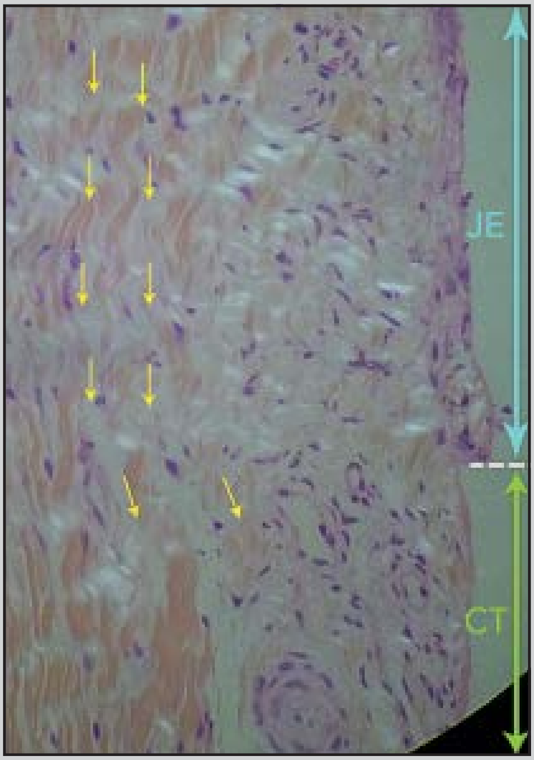
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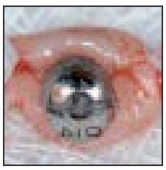
Arrangement of Peri-implant Connective Tissue Fibers Around Platform-Switching Implants with Conical Abutments and Its Relationship to the Underlying Bone: A Human Histologic Study



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The objective of this study was to clarify and evaluate the orientation of the collagen fibers around platform-switching (PS) implants with conical abutments in humans after 8 weeks of healing, and to determine how this orientation would help stabilize the soft tissue and prevent bone resorption. On PS implants, circular orientation of collagen fiber was observed as the main arrangement in a cross-sectional view. The circular collagen fibers might be the key factor in stabilizing the soft tissues around the rehabilitation, inhibiting apical migration of the soft tissues and, in turn, protecting the underlying bone.
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The use of dental implants is a successful treatment option for carrying out oral rehabilitations. Its long-term results are well documented.[1] Successful treatment of a maxillary esthetic zone is determined not only by osseointegration but also by the stability of soft tissues around the rehabilitation and how well it mimics nature. Soft tissue stability is also an important factor in the amount of bone resorption.[2] Early peri-implant bone resorption has been mainly explained by two hypotheses.[3] One is directly connected to the effect of the inflammatory cell infiltration produced by the implant-abutment interface (microgap).[4] The other is associated with connective tissue (CT) stabilization, whereby the circular fibers on the rehabilitation surface protect the internal medium.[5] Achieving soft tissue stabilization as coronal as possible is one of the main objectives in obtaining esthetic results, and may help to diminish early peri-implant bone resorption.[6]

Various authors have demonstrated different arrangement of the fibers of the connective tissue around implants in dogs and humans: parallel to long-axis,[5,7] circular or ring-shaped,[6,8,9] or inserted.[10,11] To the best of the present authors' knowledge, there are few human histologic studies that show connective tissue arrangement around the PS implant with a conical abutment profile.[11] The objective of this study was to evaluate the relationship between the arrangement of the CT fibers around PS implants with a conical abutment profile and early peri-implant bone resorption.

Materials and methods

Study population

Five healthy adult patients (4 males and 1 female) volunteered to participate in the study and signed an informed consent form based on the Helsinki Declaration of 1975, as revised in 2013. The patients required implants for implant-supported restorations and were thoroughly informed regarding the nature of the study. The patients received implant treatment and restoration at no cost.

Inclusion criteria

Patients included in this study were adults 18 years of age or older who needed one or more posterior implants in the maxilla or mandible to replace a single tooth. Patients were described as being light smokers (≤ 10 cigarettes/day) or heavy smokers (≥ 20 cigarettes/day).

Exclusion criteria

Subjects who suffered from untreated and uncontrolled periodontal disease, uncontrolled diabetes, or any other systemic disease that would compromise postoperative healing and/or osseointegration were excluded from this study.

Study design

Five consecutive human biopsies were harvested to be analyzed by light and electron microscopy. The arrangement of the peri-implant fibers around 5-mm-diameter implants using 4-mm-diameter conical healing abutments with PS design was documented.

Surgical methods

After local anesthesia was administered (Ultracain 4% 1:100.00, Normon Laboratories), crestal incisions were made and a full-thickness mucoperiosteal flap was elevated. Implant preparations were performed using a rotary instrument at 900 rpm with a surgical splint. Five full-acid-etched surface implants with a 5-mm platform diameter (Biomet 3i) were placed at subcrestal level, according to the manufacturer guidelines. Four implants were placed in the posterior maxilla, and one in the posterior mandible (Osseotite Certain Prevail, Biomet 3i).

A conical healing abutment (4-mm diameter) was placed at the time of surgery if a primary stability of greater than 35 N was attained. All implants achieved more than 35 N of torque. The technician had previously reduced the healing abutment diameter by means of a diamond burr up to 3 mm wide with a conical shape. This procedure allowed design of the proper shape and obtaining of a wider specimen, avoiding iatrogenic effects. The healing abutment was inserted manually at 15 N (Fig 1a).

The mucoperiosteal flaps were closed without tension using interrupted 5-0 monofilament suture (Arago). All sutures were removed within 2 weeks. To prevent infections, the patients received amoxicillin 875 mg after surgery as well as regular postoperative instructions. After 8 weeks without disconnecting the abutment, radiographs were taken in each case. The distance from the implant platform to the first bone-to-implant contact in the mesial and distal areas was measured. After this, a full-thickness mesiodistal biopsy of the gingiva surrounding the abutment was harvested by means of a 5-mm-diameter punch, the size of the implant platform. In some cases, a scalpel was necessary to fully remove the soft tissue sample. Each sample included the soft tissue around the abutment from the epithelium to the periosteum (Figs 1b and 1c).

To fill the gap produced by the gingivectomy after the soft tissue sample was harvested, all the patients were rehabilitated with wide emergence profile abutments following the standard protocol for the molar area.

Specimen preparation and analysis

Each of the five samples was divided into halves through the long axis of the implant using a bandsaw. One of

Fig 1 *Clinical view of one case* (a) *at the time of insertion and* (b) *at harvesting time, and* (c) *the biopsy specimen removed from the oral cavity.*

the halves was submerged in glutaraldehyde to be observed with scanning electron microscopy (SEM). The other half was submerged in 10% formol and was divided again into halves. One was observed in cross section and the other from a long axis point of view (Fig 2).

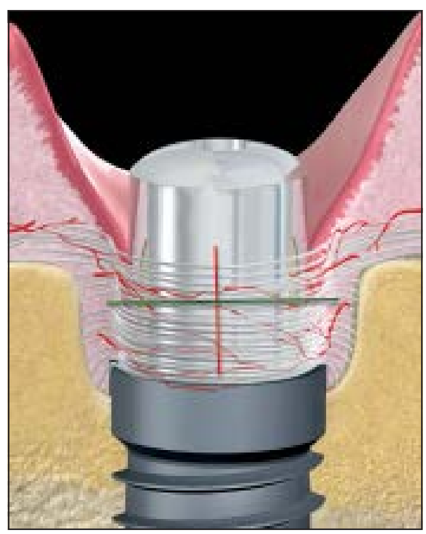

Fig 2 (left) *Specimen preparation. The red line indicates the long axis cut, and the green line shows the cross-section cut.*

Fig 3 (below) *Radiograph taken 8 weeks after surgery. Note the healthy peri-implant status and bone level.*

Light microscopy

All the specimens were stained with hematoxylin-eosin and Masson trichrome for examination under an optical microscope with polarized light at original magnifications of ×10, ×40, and ×400.

A histomorphometric analysis was made that included the following:

- Peri-implant bone resorption: distance from the implant platform to the first bone-to-implant contact (fBIC) on radiographs
- Length of the CT: Distance from the bottom of the JE to the bottom of the CT
- Length of the JE: Distance from the apical part of the JE to the coronal area where the epithelium became keratinized
- Orientation of the axis of the connective tissue fibers

Scanning electron microscopy

All the specimens were coated with gold to be examined under SEM at magnifications of ×500, ×3,500 and ×14,000.

Results

Clinical and radiographic findings

All implants were clinically stable, and radiographic examination suggested clinical osseointegration (Fig 3). The peri-implant tissue found on the healing abutment demonstrated no signs of clinical inflammation at the 8-week postoperative recall. Radiographic observations revealed

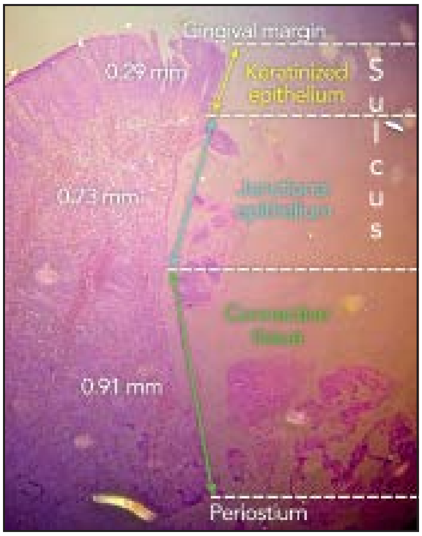

Fig 4 *Sample stained with hematoxylin-eosin (×10). The mean keratinized area* (yellow arrow) *and the mean length of the JE* (blue arrow) *and CT* (green arrow) *are shown.*

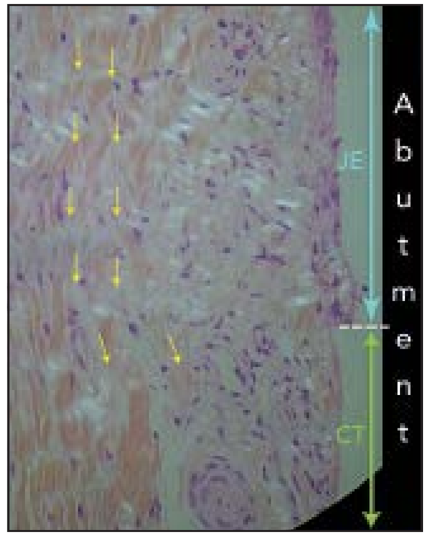

Fig 5 *Long axis view: longitudinal cut specimen stained with hematoxylin-eosin. The area previously occupied by the abutment is shown in gray. The cut was done at the bottom of the JE. A simple layer of three to four epithelial cells at the bottom of the JE is noted* (blue arrow). *Below the JE, the CT fibers are in close contact with the abutment surface* (green arrow). *The direction of the CT fibers is indicated by the yellow arrows.*

Fig 6 *Cross-sectional view: transversal cut specimen stained with Masson trichrome. The area previously occupied by the abutment is shown as a gray circle. The cut was done at the bottom of the JE. A simple layer of epithelial cells is noted* (blue arrows). *An absence of epithelial cells was noted in some areas* (black arrows). *The direction of the CT fibers is indicated by the yellow arrows. The fibers perpendicular to the abutment became circular when they reached the rehabilitation.*

maintenance of the crestal bone level around all implants. No signs of peri-implant disease or significant peri-implant bone loss were found (Fig 3). The mean distance from the implant platform to the fBIC was 0.17 mm (SD 0.21 mm) with a range of 0 to 0.68 mm.

Histologic findings with light microscope

No samples showed histologic signs of peri-implant disease, no evidence of inflammatory cell infiltrate was found, and mature connective tissue with abundant collagen fibers was observed around the healing abutments. The sulcus area was divided into two parts: the keratinized area, from the gingival margin (GM) to the area where the epithelium lost the keratinized tissue, and the JE.

The mean length of the keratinized area was 0.29 mm (SD 0.03 mm) with a range of 0.26 to 0.38 mm. The mean length of the JE was 0.73 mm (SD 0.13 mm) with a range of 0.56 to 0.98 mm. The mean thickness of the CT was 0.91 mm (SD 0.11 mm) with a range of 0.78 to 1.12 mm (Fig 4). The main arrangement of the fibers was parallel on a long-axis cut of the implant (Figs 2 and 5), and in a cross section of the implant the main arrangement of the fibers was circular (Figs 2 and 6). The level of the interface between the JE and the CT fibers in direct contact with the rehabilitation was placed coronally to the implant abutment interface (Fig 5).

Histologic findings with SEM

Histologic samples showed a soft tissue free of inflammation. The characteristics of the apical part of the JE are shown in Fig 7.

A dense matrix of CT fibers provided a scaffold for the JE cells. When the samples were accurately analyzed (×14,000), the direction of the CT fibers showed a main circular orientation surrounding the abutment (Fig 8).

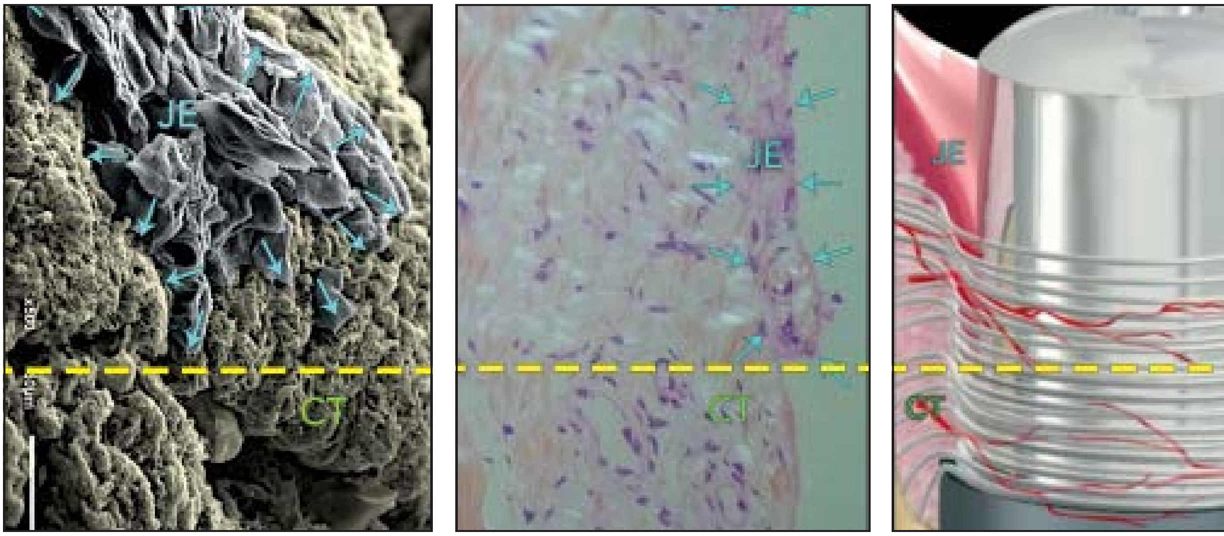

Fig 7 (a) *The inner part of the soft tissue interphase seen through the SEM (×500 magnification). The abutment has been removed and the picture shows the epithelium and CT fibers facing the abutment. The blue arrows show the bottom of the JE.* (b) *Coronoapical view of the sample through the optic microscope (×400 magnification). The blue arrows show the most apical epithelium cells of the JE.* (c) *Illustration of a PS implant with a conical abutment showing the implant-abutment tissues to clarify the architecture of the epithelium and connective tissue shown in* (a) *and* (b). *All three images are oriented in the same direction.*

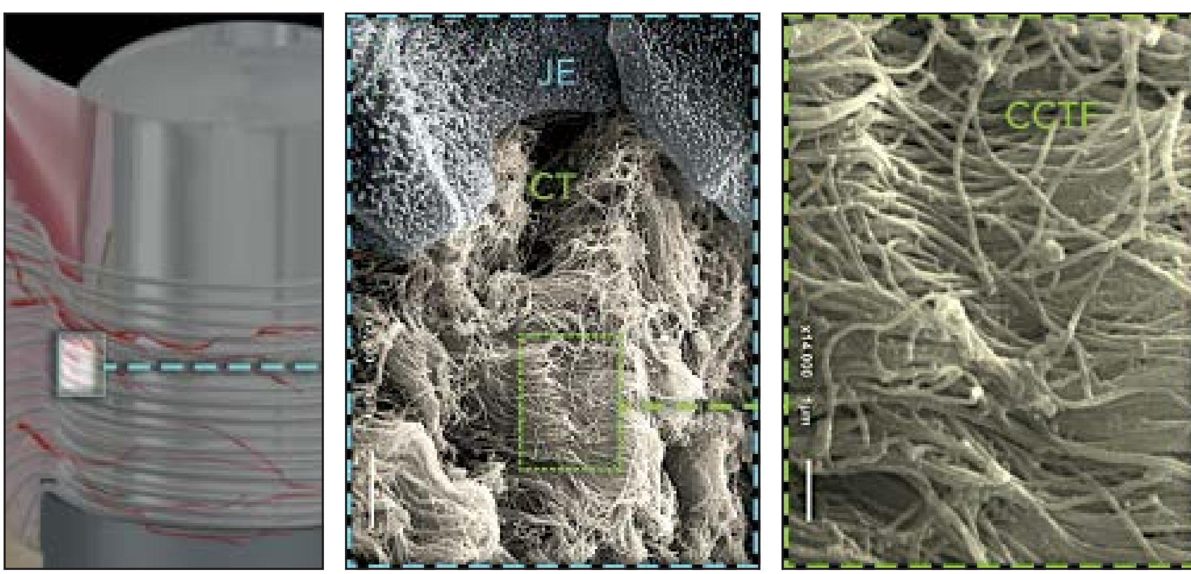

Fig 8 (a) *Illustration of a PS implant with a conical abutment. The blue rectangle highlights the area represented in* (b). (b) *SEM image at the level of the JE (×3,500) showing the most apical part of the two epithelial cells of the JE. Both lie on the CT fibers. This picture demonstrates the role of the CT fibers in inhibiting the apical migration of the JE. The green rectangle highlights the area represented in* (c). (c) *SEM image showing CT fibers (×14,000). A predominant horizontal direction surrounding the abutment is noted; these fibers assumed a circular arrangement.*

Discussion

In the present study, the samples were harvested after 8 weeks of healing. Several authors have shown that the soft tissue barrier adjacent to titanium implants was fully developed in 8 weeks in animals and humans.[12,13]

It is well known that the connective tissue forms a protective barrier around the implant or the abutment.[7] When the connective

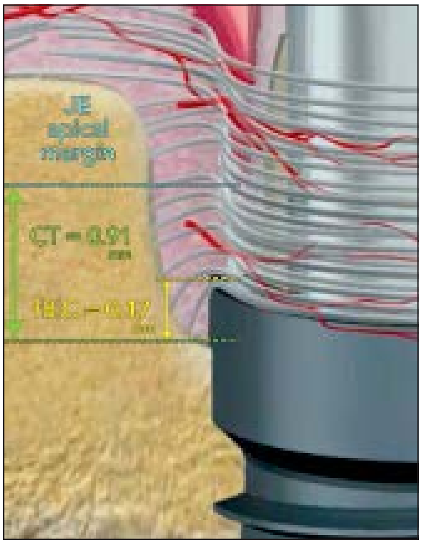

Fig 9 *Outline of a PS implant with conical abutment. The area between the apical margin and fBIC is occupied by CT fibers.*

tissue is stabilized, it prevents the apical migration of the epithelium and dictates how much bone resorption occurs.[8] It could be argued that the connective tissue acts like a ring-seal barrier, providing better resistance to mechanical and bacterial aggressions.[14] The PS concept introduced by Lazzara and Porter establishes a biologic width more coronal to the implant-abutment interface, retaining the connective tissue fibers above the platform level.[15] This allows an adequate fBIC at the platform level. In contrast, matched implants establish the biologic width apical to the implant-abutment interface up to the level of the first thread.[16–18]

From a clinical point of view, the predictability and success of the implant rehabilitation treatment are associated with the presence of a good soft tissue thickness.[2,19,20] Several studies suggested that leaving space for the peri-abutment soft tissues improved the fBIC and the esthetic results.[2,15,21,22] These studies reported better peri-implant bone preservation and esthetic success when using PS concave abutments, straight abutments, or convergent abutments than when anatomical abutments were used. In the present study, the peri-implant soft tissues showed good thickness from the clinical point of view.

From a radiologic perspective, a systematic review and meta-analysis showed that PS design may preserve peri-implant bone height and soft tissue level.[23] This study also showed that the degree of marginal bone resorption was inversely linked to the extent of the implant-abutment mismatch. Thus, the greater the peri-implant soft tissue thickness, the more peri-implant bone was preserved. In the present study, the radiologic analysis showed good peri-implant bone preservation with a mean of 0.17 mm (SD 0.21 mm) of bone resorption.

From a histomorphometric point of view, the following findings have to be considered:

- In the present study, the mean length of the sulcus (epithelial portion, keratinized epithelium, and JE) measured 1.02 mm (SD 0.16 mm). This epithelial length was shorter compared with another human histologic study that showed a mean epithelial length of 2.0 mm (SD 0.9 mm).[13] The differences between these studies could be due to the sample number or the abutment shape.
- In the present study, the mean CT thickness was 0.91 mm (SD 0.11 mm). This agrees with another human histologic study that showed a mean CT thickness of 1.1 mm (SD 0.9).[13]
- Taking into account both fBIC and the thickness of the soft tissues, the authors highlight the relationship between the rehabilitation shape and the peri-implant tissues as follows: The mean fBIC was located 0.17 mm apical to the implant platform. Coronal to the bone, the mean CT thickness was 0.91 mm. This means that a CT thickness of 0.74 (0.91 mm – 0.17 mm = 0.74 mm) remained over the implant platform. Coronal to the stable CT lay the JE (Fig 9).

From a histologic point of view, the shape of the implant-abutment rehabilitation is related to the fBIC. It has been suggested that the first point of the rehabilitation might retain the CT fibers where its diameter begins to widen.[6] This agrees with the results of the present study showing that the fBIC started just below this point (Fig 9).

An animal histologic study showed that implant-abutment connections with a concave profile established crestal bone levels immediately apical to the concavity regardless of the microgap variable.[3] Thus, the part of the implant rehabilitation where the diameter increases could act as a stop for the apical migration of the soft tissues during the reestablishment of the biologic width (Fig 8).[3,6] Several authors have suggested in human and animal histologic studies that the circular CT fibers around the rehabilitation may stabilize the CT on the rehabilitation surface (Fig 6).[9,24] This would allow preservation of the peri-implant bone from resorption.[3,6] This hypothesis agrees with the results of the present study, which shows that 81% of the CT thickness is stabilized or retained by the implant abutment discrepancy. Furthermore, from a clinical point of view it has been suggested that the conical shape of this kind of abutment would allow more soft tissue thickness than the divergent shape abutments.[25]

The present study agrees with the results of a human histologic study regarding the presence of a dominant circular system of collagen fibers around the abutment.[24] Several human and animal histologic studies noted that the circular fibers might be of clinical relevance as a mechanical protection for the underlying bone-implant interface.[6,9,24,26]

Furthermore, mature CT seems to interfere more effectively than granulation tissue with epithelial downgrowth.[8,27] Thus, it might be hypothesized that the more CT function enhances the shorter JE, the less peri-implant bone is resorbed. In the present study, the sulcus length was shorter than in similar human histologic studies, and the bone resorption was minimal compared with similar radiologic studies.[13,23] Thus, the circular fibers might be the key factor in stabilizing the soft tissues around the rehabilitation and, in turn, protecting the bone.

This finding could have clinical relevance to obtaining esthetic results and preserving the internal medium, protecting against bone resorption. The use of a PS rehabilitation design would allow stabilization of the soft tissues in a more coronal position, and the convergent abutment shape could enhance the stability and walling-off function of the soft tissues by leaving more space for the circular CT fibers.[23]

Some limitations should be considered. The implants in this study were not loaded, and permanent abutments were not used. The radiographic and histologic observations were made only on PS abutments, and no negative controls with standard (nonswitched) abutments were included. Therefore, this study cannot exclude the possibility that the same results could have been achieved without switching the abutment diameter.

Conclusions

Keeping in mind the limitations of this study, it could be concluded that the CT is of crucial importance in stabilizing the apical migration of the epithelium and protecting the bone from resorption. The discrepancy in diameter between the implant and the abutment might establish a point at which the circular CT fibers might be retained. The use of a conical abutment profile might leave more space for better soft tissue stabilization. The circular fibers might be the key factor for stabilizing the soft tissues around the rehabilitation, inhibiting the apical migration of the soft tissues, and in turn, protecting the underlying bone.

Acknowledgments

The authors reported no conflicts of interest related to this study.

References

1. Simonis P, Dufour T, Tenenbaum H. Long-term implant survival and success: A 10-16-year follow-up of non-submerged dental implants. Clin Oral Implants Res 2010;21:772–777.
2. Rompen E, Raepsaet N, Domken O, Touati B, Van Dooren E. Soft tissue stability at the facial aspect of gingivally converging abutments in the esthetic zone: A pilot clinical study. J Prosthet Dent 2007;97:S119–S125.
3. Caram SJ, Huynh-Ba G, Schoolfield JD, Jones AA, Cochran DL, Belser UC. Biologic width around different implant-abutment interface configurations. A radiographic evaluation of the effect of horizontal offset and concave abutment profile in the canine mandible. Int J Oral Maxillofac Implants 2014;29:1114–1122.
4. Ericsson I, Persson LG, Berglundh T, Marinello CP, Lindhe J, Klinge B. Different types of inflammatory reactions in peri-implant soft tissues. J Clin Periodontol 1995;22:255–261.
5. Berglundh T, Lindhe J. Dimension of the periimplant mucosa. Biological width revisited. J Clin Periodontol 1996;23:971–973.

6. Rodríguez X, Vela X, Calvo-Guirado JL, Nart J, Stappert CF. Effect of platform switching on collagen fiber orientation and bone resorption around dental implants: A preliminary histologic animal study. Int J Oral Maxillofac Implants 2012;27:1116–1122.
7. Abrahamsson I, Berglundh T, Wennström J, Lindhe J. The peri-implant hard and soft tissues at different implant systems. A comparative study in the dog. Clin Oral Implants Res 1996;7:212–219.
8. Rompen E, Domken O, Degidi M, Pontes AE, Piattelli A. The effect of material characteristics, of surface topography and of implant components and connections on soft tissue integration: A literature review. Clin Oral Implants Res 2006; 17:S55–S67.
9. Ruggeri A, Franchi M, Marini N, Trisi P, Piatelli A. Supracrestal circular collagen fiber network around osseointegrated nonsubmerged titanium implants. Clin Oral Implants Res 1992;3:169–175.
10. Nevins M, Nevins ML, Camelo M, Boyesen JL, Kim DM. Human histologic evidence of a connective tissue attachment to a dental implant. Int J Periodontics Restorative Dent 2008;28:111–121.
11. Nevins M, Camelo M, Nevins ML, Schupbach P, Kim DM. Connective tissue attachment to laser-microgrooved abutments: A human histologic case report. Int J Periodontics Restorative Dent 2012; 32:385–392.
12. Berglundh T, Abrahamsson I, Welander M, Lang NP, Lindhe J. Morphogenesis of the peri-implant mucosa: An experimental study in dogs. Clin Oral Implants Res 2007;18:1–8.
13. Tomasi C, Tessarolo F, Caola I, Wennström J, Nollo G, Berglundh T. Morphogenesis of peri-implant mucosa revisited: An experimental study in humans. Clin Oral Implants Res 2014;25: 997–1003.
14. Berglundh T, Lindhe J, Ericsson I, Marinello CP, Liljenberg B, Thomsen P. The soft tissue barrier at implants and teeth. Clin Oral Implants Res 1991;2:81–90.
15. Lazzara RJ, Porter SS. Platform switching: A new concept in implant dentistry for controlling postrestorative crestal bone levels. Int J Periodontics Restorative Dent 2006;26:9–17.
16. De Bruyn H, Vandeweghe S, Ruyffelaert C, Cosyn J, Sennerby L. Radiographic evaluation of modern oral implants with emphasis on crestal bone level and relevance to peri-implant health. Periodontol 2000 2013;62:256–270.
17. Davarpanah M, Martinez H, Tecucianu JF. Apical-coronal implant position: Recent surgical proposals. Technical note. Int J Oral Maxillofac Implants 2000;15:865–872.
18. Oh TJ, Yoon J, Misch CE, Wang HL. The causes of early implant bone loss: Myth or science? J Periodontol 2002;73: 322–333.
19. Saadoun AP, Touati B. Soft tissue recession around implants: Is it still unavoidable?--Part I. Pract Proced Aesthet Dent 2007;19:55–62.
20. Zucchelli G, Mazzotti C, Mounssif I, Marzadori M, Stefanini M. Esthetic treatment of peri-implant soft tissue defects: A case report of a modified surgical-prosthetic approach. Int J Periodontics Restorative Dent 2013;33:327–335.
21. Vela-Nebot X, Rodríguez-Ciurana X, Rodado-Alonso C, Segalà-Torres M. Benefits of an implant platform modification technique to reduce crestal bone resorption. Implant Dent 2006;15:313–320.
22. Ah SY, Han CH, Heo SJ, et al. Soft tissue responses to differential shapes of the implant abutment. J Periodontol Implant Sci 2006;36:167–176.
23. Atieh MA, Ibrahim HM, Atieh AH. Platform switching for marginal bone preservation around dental implants: A systematic review and meta-analysis. J Periodontol 2010;81:1350–1366.
24. Schierano G, Ramieri G, Cortese M, Aimetti M, Preti G. Organization of the connective tissue barrier around long-term loaded implant abutments in man. Clin Oral Implants Res 2002;13:460–464.
25. Zucchelli G, Mazzotti C, Mounssif I, Mele M, Stefanini M, Montebugnoli L. A novel surgical-prosthetic approach for soft tissue dehiscence coverage around single implant. Clin Oral Implants Res 2013;24:957–962.
26. Degidi M, Perrotti V, Shibli JA, Novaes AB, Piatelli A, Iezzi G. Equicrestal and subcrestal dental implants: A histologic and histomorphometric evaluation of nine retrieved human implants. J Periodontol 2011;82:708–715.
27. Chehroudi B, Gould TR, Brunette DM. The role of connective tissue in inhibiting epithelial downgrowth on titanium-coated percutaneous implants. J Biomed Mater Res 1992;26:493–515.