated environment of the oral cavity was a prerequisite for long-term success of the implants[25]. The absence of keratinized mucosa usually represents mobility of the peri-implant soft tissue collar. In some studies the width of the surrounding attached mucosa was inversely correlated to pocket depth[23], but in other studies no correlation could be found between the parameters[35, 39, 40].

In some studies, the role of attached mucosa at the peri-implant cuff appears to be of minor importance for the peri-implant health as long as good hygiene is practiced and achievable. Experimental research has demonstrated that keratinized mucosa is not a prerequisite for the maintenance of healthy peri-implant tissues, and its lack does not appear to result in an increased risk of loss of attachment[41, 42]. In clinical studies, it seems to indicate that healthy peri-implant tissues may be maintained even in the absence of keratinized mucosa. The sufficient width of keratinized mucosa generally did not result in more favorable results for the peri-implant parameters than a narrow zone or absence of keratinized mucosa[13, 14, 43].

However, nonkeratinized mucosa was postulated to be less resistant to mechanical irritation such as tooth brushing. The mobility of the peri-implant mucosa might affect cleaning procedures and may render these tissues more susceptible to plaque-induced inflammation. Many clinicians still believe that an implant penetrating through attached keratinized mucosa is easier to maintain and more resistant to mechanical stress[23, 30].

In the present study, mean value of keratinized mucosa index was 2.47, and the width of the keratinized mucosa was inversely correlated to sulcus bleeding on probing. Despite similar amounts of plaque accumulation, implants placed in keratinized mucosa showed significantly more decrease in modified sulcus bleeding index. A possible explanation of this increased susceptibility to plaque-induced peri-implant mucositis in the absence of keratinized mucosa may be the lack of tight tissue adaptation providing the necessary seal for a functionally optimal epithelial attachment.

In conclusion, the present study has indicated that the presence of a keratinized mucosal tissue collar around dental implants play a role for the longevity of the implant by providing a soft tissue seal that can cope with the bacterial invasion.

Probing depth is one of the fundamental parameters of periodontal examination. Mean probing depth in the present study was 3.12 mm, similar to the finding of a previous report[2, 4, 8, 9, 10, 12, 13]. Compared to the healthy natural dentition, the mean probing depth of the peri-implant mucosa in the present study was slightly higher. Probing depth depends totally on the degree of penetrability of the tissue by the probe. It is suggested, therefore, that peri-implant mucosa is more penetrable than that around natural teeth.

In stable implants the pocket probing depth ranges between 1.3 and 3.8 mm[15, 21-23], and several studies indicated that in clinically successful implants, a probe penetration of about 3 mm was observed[2, 4, 8, 9, 10, 12, 13]. Partially edentulous patients have consistently greater probing depths around implants than around teeth[15].

An increasing probing depth is more of diagnostic criterion because it usually signifies bone loss, except in the case of gingival hyperplasia or hypertrophy. In failing implants, deepened pockets are always found, but absolute pocket depth is not always indicative of implant failure[24, 30, 44]. The thickness of the mucoperiosteal flap at abutment surgery often influences the future pocket depth[2]. A tissue thickness of 5mm results with an initial 5mm implant sulcus, unless gingivoplasty or flap thinning is performed. However, implants' sulcus depths of 6 mm or more provide an environment favorable to gram-negative microorganisms and gingival inflammation, which favor loss of bone[44]. There is a direct relationship between probing depth and the effect on subgingival microflora. Therefore, the tissue thickness and implant sulcus depth should be reduced to an ideal 3 mm or less sulcular depth when esthetics are not a primary concern. Gingivoplasty or flap thinning to reduce pocket depths may be performed at the initial surgery, the uncovery surgery after initial healing, or before the final prosthetic impression.

A more accurate assessment of pocket probing depth may be obtainable after removal of the restoration that prevents probe insertion parallel to the long axis of the implant[30]. It is also recommended that sulcular probing around metal implants be accomplished with available periodontal probes of similar metal or plastic. This will help prevent scratching and electrochemical interaction between dissimilar metals, which could be detrimental to the biocompatibility of the implant[17].

The location of the probe tip subgingivally depends on the pressure used, the presence of inflammation, and the angle at which the probe is introduced next to the junctional epithelium-connective tissue zone or crest of the bone[30]. A positive correlation has been demonstrated between higher plaque distribution, gingivitis, and deeper pocket depth in natural dentition. And, this observation was demonstrating positive correlation between M-PI, M-SBI, and PD in dental implants.

All implants should be clinically immobile. It does not guarantee a direct bone-implant interface. However, It clinically means that at least a portion of the implant is in direct contact with bone, although the percentage of bone contact cannot be indicated[45].

In order to assess low degrees of implant mobility, an electronic device(Periotest® Siemens, Bensheim, Germany) was proposed. Tooth with clinical zero mobility has typical ranges around +5. Periotest values(PTVs) of a clinically stable implant most often ranges from -8 to +10[46].

In the present study, over 60% of the implants showed PTV of ≤ 0. The mean value of PTVs was -0.66 ± 4.28. The present mean PTVs remain in the negative(-1.38) and lower positive(+2.14) ranges for the mandible and maxilla respectively.

In the present study, Periotest® values (PTVs) demonstrated significant difference between the mean mandibular and maxillary PTVs, confirming the results obtained by previous studies[47, 48]. It may be due to the difference of bone quality. And, PTVs showed significant decrease in higher diameter and/or length of implant fixture. Therefore, quantity and quality of bone contacted implants were certainly the major contributing factor for reduction of implant mobility.

Clinical periodontal parameters are used for the evaluation of the peri-implant tissues. This evaluation may include the use of a modified plaque index, modified sulcus bleeding index, keratinized mucosa index, probing depth, Periotest values. Radiographic interpretation of alveolar bone levels has been proven to be a valuable measure of implant success or failure. However, many variables in radiographic technique and interpretation cause differences and errors in this assessment. There are inherent errors in using these parameters, but currently they are still the most descriptive and predictive of disease activity that can be used by the implant therapist.

Periodontal parameters were used to monitor the peri-implant soft tissue condition in a small study population. Our results confirm the periodontal parameters of other studies on dental implants. The inclusion of more patients/implants and continued follow-up studies will possibly lead to establishing the standard value of peri-implant parameters.

V. Conclusions

The purpose of this study was to evaluate modified periodontal parameters applied for dental implants and interrelationship between these parameters. In this study 178 dental implants were placed in 43 patients(mean 44.7 years) and the results were as follows.

1. Mean value of Modified Plaque Index(M-PI) was 0.83 ± 0.82.
2. Mean value of Modified Sulcus Bleeding Index(M-SBI) was 1.04 ± 0.86.
3. Mean value of Keratinized Mucosa Index (KMI) was 2.47 ± 0.95.
4. Mean value of Probing Depth(PD) was 3.12 ± 1.14 mm.
5. Mean value of Periotest Values(PTVs) was -0.66 ± 4.28.
6. M-SBI showed significant increase in higher M-PI and/or deeper PD($P < 0.01$).
7. M-SBI showed significant decrease in higher KMI($P < 0.01$).
8. There was no correlation between M-SBI and PTVs($P > 0.05$).
9. There was no correlation between PD and PTVs($P > 0.05$).

10. PTVs showed significant decrease in higher Diameter and/or Length of implant fixture($P<0.01$).
11. PTVs showed significantly low values in the mandible compared to the maxilla ($P<0.01$).

In conclusion, sulcus bleeding around the dental implant showed significant increase in higher plaque accumulation and/or deeper probing depth. Despite similar amounts of plaque accumulation, implants placed in keratinized mucosa showed significant more decrease in sulcus bleeding tendency.

When inflammation was present in sulcular tissues, increased mobility was found in natural teeth, but no correlation was found in clinically stable implants of the present study.

In clinically stable implants, there was the inverse correlation between PTVs and the diameter/length of implant fixture, having no concern with peri-implant sulcus bleeding.

Moreover, Periotest® values(PTVs) showed significantly low values in the mandible compared to the maxilla, which may be due to the difference of bone quality.

VI. References

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인공매식치의 평가를 위한 치주지수간의 상관관계

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자연치의 경우에는 치주지수간의 상관관계가 정립되어 병적인 상태에 대한 진단과 그에 따른 치료방법을 결정하는데 많은 정보를 제공하나, 인공매식치에서는 아직 논란의 여지가 많다. 이에 임상적으로 안정화되어 기능하고 있는 인공매식치에서 치주지수간의 상관관계에 관하여 연구하고자 하였다.

총 43명의 환자(평균 44. 7세)에 식립된 178개의 인공매식치를 연구에 이용하였다. 인공치아매식술을 시행한 후 1년에서 6년이 경과한 인공매식치에서 상부보철물을 제거한 후 치태지수, 치은열구출혈지수, 각화점막지수, 치주낭깊이, Periotest Values(PTVs) 등을 측정하여 각각의 분포상황과 상관관계를 분석하였다.

이 연구의 결과는 다음과 같다.

1. 치태지수의 평균값은 0.83±0.82이었다.
2. 치은열구출혈지수의 평균값은 1.04±0.86이었다.
3. 각화점막지수의 평균값은 2.47±0.95이었다.
4. 치주낭깊이의 평균값은 3.12±1.14 mm이었다.
5. Periotest Values(PTVs)의 평균값은 -0.66±4.28이었다.
6. 치태지수, 치주낭깊이가 증가함에 따라 치은열구출혈지수는 유의성있게 증가하였다 ($P<0.01$).
7. 각화점막지수가 증가함에 따라 치은열구출혈지수는 유의성있게 감소하였다($P<0.01$).
8. 치은열구출혈지수와 매식치동요도 사이에서는 유의성있는 상관관계를 발견할 수 없었다 ($P>0.05$).
9. 치주낭깊이와 매식치동요도 사이에서도 유의성있는 상관관계를 발견할 수 없었다($P>0.05$).
10. 인공매식치의 직경과 길이가 증가함에 따라 매식치동요도는 유의성있게 감소하였다 ($P<0.01$).
11. 하악에서의 매식치동요도가 상악의 경우와 비교하여 유의성있게 작았다($P<0.01$).

결론적으로, 인공매식치에서도 자연치에서와 동일한 양상으로 치태가 많을수록, 그리고 치주낭깊이가 깊을수록 염증의 심도와 관련이 깊은 것으로 생각된다. 특히, 인공매식치의 경우에는 같은 양의 치태가 존재시에 각화치은이 충분히 있는 쪽이 염증발생이 적은 것으로 나타났다.

치주조직에 염증이 존재하는 경우, 자연치아에서는 치아의 동요도가 증가하는 것으로 알려져 있으나, 이 실험의 인공매식치에서는 유의성있는 상관관계를 발견할 수 없었다. 임상적으로 안

정화된 인공매식치의 동요도는 염증정도에는 큰 영향을 받지 않고 인공매식치의 직경과 길이가 증가함에 따라 감소함을 보여주고 있다. 또한, 인공매식치의 동요도는 상하악골의 골질에 따라 차이가 있음을 명확히 보여주고 있다.