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Immediate implants at fresh extraction sockets: an experimental study in the beagle dog comparing four different implant systems. Soft tissue findings

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Abstract

Objectives: To evaluate whether different implants placed immediately upon tooth extraction may affect the dimension and composition of the peri-implant soft tissues.

Material and Methods: Eight beagle dogs received implants randomly installed into the distal socket of 3P3 and 4P4. Four commercially available implant systems were evaluated: 3i Osseotite Certain straight; Astra MicroThread™-OsseoSpeed™; Thommen SPI Element®; and Straumann ITI standard. Each animal provided four test implant sites. All animals were sacrificed 6 weeks after implant placement, providing specimens for the evaluation of the soft tissue dimensions by histometric analysis.

Results: The biological width at 6 weeks after implant placement consisted of a junctional epithelium measuring between 2 and 2.7 mm and a connective tissue component between 1 and 1.8 mm with no statistical differences among the four implant systems.

Conclusion: This study failed to demonstrate differences in the soft tissue healing outcome when placing four different implant systems into fresh extraction sockets. Nevertheless, the length of the epithelium achieved with the four implant systems is longer than what has been reported when placing implants in healed-ridge experimental models.

Key words: biological width; fresh extraction socket; implant surface; soft tissue barrier

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Immediate implant placement after tooth extraction (type I protocol; Hämmerle et al. 2004) has become a common surgical approach in clinical practice. The outcome of this procedure has been shown to be as predictable as placing implants into healed sites, with reported survival rates ranging between 93% and 100% (Polizzi et al. 2000, Schropp et al. 2003, Covani et al. 2004, Ganeles & Wismeijer 2004, Botticelli et al. 2008).

Histological studies investigating the healing of implants placed into fresh extraction sockets and in healed ridges have shown that similar patterns of osseointegration occur in both humans (Wilson et al. 1998, Paolantonio et al. 2001) and animals (Anneroth et al. 1985). An experimental study in the dog showed, however, that implants placed into fresh extraction sockets were associated with marked osteoclastic activity, resulting in dimensional alterations, both in width and in height, of the buccal and lingual socket walls (Araujo et al. 2005). Botticelli et al.

Conflict of interest and source of funding statement

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(2004) corroborated these findings in humans, demonstrating that the buccal–lingual dimensions of the ridge were markedly reduced (buccal >50%, lingual about 30%) 4 months after the immediate placement of implants.

Besides these changes in the alveolar ridge dimensions surrounding an immediately placed dental implant, it is also relevant to study how the surgical technique and the implant design may influence the peri-implant soft tissue healing. There is a constant dimension of the soft tissue attachment to dental implants, termed ''peri-implant biological width'', which has been documented in several studies (Berglundh et al. 1991, Buser et al. 1992). In natural teeth, the combined dimensions of the sulcus depth (SD), junctional epithelium (JE) and connective tissue attachment average 1.34 (SD 0.84), being 1.14 (SD 0.49) of epithelium and 0.77 (SD 0.32) mm of connective tissue (Vacek et al. 1994). Berglundh & Lindhe (1996) studied the biological width around implants demonstrating similar dimensions, with a mean JE of 2.1 mm and a connective tissue component of 1.8 mm. These dimensions were later confirmed evaluating the morphogenesis of the peri-implant mucosa around dental implants placed into edentulous ridges. Results from this experimental study in the Labrador dog reported that the peri-implant biological width dimension and composition were stable between 6 and 12 weeks after implant insertion (Berglundh et al. 2007).

Different experimental studies on implants placed into healed ridges have demonstrated that this peri-implant soft tissue dimension is independent of (i) the implant surface (Abrahamsson et al. 2002); (ii) the implant design, whether it is a one-piece or a two-piece implant (Abrahamsson et al. 1996); (iii) the implant loading conditions (Cochran et al. 1997); and (iv) the surgical protocol, whether it is submerged or non-submerged healing (Abrahamsson et al. 1999). It has been demonstrated, however, that the implant shoulder position with respect to the alveolar ridge may influence the healing of the soft tissues. A clear tendency towards a longer dimension of the biological width was observed in an experimental animal when implants were placed in a subcrestal position (Pontes et al. 2008). Different abutment materials have also been investigated with respect to soft tissue healing (Abrahamsson et al. 1998). Although similar soft tissue dimensions were attained when comparing titanium and gold alloy abutments (Abrahamsson & Cardaropoli 2007), Welander et al. (2008) demonstrated a marked apical shift of the epithelial barrier and increasing dimensions of the biological width when Au–Pt alloy abutments were used.

Although the concept of biological width around implants placed into healed edentulous ridges has been investigated extensively, only limited information is available on the soft tissue dimensions when implants are placed immediately upon tooth extraction. Araújo & Lindhe (2005) reported on the dimensions of the peri-implant biological width when Straumann® implants were placed into fresh extraction sockets. The distance between the marginal portion of the mucosa and the most coronal bone-to-implant contact averaged 3.9 (SD 0.5) and 2.6 (SD 0.4) mm, at the buccal and lingual aspects, respectively. These results were further corroborated by a similar study from the same group (Araujo et al. 2006). However, the only experimental study that compared implants placed in edentulous ridges *versus* implants placed immediately in fresh extraction sockets demonstrated a longer soft tissue barrier at immediately placed implants after 8 months of healing (Schultes & Gaggl 2001). This longer soft tissue dimension in the immediate implant protocol was corroborated in a recent experimental study assessing the formation of the biological width around immediately placed 3i® implants (Vignoletti et al. 2009b). These authors reported a biological width of 5 mm, with 3–3.5 mm of the epithelial component and 1–1.5 mm of the connective tissue component after 8 weeks of healing.

It is, therefore, hypothesized that differences in the soft tissue dimensions in immediately placed implants could be due to different implant designs or surfaces that may influence the healing of peri-implant soft tissues. Hence, the objective of this experimental study was to assess whether different implant systems placed immediately upon tooth extraction would affect the dimensions of the peri-implant soft tissues.

Material and Methods

The experimental model used in this study was described recently in a recent publication (de Sanctis et al. 2009). Briefly, four commercially available implant systems were evaluated (Fig. 1): 3i (Biomet 3i, Palm Springs, FL, USA) Osseotite Certain straight ∅3.25 mm/L = 8.5, 11.0 mm; Astra (Astra Tech, Molndal, Sweden) MicroThread™-OsseoSpeed™ ∅3.5 mm/L = 9.0, 11 mm; Thommen (Thommen Medical AG, Waldenburg, Switzerland) SPI Element® ∅3.5 mm/L = 9.5 mm; Straumann (Straumann AG, Basel, Switzerland) ITI standard ∅3.3 mm/L = 8, 12 mm.

Eight beagle dogs were selected for the study. Each animal provided four test implant sites, with a total of 32 implants studied. Once the animals were anaesthetized, intra-sulcular incisions were performed and full-thickness flaps were reflected in order to gain access to the alveolar crest. Third and fourth pre-molars were then extracted with minimal trauma, aiming to preserve the walls of the sockets. The distal socket of each pre-molar was chosen as the implant-recipient site, while the mesial sockets were allowed to fill with blood and heal without intervention. The four implants were randomly assigned to the distal sockets of 3P3 and 4P4, on each side of the mandible. Osteotomies were performed in the sockets according to the specific implant recommended surgical protocols, ensuring that the implant shoulder was placed at the level of the marginal portion of the buccal plate for 3i and Astra

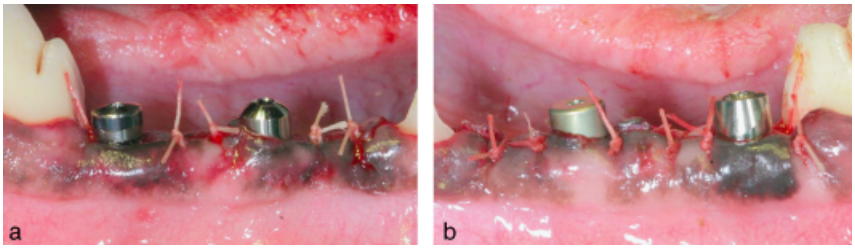

Fig. 1. Flaps were sutured in order to allow a one-stage healing protocol. Four implant systems were tested. (a) Astra 3.5 MicroThread™-OsseoSpeed™ (Astra Tech) and Osseotite Miniplant Certain straight (Biomet 3i). (b) Thommen 3.5 SPI Element® (Thommen Medical) and Straumann 3.3 ITI Standard (AG).

implants. Thommen and Straumann implants presented a coronal polished collar of 1 and 1.8 mm, respectively. Because of this geometrical difference, the implants were inserted in order to leave the polished collars above the alveolar crest. Healing abutments were then secured and the flaps were sutured with 4-0 vicryl resorbable sutures, aiming for non-submerged postoperative healing (Fig. 1a and b). Plaque control was achieved using a chlorhexidine solution sprayed on all mandibular tooth sites on a 3 day/week regimen. Six weeks after implant placement, the animals were sacrificed and biopsies were obtained for histological processing (Fig. 2a and b).

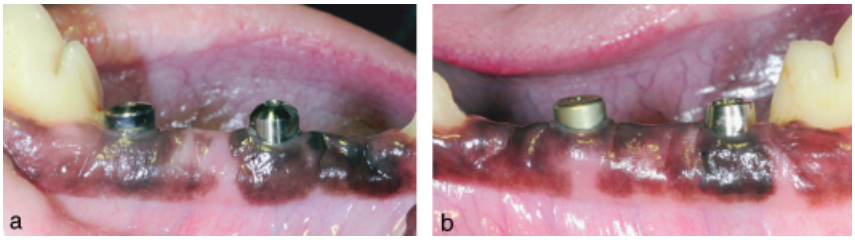

Fig. 2. (a and b) Clinical situation after 6 weeks of healing.

Histological processing

Animals were sacrificed with an overdose of sodium pentothal and perfused with a fixative solution (Karnovsky 1965) through the carotid arteries. The mandibles were freed from their attached tissues and cut in halves by means of a section between the central incisors. Calcified bucco-lingual ground sections were prepared according to the methods described by Donath & Breuner (1982) and in accordance with the protocol outlined by de Sanctis et al. (2009).

Histological and histometric evaluation

The histometric evaluation was carried out using a Nikon Eclipse Ti microscope (Nikon, Heidelberg, Germany) equipped with image analysis software (Q-500 MC; Nikon). Four bucco-lingual sections per animal were analysed and the following landmarks (Fig. 3) were identified on the buccal and lingual side of the implants:

PM: the margin of the peri-implant mucosa.
aJE: the apical border of the JE.
B: the most coronal position of bone-to-implant contact.

Linear distances between the landmarks were measured and expressed in millimetres.

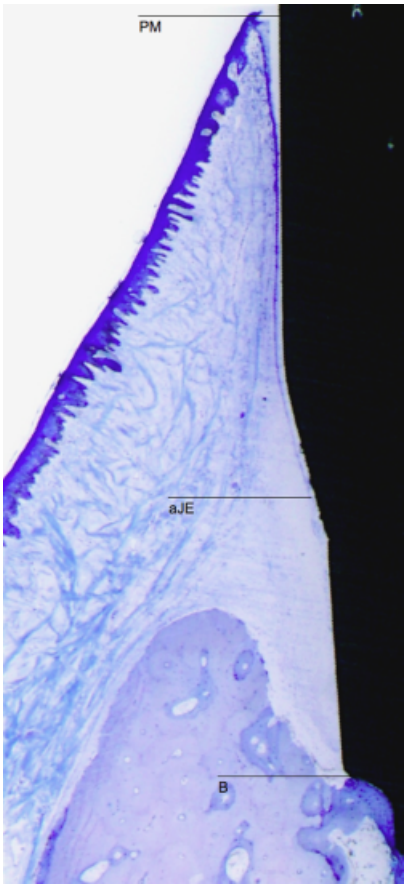

Fig. 3. The following landmarks were identified on the buccal and lingual side of the implants: PM, margin of the peri-implant mucosa; aJE, apical border of the junctional epithelium; B, most coronal position of bone-to-implant contact. Levai Laczko staining. Original magnification × 2.5 (Thommen SPI Element® implant).

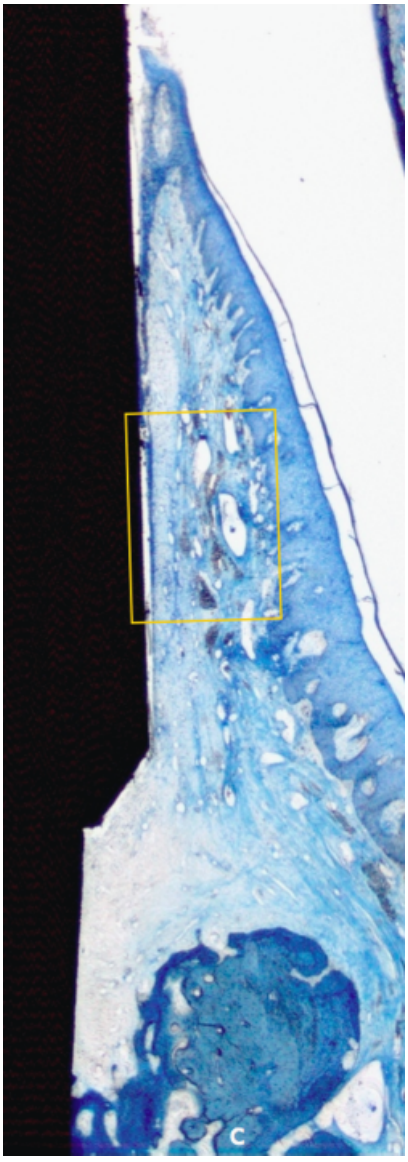

Fig. 4. Ground section representing implant and supracrestal soft tissues. Osseotite Certain straight implant (Biomet 3i). Inset Fig. 5. Levai Laczko staining. Original magnification × 2.5.

Results

Histological observations

The supracrestal soft tissues were composed of a dense connective tissue and a mature JE. The apical extension of the JE was variable, reaching different positions with respect to the healing abutment or the implant surface. The connective tissue was dense and rich in elongated fibroblasts in a zone close to the implant surface. Lateral to this area, collagen fibres running parallel to the long axis of the implant were observed (Figs. 4–7). Occasional inflammatory cells were identified in the proximity of the blood vessels. Gross histological observations made on ground sections demonstrated similar findings between the four implant systems (Figs. 8–11).

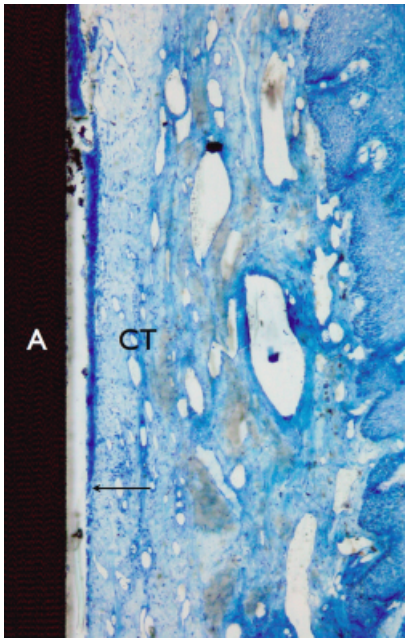

Fig. 5. Most apical extension of the junctional epithelium (arrow). The connective tissue (CT) lateral to the juntional epithelium appears infiltrated with inflammatory cells. A, abutment surface. Original magnification × 10. Levai Laczko staining.

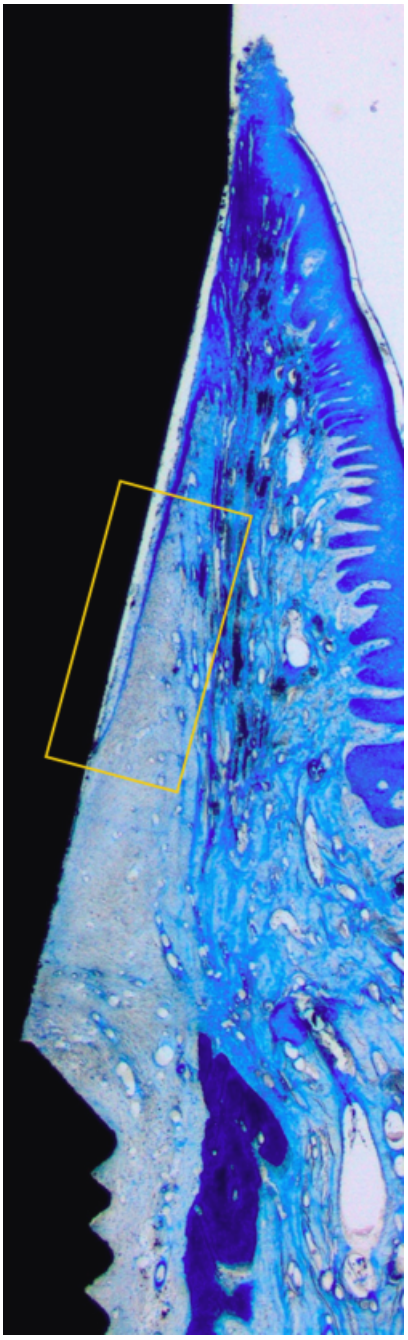

Fig. 6. Ground section representing implant and supracrestal soft tissues. Astra (Astra Tech) MicroThread™-OsseoSpeed™. Inset, Fig. 7. Levai Laczko staining. Original magnification × 2.5.

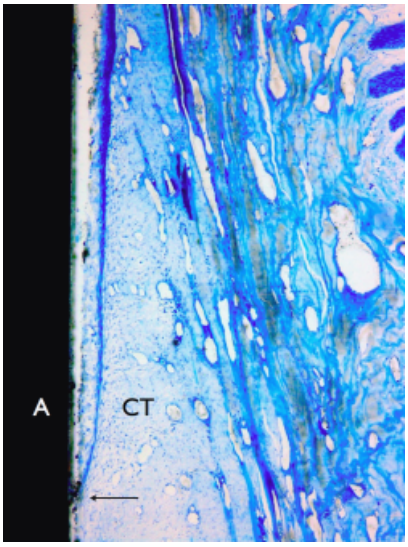

Fig. 7. Most apical junctional epithelium (black arrow). Note the collagen fibres lateral to the cell-rich area of connective tissue (CT) and inflammatory cells close to the vessels. Levai Laczko staining. Original magnification × 10. A, abutment surface.

Histometric analysis

The soft tissue histometric measurements are shown in Tables 1–3. The biological width 6 weeks after implant placement averaged between 3.40–4.17 and 2.85–3.20 mm at the buccal and lingual aspects, respectively. On the buccal aspect, the soft tissue barrier was comprised of a JE that measured between 2.32 and 2.70 mm and a connective tissue ranging between 1.07 and 1.85 mm. The corresponding values at the lingual side were 1.64–2.02 mm of epithelium and 0.93–1.46 mm of connective tissue.

The mean length of the JE at the buccal aspect was 2.33 (SD 0.95), 2.59 (SD 0.89), 2.32 (SD 0.46) and 2.70 (SD 0.63) mm for 3i, Astra Tech, Thommen and Straumann implants, respectively. 3i implants reported the shortest JE, although the differences between the implant systems were not statistically significant (Table 1). The corresponding values at the lingual side were 1.71 (SD 0.68), 1.64 (SD 0.57), 1.77 (SD 0.50) and 2.02 (SD 0.96) for 3i, Astra Tech, Thommen and Straumann implants, respectively. These differences were also not statistically significant.

The mean length of the connective tissue at the buccal aspect amounted to 1.85 (SD 0.83), 1.49 (SD 0.42), 1.07 (SD 0.44) and 1.44 (SD 0.94) for 3i, Astra Tech, Thommen and Straumann implants, respectively. The corresponding values at the lingual side were 1.46 (SD 0.59), 1.21 (SD 0.41), 0.93 (SD 0.47) and 1.18 (SD 0.94) mm for 3i, Astra Tech, Thommen and Straumann implants, respectively. Thommen implants presented the shortest connective tissue length, although differences were not statistically significant (Table 2).

The overall mean length of the biological width was, on the buccal side, 4.17 (SD 0.34), 4.09 (SD 1.38), 3.40 (SD 0.56) and 4.14 (SD 0.94) mm for 3i, Astra Tech, Thommen and Straumann implants, respectively, whereas the corresponding values at the lingual side were 3.18 (SD 0.62), 2.85 (SD 0.42), 2.70 (SD 0.42) and 3.20 (SD 1.01) mm. Thommen implants presented the shortest dimension of biological width both at the buccal and lingual aspects. Nevertheless, differences between the systems were not statistically significant (Table 3).

Discussion

This animal experiment compared four commercially available implant systems and evaluated the influence of the different surfaces and designs on the peri-implant soft tissue dimensions after 6 weeks of healing when implants were placed immediately upon tooth extraction.

The four implant systems used in the present study presented internal connections with different implant/abutment interfaces. Astra Tech implants presented a platform-switch connection by using healing abutments with reduced diameter resulting in a circumferential horizontal wider space. 3i, Thommen

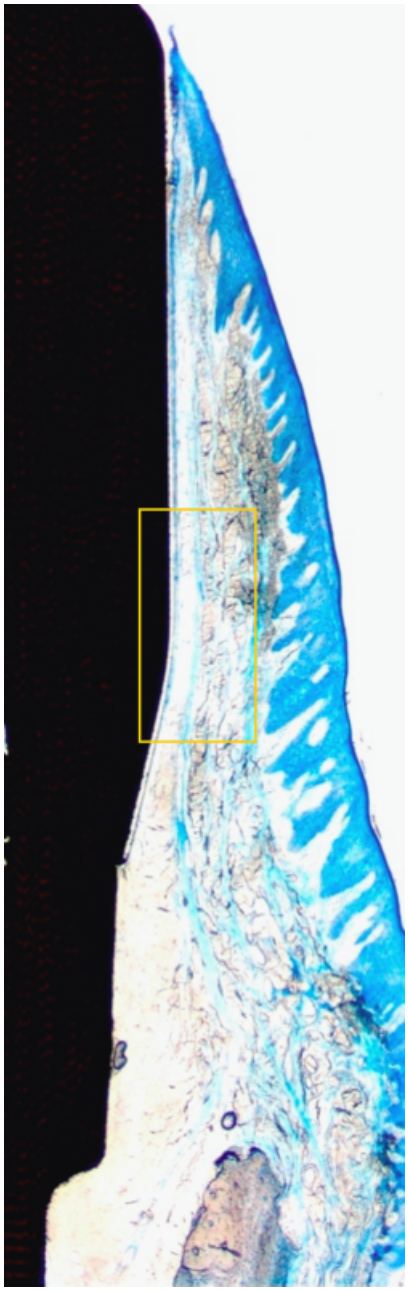

Fig. 8. Ground section representing implant and supracrestal soft tissues (Thommen SPI Element® implant). Inset, Fig. 9. Levai Laczko staining. Original magnification × 2.5.

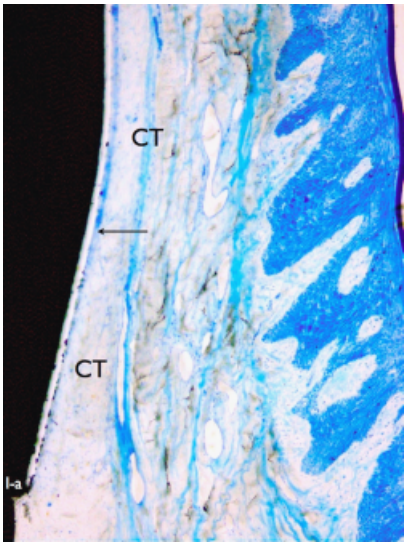

Fig. 9. Most apical extension of the junctional epithelium in intimate contact with the abutment surface (arrow). The connective tissue apical and lateral to it appears to be free of inflammatory cells. I–a, implant–abutment interface. Levai Laczko staining. Original magnification × 10.

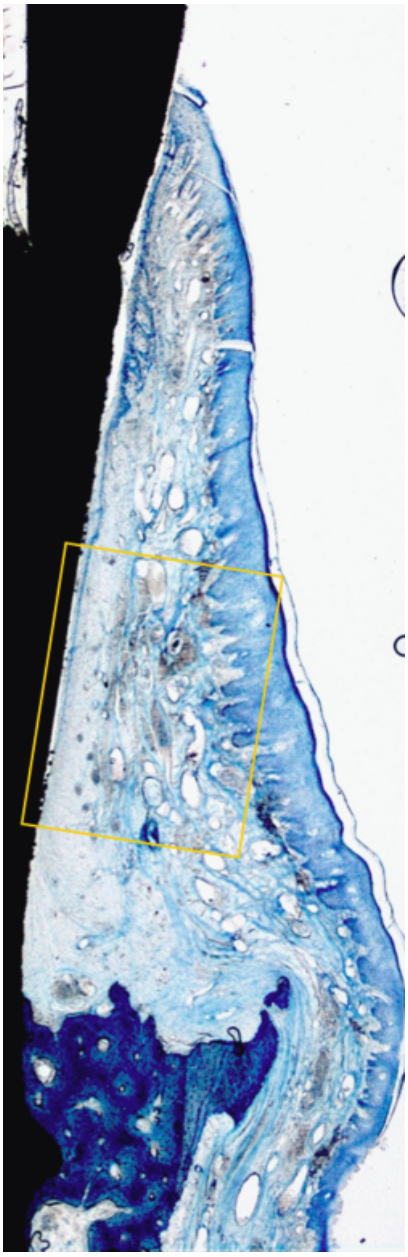

Fig. 10. Ground section representing implant and supracrestal soft tissues. Straumann ITI Standard (AG). Inset, Fig. 11. Levai Laczko staining. Original magnification × 2.5.

and Straumann implants used straight healing abutments of the same diameter of the implant platform. Additionally, Thommen and Straumann implants presented characteristics of one-piece implants with a polished collar of 1 and 1.8 mm, respectively, in comparison with Astra Tech and 3i, placed at the crestal level (two-piece implants). The overall mean dimensions of the peri-implant mucosa ranged between 3.4 and 4.6 mm after 6 weeks of healing of implants placed immediately after tooth extraction. At the buccal aspect, the soft tissue barrier was comprised of an epithelial tissue portion measuring 2.3–2.7 mm and a connective tissue portion measuring 1–1.8 mm. The corresponding values on the lingual side were 1.6–2 and 0.9–1.4 mm, respectively. Although a tendency towards shorter dimensions of both JE and connective tissue was observed for Thommen implants (Tables 1–3), histometric measurements did not demonstrate statistically significant differences when the four systems were compared. Similar to the present experimental design, Abrahamsson et al. (1996) placed one-piece dental implant (Straumann) and two-piece implants (3i and AstraTech) into the healed crest of beagle dogs. The authors evaluated the dimensions of the peri-implant mucosa after 6 months of healing and showed no differences between the three systems.

In recent years, attention in implant dentistry has been directed towards the inward repositioning of the implant/abutment interface, commonly termed as platform switching (Lazzara & Porter 2006). According to this concept, the more internal localization of the implant/abutment interface would limit the influence of the inflammatory cell infiltrate that usually occurs adjacent to the implant/abutment interface, on the crestal bone resorption and soft tissue healing (Ericsson et al. 1995).

Becker et al. (2007) investigated in the beagle dog the influence of a 0.5 mm horizontal mismatch at the implant/abutment interface on the early soft tissue healing of implants placed into healed ridges. The implants with matching healing abutments (control implants) showed, on the buccal aspect, an apical migration of the JE of 0.5 (SD 0.3), 0.7 (SD 0.1) and 0.9 (SD 0.4) mm after 7, 14 and 28 days of healing, respectively.

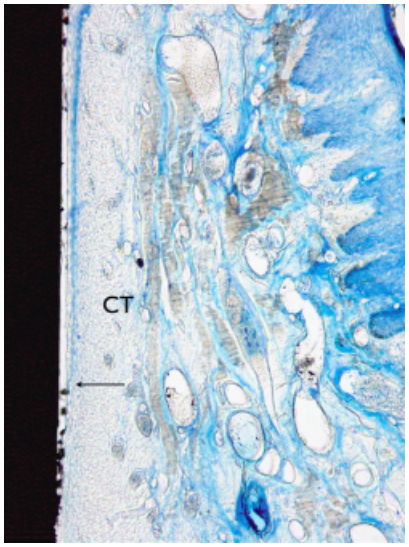

Fig. 11. Most apical extension of the junctional epithelium (arrow). Note the collagen fibres lateral to the cell rich area of connective tissue (CT) and the absence of inflammatory cells. Levai Laczko staining. Original magnification × 10.

Table 1. Results from the histometric measurements (mean and SD)

Implant	PM–aJE buccal	PM–aJE lingual
3i	2.33 (0.95)	1.71 (0.68)
Astra Tech	2.59 (0.89)	1.64 (0.57)
Thommen	2.32 (0.46)	1.77 (0.50)
Straumann	2.70 (0.63)	2.02 (0.96)

See Fig. 3 for landmarks.
PM, the margin of the peri-implant mucosa; aJE, the apical border of the junctional epithelium; SD, standard deviation.

Table 2. Results from the histometric measurements (mean and SD)

Implant	aJE–B buccal	aJE–B lingual
3i	1.85 (0.83)	1.46 (0.59)
Astra Tech	1.49 (0.42)	1.21 (0.41)
Thommen	1.07 (0.44)	0.93 (0.47)
Straumann	1.44 (0.94)	1.18 (0.94)

See Fig. 3 for landmarks.
aJE, the apical border of the junctional epithelium; B, the most coronal position of bone-to-implant contact; SD, standard deviation.

The corresponding values for the test implants were 0.1 (SD 0.1), 0.2 (SD 0.1) and 0.2 (SD 0.1) mm, respectively. The authors concluded that the inward repositioning of the implant/abutment interface limited the down-growth of the JE. Nevertheless, the same group investigated the influence of the platform switching concept after 4, 8, 12 and 24 weeks of healing (Becker et al. 2009). In this second longer term study, the histometric measurements failed to demonstrate statistically significant differences between test and control implants, thus suggesting that the difference observed in the Becker et al. (2007) study disappeared during healing. A different surgical protocol was utilized in this study and the longer (6 weeks) healing period may explain the similar histological outcome observed when the four implant systems were compared irrespective of the different platform/abutment interface.

Table 3. Results from the histometric measurements (mean and SD)

Implant	PM–B buccal	PM–B lingual
3i	4.17 (0.34)	3.18 (0.62)
Astra Tech	4.09 (1.38)	2.85 (0.42)
Thommen	3.40 (0.56)	2.70 (0.42)
Straumann	4.14 (0.94)	3.2 (1.01)

See Fig. 3 for landmarks.
PM, the margin of the peri-implant mucosa; B, the most coronal position of bone-to-implant contact; SD, standard deviation.

Recently, Berglundh et al. (2007) described the morphogenesis of the peri-implant mucosa after placing implants into healed ridges. The authors observed that the overall dimensions of the peri-implant mucosa measured approximately 3.5 mm. The tissue maturation and collagen fibre organization was evident from 6 to 12 weeks of healing, whereas the formation of the barrier epithelium was completed between 6 and 8 weeks. The soft tissue barrier was comprised of a barrier epithelium and a connective tissue that measured approximately 2 and 1.5 mm, respectively. The findings from the present investigation corroborate these results only partially because, although the connective tissue portion demonstrated similar dimensions, the JE was consistently longer, ranging between 2.00 (SD 0.95) and 2.70 (SD 0.63) mm.

The observation of a longer soft tissue barrier at implants placed immediately after tooth extraction has been reported previously by other investigators (Schultes & Gaggle 2001, Rimondini et al. 2005). Results from the latter study showed an average dimension of the JE of 3.02 mm at day 30, which remained stable until day 60. The formation of the peri-implant mucosa after 1 week to 2 months of healing was recently described after immediate implant placement into fresh extraction sockets (Vignoletti et al. 2009b). The authors observed that the epithelium already measured 2.35 (SD 0.84) mm at 1 week of healing. At the end of the study, the mean position of the JE was 3.34 (SD 0.75) mm apical to the mucosal margin. The authors concluded that soft tissue healing around implants placed into fresh extraction sockets may result in a longer epithelial interface than implants placed into a healed ridge.

Blanco et al. (2008) reported shorter soft tissue dimensions by means of a flapless approach as compared with a flapped surgical approach, when placing implants into fresh extraction sockets in the beagle dog. Hence, it may be speculated that the reduced bone resorption that may occur after a flapless extraction may influence the soft tissue healing. The question remains as to whether the less traumatic extraction and implant placement procedure due to the flapless surgical technique may influence the dimensions of the hard and soft tissues. Nevertheless, results from two experimental studies in the beagle dog demonstrated that (i) marked ridge alterations were observed at the buccal aspects of implants placed immediately after tooth extractions, whereas the lingual wall failed to show bone resorption (Vignoletti et al. 2009a), and (ii) soft tissue dimensions around immediately placed implants were similar between the buccal and the lingual aspects (Vignoletti et al. 2009b). Hence, results from these recent investigations may suggest that the longer soft tissue dimensions are independent of the buccal/lingual bone resorption and it is therefore conceivable that other factors, besides bone resorption, must play a role in order to reach this histological outcome.

In conclusion, this animal experimental study showed that different implant designs and surface modifications did not influence the soft tissue dimensions after 6 weeks of healing. Within the limits of this experimental study, a tendency towards longer dimensions of the epithelium was observed with all the implant systems tested. Therefore, a different length of the JE and a different dimension of the overall supracrestal soft tissue barrier may be of clinical relevance and consequently deserves further investigation.

Acknowledgements

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Clinical Relevance

Scientific rationale for the study: Immediate implant placement after tooth extraction is a common surgical protocol in clinical practice. Limited information is available, however, on the possible influence that different implant designs and surface modifications may have on the dimensions of the biological width. It is, therefore, relevant to study whether using implants with a different design would influence the healing outcome when using this surgical protocol.
Principal findings: The histological results failed to demonstrate significant differences among the implant systems studied. The dimensions of the soft tissue barrier were not significantly different when the four implant systems were compared. Nevertheless, these dimensions were longer than what has been reported in similar experimental studies when implants were placed in healed alveolar ridges.
Practical implications: The placement of a dental implant immediately upon tooth extraction may result in different soft tissue dimensions, independent of the type of implant used. This finding may have clinical implications.