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Tissue alterations at implant-supported single-tooth replacements: a 1-year prospective clinical study

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Abstract

Objectives: The aim of this prospective study was to evaluate dimensional alterations of the peri-implant tissues at single-tooth restorations from the time of implant placement to 1-year post-loading.

Material and methods: Eleven patients, aged 18–36 years, subjected to single-tooth replacements with implant-supported restorations (Brånemark implant® system) in the maxillary anterior region were included in the analysis. The implant installation was performed as a two-stage procedure with a 6-month healing interval. Bone dimensions were determined by direct assessments immediately following implant placement and at abutment connection. The prosthetic restoration was placed approximately 1 month after abutment surgery. Radiographic and clinical examinations were performed at crown placement and at 1-year post-loading. Assessments of the soft tissues at the implant site and at the neighboring teeth were performed before and during implant placement, before abutment connection, after crown placement and at the 1-year follow-up examination. Mean values and standard deviations were calculated for each variable and interval, with the subject as the statistical unit.

Results: At the time of abutment connection, a mean loss of bone height at the facial and lingual aspect of the implant amounting to 0.7–1.3 mm ($P<0.05$) was recorded, whereas no significant change was noted at proximal sites. A mean reduction of 0.4 mm of the labial bone thickness was observed between implant placement and the second-stage surgery. The radiographic bone-to-implant level showed a mean loss of 0.9 mm between abutment connection and crown placement ($P<0.05$) and a further 0.7 mm loss at 1 year ($P<0.05$). The thickness of the labial mucosa was increased at crown placement followed by a slight remission at 1 year. During the corresponding interval, a mean apical displacement of the labial soft tissue margin of 0.6 mm had taken place ($P<0.05$). A papilla fill of $\geq$ 50% was observed at a frequency of 32% at crown placement and 86% at 1 year.

Conclusions: The results demonstrated that following implant surgery remodeling takes place, which is manifested in diminished bone dimensions, both horizontally and vertically, at the facial aspect of the implant. The observed soft tissue alterations after the crown placement may affect the esthetic appeal of the restorative therapy.

The level of bone support and the soft tissue dimensions around the implant-supported single-tooth restoration are factors suggested to be important for the esthetic outcome of implant therapy (Belser et al. 1998). Implant position in relation to neighboring teeth as well as in relation to the buccal–lingual dimension of the alveolar ridge are factors shown to influence the degree of bone remodeling following

implant placement (Esposito et al. 1993; Spray et al. 2000). Thus, it was demonstrated that placement of an implant closer than 3 mm from the adjacent tooth resulted in loss of proximal bone height during the healing phase (Esposito et al. 1993). Further, significantly greater amounts of facial bone loss were observed between implant placement and abutment connection surgery for implants that, following placement, had a facial bone thickness of less than 1.8 mm (Spray et al. 2000). As the bone level constitutes the base for the supra-crestal soft tissue, and evidence supports the existence of a 'biological width' of the supra-crestal soft tissue around the implant similar to that defined for the natural tooth (Gargiulo et al. 1961; Berglundh & Lindhe 1996; Cochran et al. 1997), bone loss may negatively influence the soft tissue topography and the esthetic outcome of the implant therapy. However, the thickness of the mucosa at the facial aspect of the implant may also influence the height of the supra-crestal soft tissue portion (Bengazi et al. 1996). Thus, the placement of an implant in an extreme facial position may result not only in a bone dehiscence but also in a thin supra-crestal mucosa corresponding to observations made following facial displacement of a tooth (Wennström et al. 1987).

Other factors indicated to influence the position of the soft tissues topography and esthetics at implant-supported restorations are crown dimensions, contact point position, tooth–implant distances and implant diameter (Chang et al. 1999). In a study by Jemt (1999), attempts were made to guide the establishment of papillae by the use of a provisional resin crown inserted at time of surgery for abutment connection. However, the results at 2 years did not support the hypothesis of possible soft tissue guidance by means of temporary crowns, for improved soft tissue esthetics of single-tooth restorations. Interestingly, data reported by Choquet et al. (2001) showed the presence of a mean proximal soft tissue height of about 4 mm independent of the degree of papilla fill adjacent to single implants. These findings may indicate that the peri-implant soft tissue position and dimensions are primarily controlled by biological factors and may not be possible to manipulate to a significant degree by the use of various procedures connected with the prosthetic restoration.

The aim of the present prospective study was to evaluate dimensional alterations of the peri-implant hard and soft tissues from the time of implant placement to 1-year post-loading at single-tooth restorations using the Brånemark Implant® system.

Material and methods

Subject sample

The subjects for the present study were consecutively selected among partially dentate patients referred to the Brånemark Clinic (Göteborg, Sweden), for single-tooth replacements with implant-supported restorations in the maxillary incisor tooth region. For inclusion, the patients should (i) not require restorative treatment of the adjacent teeth, (ii) not require bone grafting/augmentation procedures and (iii) be in good general health as evaluated by a completed general health questionnaire and clinical judgment.

Sixteen patients agreed to participate and signed the information consent form. Five of the patients, however, had to be excluded during the course of the study because they refused to attend scheduled appointments for follow-up. Thus, 11 patients (one female, 10 males), aged 18–36 years (mean age 26 years; SD 6.7), remained for evaluation at 1 year of follow-up.

Implant therapy

All patients had had the tooth extracted at least 6 months prior to implant surgery. A removable prosthesis was therefore used for temporary rehabilitation in all cases. The implant therapy was planned based on careful radiographic and clinical evaluations.

The insertion of the implant (Brånemark implant® system, Nobel Biocare, Göteborg, Sweden) was performed as a two-stage procedure (Lekholm et al. 1999). All patients were given a prophylactic dose of antibiotics (Amoxicillin 3 g) 1 h prior to surgery. Following local anesthesia, a mid-crestal incision was made in the edentulous area and extended intra-crevicularly around the adjacent teeth. No releasing incisions were used. Full-thickness flaps were elevated labially and lingually to expose the bone ridge. The preparation of the recipient site for the implant was performed with the aim of achieving the most optimal insertion position with respect to esthetics (Lekholm 2003). Following insertion, the implants were completely surrounded by bone and placed with the top of the cover screw positioned even with the buccal bone crest. The flaps were repositioned to cover the implant completely and were secured in position by interrupted sutures. The sutures were removed 7–10 days after the surgery.

The second-stage surgery was performed 6 months after implant placement. A mesio-distal crestal incision, limited to the implant site, was placed and the ridge mucosa was elevated to uncover the implant, followed by replacement of the cover screw with a standard healing abutment (Nobel Biocare). The mucosal flap was adjusted to the healing abutment and sutured in position. The impression for crown restoration was taken from the implant level 2 weeks later, and the prosthetic restoration was placed approximately 1 month after abutment surgery. All patients were prosthetically restored with an individually fabricated alumina oxide abutment and a cemented all-ceramic crown (Procera®, Nobel Biocare). Instruction in tooth cleaning with the use of a regular toothbrush was given at the completion of the restorative treatment. The patients were recalled for a radiographic and clinical follow-up examination 1 year after crown placement.

Clinical assessments

Soft tissue assessments

Assessments of the soft tissues at the implant site and at the neighboring teeth were performed before implant placement, before abutment connection, after crown placement and at the 1-year follow-up examination by one examiner (G. C.). Before the start of the study, the examiner was trained to adequate levels of accuracy and reproducibility for the various measurements and indices to be used (Polson 1997). The examinations included the following assessments:

1. *Mucosa thickness* – assessed with the use of a calibrated ultrasonic device (SDM, Krupp Corp., Essen, Germany; Eger et al. 1996) at the mid-point of the

edentulous ridge at the time of implant placement and abutment connection. The assessment was performed at the top of the crest and at the facial aspect of the edentulous ridge. Following crown placement and at 12 months, the measurement was performed approximately 3 mm apical to the soft tissue margin at the facial aspect of the implant-supported crown. A corresponding reference point was used for the same assessment at the facial aspect of neighboring teeth. Double recordings were performed, and the mean value was calculated.

2. *Soft tissue height* – the distance from the soft tissue margin to the bottom of the probable pocket at the facial site of the implant and neighboring teeth. The soft tissue height was assessed at crown placement and at 1 year.
3. *Soft tissue level* – the distance between the border of an individually fabricated occlusal stent and the soft tissue margin at the facial site of the implant and neighboring teeth. The soft tissue level was assessed at crown placement and at 1 year.
4. *Height of keratinized mucosa* – the distance between the soft tissue margin and the mucogingival line at the facial aspect of the implant site and neighboring teeth.
5. *Papilla fill index (PFI)* – assessed using a scoring system described by Jemt (1997) mesial and distal to the implant-supported crown and at the remote interdental site of the neighboring teeth (tooth/tooth site).

All linear measurements were performed to the closest 0.5 mm with the use of a force-controlled periodontal probe (Brodontic®, Amsterdam, The Netherlands) set at a force of 0.25 N and having 1 mm markings (probe tip diameter 0.45 mm).

In addition, *soft tissue condition*s were assessed at mesial, facial, distal and lingual sites of the implant and neighboring teeth according to the criteria of the mucositis score (Bengazi et al. 1996). *Oral hygiene status* was determined by scoring the presence/absence of plaque in the area of the soft tissue margin at four surfaces of the implant-supported crown and neighboring teeth.

Bone assessments

Direct measurements of bone dimensions were performed at the time of implant placement and abutment connection as follows:

1. *Buccal bone thickness at implant* – measured by the use of a specially designed measurement device connected to the implant. The measurement was performed at three different levels facial to the implant, at the marginal edge of the implant, 2, and 4 mm apical to the bone crest, respectively.
2. *Bone crest level* – measured as the distance from the implant/abutment connection level (I/A level) to the bone crest at mesial, facial, distal and lingual aspects of the implant with the use of a periodontal probe. A positive value was obtained when the crest was positioned coronal to the I/A level.
3. *Width of alveolar ridge* – the facial–lingual dimension of the ridge was assessed with the use of a sliding caliper at the mid-point of the edentulous area.

The average value of double recordings was used for the data analysis.

Radiographic assessments

Intra-oral radiographs were taken at abutment connection, at crown insertion and at 12-month follow-up using a standardized parallel technique (Gröndahl et al. 1996). On the radiographs, one trained examiner (G. C.) performed assessments of the *bone level* at the mesial and distal aspect of the implant and neighboring teeth by the use of a scaled, magnifying lens (× 7). The I/A connection level was used as the reference line for the assessments at the implant, while at the teeth the reference was the cemento-enamel junction (CEJ).

The intra-examiner reproducibility of bone-level measurements was determined by repeated assessments with a 1-week interval. The mean difference of replicate pairs of measurements was 0.05 mm (SD 0.16). All of the measurements were reproduced within a difference of ± 0.5 mm.

Data analysis

The data representing the proximal surfaces of the two teeth adjacent to the implant were collapsed to generate a mean value to represent the *implant-facing* and *tooth-facing* sites of the neighboring teeth, respectively. Mean values and standard deviations were calculated for each variable with the subject as the statistical unit. Statistical analysis of differences in recorded variables was performed by the use of the paired sign test.

Results

Bone assessments (Table 1)

Implant site

The assessment of the position of the bone margin performed immediately after insertion of the implants revealed that the bone

Table 1. **Hard tissue assessments at implant site and adjacent teeth**

	Implant placement	Abutment connection	Crown placement	12 months
Direct assessments				
Implant site				
Bone margin				
Buccal	+ 1.1 (1)	+ 0.4 (0.5)*	–	–
Lingual	+ 1.8 (1.4)	+ 0.5 (0.8)*	–	–
Proximal	+ 3.0 (1)	+ 2.9. (1.1)	–	–
Buccal bone thickness				
At implant head level	1.2 (1)	0.8 (0.3)	–	–
2 mm apical-to-implant level	1.3 (0.8)	0.9 (0.4)	–	–
4 mm apical-to-implant level	0.9 (0.7)	1.1 (0.8)	–	–
Width of alveolar bone ridge	6.0 (1.3)	5.6 (0.9)	–	–
Radiographic assessments				
Bone level				
Implant (from I/A)	–	– 0.2 (0.4)	– 1.1 (0.4)*	– 1.8 (0.7)*
Adjacent tooth sites (from CEJ)	–	– 1.9 (1.1)	– 2.1 (1.1)	– 2.5 (0.9)

Mean values and standard deviations (SD) in millimeter.
*$P < 0.05$ (paired sign test).
I/A, implant/abutment connection level; CEJ, cemento-enamel junction.

margin around the implant was positioned coronal to the implant plateau surrounding the hex: on the average 1.1 mm (SD 1) at the facial, 1.8 mm (1.4) at the lingual and 3 mm (1) at the proximal aspect. At the time of abutment connection, a loss of bone height at the facial and lingual aspect of the implant had taken place, averaging between 0.7 and 1.3 mm ($P<0.05$), whereas no significant change was noted at proximal sites.

The labial bone thickness, assessed following implant placement, was 1.2 mm (1), 1.3 mm (0.8) and 0.9 mm (0.7) at the three different depth levels for measurements. At the two most marginal measurement points, a non-significant mean reduction of 0.4 mm of the labial bone thickness was observed at the second-stage surgery. The total facial–lingual width of the alveolar process decreased from 6 mm (1.3) at the time of implant installation to 5.6 mm (0.9) at abutment connection, i.e. a reduction corresponding to the reduced thickness of the labial bone at implant head level.

The radiographic proximal *bone-to-implant level*, in relation to the level of the I/A connection, was −0.2 mm (0.4) at the second-stage surgery. At crown placement, the corresponding figure had increased to −1.1 mm (0.4) ($P<0.05$). A further increase of the distance to −1.8 mm (0.7) was noted at the 1-year follow-up ($P<0.05$).

Adjacent teeth

The mean radiographic bone level at the tooth surfaces facing the implant site was −1.9 mm (1.1) at the time of abutment surgery, −2.1 (1.1) at crown placement and −2.5 mm (0.8) at the 1-year follow-up ($P>0.05$).

Soft tissue assessments (Table 2 and Fig. 1)

Implant site

The mucosa thickness at the edentulous crest was on the average 2.2 mm (0.7), before implant placement while at the time of abutment connection the thickness was 3.2 mm (0.8). The corresponding figures at the labial aspect of the edentulous ridge were 1.3 mm (0.8) and 1.6 mm (0.7), respectively. Following crown placement, the labial mucosa increased in thickness to 2.5 mm (0.3) ($P=0.07$). At the 1-year follow-up, a slight remission in mucosa thickness was noted (2.2 mm). During the corresponding time interval, an apical displacement of the labial soft tissue margin of, on average, 0.6 mm (0.7) had taken place ($P<0.05$).

The mean height of the keratinized mucosa was 4.6 mm (1.4) before implant placement, and showed no significant alterations over the observation period.

The frequency distribution of the PFI scores (Fig. 1) revealed that at crown placement, 15 out of 22 proximal sites (68%) had a score of 0–1 (<50% papilla fill) and only two papillae completely filled out the space between the implant and the tooth. At the 1-year follow-up, a papilla fill of ≥ 50% was observed at 19 sites (86%), out of which four (18%) demonstrated complete papilla fill.

At 12 months, all but one patient showed a peri-implant mucosa without clinical signs of inflammation. The remaining subject demonstrated minute signs of soft tissue inflammation (mucositis score 1).

Adjacent teeth

On an average, 43% of the gingival units around the two teeth adjacent to the implant site showed bleeding on probing (Mucositis score 2) at the initial examination, while the figure was 22% at the 1-year follow-up. The mean probing depth at the

Table 2. **Soft tissue assessments at implant site and adjacent teeth**

	Implant placement	Abutment connection	Crown placement	12 months
Implant site				
Mucosa thickness				
Crest	2.2 (0.7)	3.2 (0.8)	–	–
Labial	1.3 (0.8)	1.6 (0.7)	2.5 (0.3)	2.2 (0.5)
Height of keratinized mucosa	4.6 (1.4)	4.3 (1.6)	4.1 (1.1)	4.5 (1.7)
Soft tissue height (labial)	–	–	2.5 (1.4)	2.4 (0.8)
Soft tissue level – change	–	–	–	0.6 (0.7)*
Adjacent teeth				
Mucosa thickness (labial)	0.9 (0.4)	1.1 (0.4)	1.1 (0.4)	1 (0.3)
Height of keratinized mucosa	4.4 (1)	–	4.2 (1.2)	4.5 (1.5)
Soft tissue height (labial)	–	–	1.6 (0.4)	1.8 (0.4)
Soft tissue level – change	–	–	–	0.2 (1.1)

Mean values and standard deviations (SD) in millimeter.
*$P<0.05$ (paired sign test).

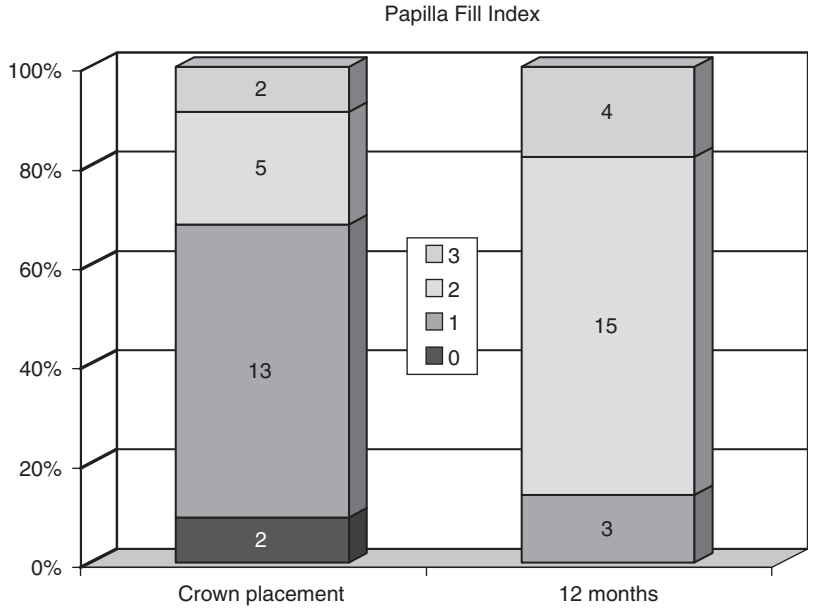

Fig. 1. Frequency distribution of various degrees of papilla fill adjacent to the implant crown according to the index by Jemt (1997) at crown placement and at 12-month follow-up.

various tooth sites was around 2 mm at all observation intervals.

The mucosa thickness at the labial aspect of the teeth was on average 0.9 mm (0.4), and the height of keratinized tissue measured 4.4 mm (1) at the time of implant surgery. No significant changes were observed with regard to these assessments during the study period.

The frequency distribution of the various PFI scores showed that 20 out of the 22 *tooth-facing sites* (91%) presented with complete papilla fill, whereas two sites displayed a fill corresponding to score 2. There was no change in the frequency distribution of PFI scores for the teeth during the 1-year follow-up.

Discussion

The present study focused on dimensional alterations of the peri-implant hard and soft tissues during two different phases of the treatment with implant-supported single-tooth restorations: the surgical phase (i.e. pre-treatment to abutment connection surgery) and the prosthetic phase (i.e. abutment connection to 1 year). It was observed that, following implant placement, resorption of the bone occurred, which was manifested as a 0.7–1.3 mm reduction of the bone height at the buccal and lingual aspects of the implant at the time of abutment connection, while on average only 0.1 mm loss of bone height was observed at proximal sites. In addition, a reduction of about 0.4 mm in the thickness of the bone buccal to the implant was recorded. The magnitude of these hard tissue alterations corresponds to bone alterations observed at teeth following periodontal flap surgery (Kohler & Ramfjord 1960; Wilderman et al. 1960; Wilderman 1963; Donnenfeld et al. 1964; Tavtigian 1970; Wood et al. 1972). In the studies referred to, a mean loss of crestal alveolar bone varying between 0.2 and 1 mm was reported. Further, whether a partial or a full-thickness flap procedure was used did not seem to affect the amount of bone resorption taking place as a consequence of the surgical intervention (Wood et al. 1972), while teeth with the thinnest radicular bone consistently demonstrated the most pronounced bone loss post-operatively (Wood et al. 1972; Yaffe et al. 1994). From a study of 2685 implants, Spray et al. (2000) reported a mean facial bone loss of 0.7 mm between implant placement and abutment connection, and that the vertical bone loss significantly increased with decreased thickness of the bone at implant placement. Taken together, the observations indicate that the surgical trauma inflicted by flap elevation may induce remodeling of the surface layer of the alveolar bone in the exposed area, and that the degree of vertical bone loss, as a consequence of this bone remodeling, is influenced by the thickness of the remaining bone facial to the implant following its placement.

Another consideration in relation to the loss of facial–lingual bone crest dimension is the bone resorption over time that occurs following extraction of a tooth. In clinical studies (Pietrokovski & Massler 1967; Schropp et al. 2003; Botticelli et al. 2004), a pronounced resorption of the facial part of the ridge was documented, resulting in reduction of the thickness of the ridge by about 50% as a consequence of the removal of a tooth, and that the major part of this remodeling took place during the first 3–6 months following tooth extraction. However, it is less likely that this natural remodeling of the alveolar crest may have been a major contributing factor to the loss of bone height observed in the current study as the tooth extractions had been performed at least 6 months before the implant installation surgery in all cases.

During the second phase of the present study, i.e. from abutment connection to 1 year of follow-up, the radiographic assessments of *bone-to-implant level* at proximal sites revealed a significant loss of, on average, 1.6 mm. The greater part of this loss occurred during the interval between abutment connection and crown placement (time interval about 1 month). Other studies on single-tooth replacements utilizing the same implant system as in the present study have reported similar or even a lesser degree of initial changes in bone-to-implant levels (e.g. Esposito et al. 1993; Andersson et al. 1998; Naert et al. 2000; Haas et al. 2002). There may be several reasons underlying this finding. First, the surgical manipulation of the site in conjunction with the abutment connection may cause a tissue trauma resulting in bone remodeling (Naert et al. 1999). Second, it has been suggested that a small inflammatory cell infiltrate may always be present at the implant–abutment connection level, the presence of which may result in some bone loss (Abrahamsson et al. 1998). Third, because of the loss of facial bone height, a circumferential remodeling of the bone level adjacent to the implant may take place to equilibrate the level with the facial bone wall (Carmagnola et al. 1999; Cardaropoli et al. 2003; Hartman & Cochran 2004). Such bone remodeling may manifest itself as a reduced proximal bone-to-implant level in the radiograph (Wennström et al. 2005). However, the magnitude of facial bone loss may differ depending of the design and surface topography of the implant (Malevez et al. 1996; Norton 1998; Hansson 1999).

With regard to the dimensions of the peri-implant soft tissues, an increased thickness of the mucosa facial to the implant was noted after crown placement, followed by a slight remission at the 1-year follow-up examination. In a recent 1-year study of soft tissue alterations following placement of single-implant restorations, Henriksson & Jemt (2004) also found a comparable significant increase of the buccal volume after crown placement and a significant reduction at 1 year. Interestingly, in the current study, the reduction in the soft tissue thickness was accompanied by a significant, apical displacement of the soft tissue margin of, on average, 0.6 mm. This magnitude of soft tissue recession during the early phase of follow-up after implant crown placement is in accord with previously published data (Bengazi et al. 1996; Grunder 2000; Small & Tarnow 2000). Bengazi et al. (1996) suggested that this early apical displacement of the soft tissue margin might be because of a modeling process of the peri-implant soft tissues for its adaptation to adequate biological dimensions as demonstrated in experimental studies (Abrahamsson et al. 1996; Berglundh & Lindhe 1996; Cochran et al. 1997). Furthermore, results of studies focused on marginal soft tissue dimensions indicated that there might be a relationship between the thickness of the mucosa and the height of the free portion of the marginal tissue. Hence, both at teeth (Olsson et al. 1993; Eger et al. 1996) and implants (Chang et al. 1999), a relationship between the thickness and the height of

about 1 : 1.5 can be calculated, an observation that is supported by the data in the current study.

An improved papilla fill was observed from the time of crown placement to 1 year. This finding is in agreement with previous reports in the literature (e.g. Jemt 1997, 1999; Chang et al. 1999; Choquet et al. 2001; Henriksson & Jemt 2004). Considering that the crown was placed about 1 month following abutment surgery, it is reasonable to assume that the topography of the proximal soft tissue had not established its final outline at crown placement. According to data reported by Choquet et al. (2001), about 4 mm of soft tissue height at the proximal sites is established independent of the degree of papilla fill. The interpretation of these findings is that there may be a biological limit for the proximal soft tissue height, and that attempts to improve the papilla fill, e.g. by means of oversized temporary crowns (Jemt 1999), may not be a successful approach. In fact, the author reported a similar volume of soft tissue adjacent to single-implant restorations regardless of whether a provisional crown was placed at the time of abutment connection or the soft tissue was first allowed to heal around a temporary abutment. Further, the suggestion by Jemt (1999) to improve the papilla fill through plaque-induced inflammation of the soft tissue during the initial healing phase after abutment connection surgery may be a questionable approach if the soft tissue dimensions are controlled by biological factors. In addition, creating pathology cannot be an acceptable means to satisfy the patient's esthetic demands.

Conclusion

Within the limitations of the present study, the assessments of hard and soft tissue alterations at implant-supported single-tooth restorations demonstrated that, following implant placement in the healed alveolar ridge, remodeling of the bone takes place, which is manifested in diminished dimensions, both horizontally and vertically, at the facial aspect of the implant. During the interval between crown placement and 1 year, a significant apical displacement of the soft tissue margin at the facial aspect of the implant was observed, while an improved soft tissue height (papilla fill) was seen at proximal sites.

要旨

目的：本前向き研究の目的は、単独歯修復においてインプラント周囲組織の寸法変化をインプラント埋入時から荷重後１年後まで評価することであった。

材料と方法：年齢１８－３６歳の、上顎前歯部単独歯欠損についてインプラント（**Branemark implant ®system**）支持の修復物の治療を受けた患者１１名を分析した。インプラントは、２回法で埋入し６ヶ月の治癒期間を設けた。骨の寸法は、インプラント埋入時とアバットメント連結直後に直接計測した。補綴物は、アバットメント連結後約１ヶ月後に装着した。レントゲン検査と臨床診査をクラウン装着時と荷重後１年後に行った。インプラント部位及び隣在歯の軟組織は、インプラント埋入前、埋入術中、アバットメント連結前、クラウン装着後と１年後の再検査時に評価した。平均値と標準偏差を、被験者を統計学的単位として、各変数と区間について計算した。

結果：アバットメント連結時の骨高径の平均喪失量は、インプラントの頬側と舌側では０．７－１３ｍｍ（ｐ＜０．０５）であり、隣接面では有意な変化は認められなかった。唇側骨の厚みは、インプラント埋入時と二次手術時の間に平均０．４ｍｍの減少が記録された。レントゲン像上の骨－インプラントのレベルは、アバットメント連結時とクラウン装着時の間に平均０．９ｍｍ（ｐ＜０．０５）減少しており、１年後にはさらに０．７ｍｍ減少していた（ｐ＜０．０５）。唇側粘膜の厚みはクラウン装着時に増加していたが、１年後にはわずかに減少していた。同期間に唇側軟組織のマージンは、平均０．６ｍｍ根尖側に移動した（ｐ＜０．０５）。≧５０％の歯間乳頭の増加が、クラウン装着時には３２％、１年後には８６％の頻度で認められた。

結論：これらの所見は、インプラント手術後に、インプラント頬側で水平的及び垂直的な骨のリモデリングが起こり、骨寸法が減少する事を示した。クラウン装着後に観察された軟組織の変化は、修復治療の審美性に影響を及ぼす可能性がある。

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