Recent studies in animals have shown pronounced resorption of the buccal bone plate after immediate implantation. The use of flapless surgical procedures prior to the installation of immediate implants, as well as the use of synthetic bone graft in the gaps represent viable alternatives to minimize buccal bone resorption and to favor osseointegration. The aim of this study was to evaluate the healing of the buccal bone plate following immediate implantation using the flapless approach, and to compare this process with sites in which a synthetic bone graft was or was not inserted into the gap between the implant and the buccal bone plate. Lower bicuspids from 8 dogs were bilaterally extracted without the use of flaps, and 4 implants were installed in the alveoli in each side of the mandible and were positioned 2.0 mm from the buccal bone plate (gap). Four groups were devised: 2.0-mm subcrestal implants (3.3 \times 8 \text{ mm}) using bone grafts (SCTG), 2.0-mm subcrestal implants without bone grafts (SCCG), equicrestal implants (3.3 \times 10 \text{ mm}) with bone grafts (ECTG), and equicrestal implants without bone grafts (ECCG). One week following the surgical procedures, metallic prostheses were installed, and within 12 weeks the dogs were sacrificed. The blocks containing the individual implants were turned sideways, and radiographic imaging was obtained to analyze the remodeling of the buccal bone plate. In the analysis of the resulting distance between the implant shoulder and the bone crest, statistically significant differences were found in the SCTG when compared to the ECTG ($P = .02$) and ECCG ($P = .03$). For mean value comparison of the resulting linear distance between the implant surface and the buccal plate, no statistically significant difference was found among all groups ($P > .05$). The same result was observed in the parameter for presence or absence of tissue formation between the implant surface and buccal plate. Equicrestally placed implants, in this methodology, presented little or no loss of the buccal bone. The subcrestally positioned implants presented loss of buccal bone, even though synthetic bone graft was used. The buccal bone, however, was always coronal to the implant shoulder.

**Key Words:** immediate implant, synthetic bone graft, tooth socket, tooth extraction, gap filling

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**Introduction**

Since the early dental implant installation techniques, innumerable modifications have been proposed in order to reach faster, less invasive, and more esthetic ways to restore missing teeth. One of
these breakthrough innovations was the development of a technique that comprises the installation of implants immediately after tooth extraction, eliminating the necessity of having to wait for the alveoli to heal, which is the standard procedure under the traditional technique. Among the advantages of immediate implant installation are the reduction in the number of necessary surgical interventions and reduced treatment period, improved implant orientation during its installation, preservation of the tooth extraction area, and improved esthetics of the surrounding soft tissues. High success rates have been documented following immediate implant installation in extraction sockets.

One of the main requirements for success in implants is the maintenance of peri-implant tissues so that osseointegration and esthetic aspects are not jeopardized. Several classic studies from the 1960s showed the resorption of the alveolar process following tooth extraction, which is significantly more pronounced in the buccal region. When teeth are present, blood flow is provided through 3 main sources: the periodontal ligament, the perios- teum, and the bone tissue. After a tooth is extracted, the periodontal ligament disappears, and only 2 nourishment sources remain. In addition, the cortical bone is poorly vascularized when compared to the medullary bone; therefore, when a flap is raised for implant installation, supra-periosteal blood supply ceases, leaving only the poorly vascularized bone without its medullary component, leading to bone resorption in the initial stages. Such bone remodeling in response to inadequate blood supply becomes more critical in the buccal region due to characteristics naturally inherent to this region’s nature and anatomy, which may lead to serious compromises both for osseointegration and esthetics. In light of such facts, not raising a flap before implant installation may represent an alternative to minimize buccal bone plate resorption since such procedure will preserve supraperiosteal vascularization. Moreover, flapless surgeries preserve soft tissue structure and further reduce gingival recession, important factors for esthetics. Other advantages are reduced surgical time, minimized bleeding, and reduced postoperative discomfort for the patient. Some studies show that implants installed under flapless surgeries yield more predictable outcomes, as long as the appropriate technique is employed and patients are well selected.

The correct placing of immediate implants in relation to the alveoli bone walls is another paramount factor for satisfactory results. Since bone tissue suffers constant remodeling, both vertically and horizontally during the healing process, all dimensions must be carefully taken into consideration for adequate implant positioning. Numerous studies have shown that the bone crest is located 1.5 to 2 mm apical to the implant and the abutment junction, regardless of the implant position in relation to the bone crest at implant installation. Such bone loss is justified by the formation of biologic spaces in the peri-implant tissues. However, when implants utilize Morse cone connections, bone crest lies at the same height of the cervical portion of the implant, and bone loss, which is observable with the utilization of internal connection systems, does not occur below the implant shoulder. Furthermore, the abutment is smaller than the implant diameter (platform shifting), which provides better lodging for the peri-implant soft tissues, allowing them to act as a protective barrier for the bone-implant interface. Due to the specific characteristics of the implant-abutment connection, a smaller emergence profile is obtained when the implant is installed more apically.

Regarding the horizontal positioning of immediate implants (buccolingually or mesiodistally), it is common to observe a lack of adaptation to the socket walls in the cervical portion of the implant. This gap can be filled by soft tissues and thus may lead to osseointegration problems. The use of membranes and/or grafting materials to fill the peri-implant residual defects has been proposed. Such procedures can impede epithelial invagination into these defects maintaining the necessary space for osteogenesis. Some authors associate these procedures with some complications, such as membrane exposure and delayed peri-implant bone healing. On the other hand, some studies showed increased bone-implant contact after membranes were utilized. There is no consensus in scientific literature for the need of associating regenerative techniques with immediate implant installation techniques. The use of membranes or grafting materials can be an extra element, but they do not seem to be necessary in all cases. Another question that remains unanswered is whether osseointegra-
tion truly occurs in these regions, due to several characteristics of the involved materials.27

In an attempt to optimize osseointegration, many bone-replacing materials have been presented as an alternative to fill these gaps. These materials, which may be xenogenous, allogenous, or synthetic exhibit osseoconducting properties and act as a scaffold for cell adhesion and proliferation, thus facilitating gap filling.28–30 Among the employed biomaterials are allogenous bone (demineralized freeze-dried bone allograft), anorganic bovine grafts, bovine hydroxyapatite and synthetic hydroxyapatite,27 which have been used in conjunction with immediate implantation with many of them showing successful results.21,26,30

For the development of biomaterials aimed at improving bone healing, some researchers have focused their studies on synthetic grafts. Among such grafts, one can cite biphasic calcium phosphate (BCP), which is being utilized more and more as a bone replacement material in orthopedic, oral, and maxillofacial applications.30,31 Chemically similar to human bone, biphasic calcium phosphate is constituted of a combination of hydroxyapatite (HA) and tricalcium phosphate (TCP), meaning it is a 2-phase material. The dissolution of TCP supplies the basic material for calcium and phosphate ions, thus triggering mineralization. At the same time, HA also maintains the scaffold for osteoblast adhesion and formation of new bone maintaining the volume against excessive resorption.30,32 Consequently, BCP is cited as a biocompatible, bioactive, and osseoconducting bone graft material when implanted into bone defects.33–36

Histologic evaluations demonstrated that BCP promotes osteoblastic and osteoclastic activity characterizing a bone remodeling process 12 weeks later, and making evident the importance of alkaline phosphatase in the osteoblastic formation process.36 In a study by Farinha et al,37 alkaline phosphatase’s resorption and posterior bone migration were observed in the evaluated areas. Additionally, it was noted that the inherent properties of this material positively influence cellular bonding, migration, proliferation, and differentiation, reassuring its potential for mineralization and bone remodeling. Compared to different bone grafts, BCP revealed substantially higher osteogenic capacity, and it also seemed to be as safe and efficient as autogenous bone graft.38

Developed as a new synthetic bone substitute, a specific BCP (BoneCeramic, Straumann, Basel, Switzerland) is a combination of 60% hydroxyapatite \( \text{[Ca}_{10} \text{(PO}_{4}\text{)}_{6} \text{(OH)}_{2}] \) and 40% tricalcium phosphate \( \text{[Ca}_{3} \text{(PO}_{4}\text{)}_{2}] \), which is part of biphasic calcium phosphates. It is composed of interconnected pores ranging from 100 to 500 \( \mu \text{m} \) and has a porosity index of 90%, which grants maximum space for vascularization, osteoblast migration, and new bone formation.

Histologically, it was demonstrated that this specific proportion promoted formation of new nonmineralized and mineralized bone matrices in contact with the particles, which were resorbed at large (74%) when compared to another bone graft (62%) in the period of 6 to 8 months.39 Furthermore, in terms of phase proportion, it was proved that HA’s superior ratio in BCP is associated with a more accelerated bone formation.33

Therefore, the aim of this study was to evaluate radiographically buccal bone plate remodeling following immediate implantation using flapless procedures and comparing this process between sites that received or did not receive BCP in the gap between the implant and the buccal bone plate.

**MATERIALS AND METHODS**

This study protocol was approved by the Experimental Research Ethics Committee of the Campi of Ribeirão Preto, University of São Paulo, Brazil (protocol 06.1.458.53.5).

Eight young adult male dogs of undefined breed, weighing approximately 20 kg each and raised at a private kennel, were used. All selected animals had perfect mandibles, no generalized occlusal trauma, no viral or fungal mouth lesions (Figure 1a), good overall health, and no systemic compromises attested by veterinary exams. The dogs were immunized with vaccines, received antiparasitic treatment, and were submitted to dental prophylaxis using ultrasound for removal of dental plaque and biofilm.

The night preceding the surgeries, the animals received 20 000 IU of penicillin intramuscularly and streptomycin at 1.0 g/10 kg of weight. Since such dosage allows antibiotic coverage for 4 days, a new dose was administered 4 days later, totaling 8 days of antibiotic protection. The previously mentioned broad-spectrum antibiotic is commonly used to...
treat infections in small animals and thus was chosen before the implant surgeries.

The animals were kept in fast since the night preceding the surgical procedures. For the surgery itself, the dogs were preanesthetized with 10% zolazepam at 0.10 mL/kg and acepromazine at 2.0%. Anesthetic maintenance was obtained using volatile anesthetics, and the animals were submitted to tracheal intubation with a Magill probe for adaptation of the anesthetic device and for administration of isoflurane (2%). Additionally, local anesthesia was used at the bicuspid (P1, P2, P3, and P4) regions.

The procedures for extraction of the 4 lower bicuspsids were completed without flaps (Figure 1b and c). The teeth were buccolingually sectioned so the roots could be removed with as little trauma as possible avoiding damage to the alveoli bone walls (Figure 1b). The following sockets were selected for implant placement (Bone Level SLActive, Straumann): P2 mesial, P3 distal and mesial, and P4 mesial, totalling 4 implants in each side of the mandible (Figure 1c and d). All implants were positioned so that their cervical portion was placed 2.0 mm from the buccal bone plate (buccolingually), allowing a 2.0-mm gap (Figure 1e). On one side, 4 implants measuring 3.3 × 8 mm were positioned 2.0 mm subcrestally (apicocoronally), and on the other side, 4 implants measuring 3.3 × 10 mm were positioned equicrestally.

Following implant installation, the transfers were placed for silicon impression and fabrication of the temporary restoration (Figure 1f). The 4 implants where then placed in each hemimandible, and 2 received BCP for gap filling between the implant and buccal alveolar bone wall; 2 others received no grafting material and thus healed solely with the aid of the coagulum (Figure 2a and b). The following groups were devised: equicrestal with BCP (test, ECTG), equicrestal with coagulum (control, ECCG), subcrestal BCP (test, SCTG), and subcrestal with coagulum (control, SCCG).

Once the implants were in place, the relation between the installed implant and the buccal bone plate was verified, and the distance between the cervical-most portion of the implant and the buccal bone plate was registered, as well as the distance between the implant and the lingual bone plate buccolingually, whenever applicable. The next step was the adaptation of the protective covering screws (Figure 2c).

The remaining sockets (P2 distal and P4 distal)
were used to study the dynamics of the healing process in flapless surgical sites, with or without the use of BCP (Figure 2b). Randomly, in 1 hemimandible, 1 socket received the graft and the other did not; on the opposing side, this order was inverted. Posteriorly, the wounds were sutured with silk suture 4-0 (Shalon, São Luís de Montes Belos, GO, Brazil) in both sides of the mandible.

The animals received analgesic, nonsteroidal anti-inflammatory agents and multivitamin complex shots. Seven days later, sutures were removed, prosthetic connections were adapted, and temporary metallic prostheses were installed at the same time, thus characterizing the presence of an early load (Figure 2d).

The dogs were weekly anesthetized for mineralized biofilm removal with ultrasound and use of chlorhexidine digluconate sprays at 0.12%. After 12 weeks the animals were sacrificed. In order to reach euthanasia a 20% potassium chloride dose was used at 100 mg/kg, intravenously.

The hemimandibles were removed, dissected, radiographed, cut, and fixed using 4% formalin at pH 7 for 10 days and transferred to a 70% ethanol solution to wait for processing (Figure 3a through c). The samples were dehydrated in increasing alcohol concentrations until 100% concentration was reached. They were embedded in LR White resin (London Resin Company Ltd, Berkshire, England) and then sectioned buccolingually (Figure 3d) following Donath and Breuner’s technique for hard tissues.
**Radiographic Analysis**

Digital and standardized radiographic images were taken from all sectioned implants (buccolingually). Each implant, following embedment in acrylic resin, was turned sideways, and the radiographs were taken from the proximal sides (Figure 3d), therefore revealing in detail the buccal and lingual walls for each implant. The parameter for such evaluation was the standardized positioning of the implant in relation to the buccal bone plate. The analysis was performed using image tool software (Trophy Radiologie, Vincennes, France) to verify and determine the resulting distances between the implant shoulder and the bone crest level (Figure 4a), the resulting linear distance from the highest point between the implant surface and the buccal bone wall (Figure 4b), and the radiolucent area within the gap (Figure 4c).

**Statistical Analysis**

Results were submitted for statistical analysis using Friedman nonparametric tests, considering a significance level of $P < .05$. Wilcoxon test was also used with Bonferroni correction to detect where significant statistical differences had occurred.

**Results**

**Clinical findings**

After implant placement, healing was uneventful. There were no complications throughout the experimental period. The temporary prosthesis also
remained stabilized throughout the entire experimentation, and no occurrences or complications were observed.

**Radiographic analysis**

When the test and control equicrestal groups were analyzed (ECTG and ECCG) for resulting distance between implant shoulder and bone crest level, no statistically significant differences were found ($P > .05$). The results did not show statistically significant differences when comparing test and control equicrestal and subcrestal groups either ($P > .05$). However, when comparing test and control equicrestal and subcrestal groups, there were statistically significant differences for the test subcrestal group (SCTG) when compared with the test equicrestal ($P = .02$) and control equicrestal groups (ECTG and ECCG) ($P = .03$).

For mean value comparison, the linear distance between implant surface and buccal socket wall did not output any statistically significant differences between test and control equicrestal and subcrestal groups ($P > .05$).

The same result was observed for radiolucency between implant surface and buccal socket wall in which no statistically significant differences were detected between test and control equicrestal and subcrestal groups ($P > .05$).

In the analysis of the radiographic image, it was possible to observe the radiographic aspects of the buccal bone wall lightly above the implant shoulder and the gap filled with synthetic bone graft in the ECTG group (Figure 5a). In the ECCG group, the radiographic aspect of the buccal bone wall showed a little loss, and the gap was partially filled with new tissue (Figure 5b). The SCTG group showed radiographic aspects of the buccal bone wall above the implant shoulder as well as the gap was filled with synthetic bone graft (Figure 5c). However, the radiographic aspects of the buccal bone wall in the SCCG group were slightly above the implant shoulder, and the gap was partially filled with new tissue (Figure 5d).

**Discussion**

Functional and esthetic implant successes are strongly correlated to the buccal bone resorption at the implant cervical region. This study evaluated radiographically, buccal bone plate remodeling following immediate implantation, using flapless procedures, and comparing this process between sites that received or did not receive synthetic bone grafts in the gap between the implant and the buccal bone plate.

In the present study, the resorption of the buccal bone wall (IS-BC) in the crestal groups (ECTG and ECCG) was smaller when compared to the subcrestal groups (SCTG and SCCG). In accordance with Hermann et al and Piattelli et al, who reported that when the implant-abutment junction was positioned deeper within the bone, a more pronounced loss of vertical crestal bone height was observed. The authors attributed this finding to the implant/abutment connection used. Some implant systems may also permit micromovements at the abutment-implant connection during clinical function that finally leads to localized inflammation and crestal bone loss.

The subcrestal positioning of implants in the present study resulted in bone located above the implant shoulder, as demonstrated by the radiographic results of the distance between implant shoulder and bone crest level. It has been speculated that the Morse cone connections that allow abutments to emerge from a more central area of the implant (platform-shifting protocol) may help protect the peri-implant soft and mineralized tissues and reduce the rate of bone resorption by positioning the implant-abutment junction away from the external, outer edge of the implant and neighboring bone, and thereby decreasing potential abutment inflammatory cell infiltrate on the surrounding tissues. However, the resorption of the buccal bone wall was 1.18 mm in the group with bone graft (SCTG) and 1.59 mm in the group without bone graft (SCCG). On the other hand, the resorption did not occur in the equicrestal group with bone graft (ECTG) (+0.09 mm) and was −0.19 mm in the equicrestal group without bone graft (ECCG). These findings showed statistically significant differences when comparing the ECTG group with the ECCG and SCTG groups. In the subcrestal groups, the bone remained above the implant shoulder, but implant placement was 2.0 mm subcrestal, which indicates that bone loss occurred, but did not expose the implant. The good results obtained in the equicrestal groups probably occurred due to the 2.0-mm gap that was filled with the synthetic bone graft in association.
with the design of the implant (Cone Morse) and the SLActive surface on the entire length of the implant along with the used flapless approach, since a very small loss of bone (−0.19 mm) occurred without the bone graft.

Recently, some studies\textsuperscript{46–48} investigated the effectiveness of the flapless approach as an alternative to buccal bone preservation at least to some extension. This may have a particular impact when dealing with immediate implant therapy, considering that tooth extraction eliminates the periodontal ligament blood supply, leaving only the vascularization provided by the periosteum. Therefore, raising a mucoperiosteal flap in this situation may strongly compromise the blood supply that comes from the periosteum, and it can promote the buccal bone wall resorption. Barros et al\textsuperscript{46} observed a loss of bone height at least 2 times more pronounced in the group where immediate implants were installed after the elevation of mucoperiosteal flap, than in the group without flap elevation. Furthermore, Fickl et al\textsuperscript{48} had similar results and highlighted the great impact of this finding in thin periodontal biotypes, where the osteoclastic activities of the internal and external sides could merge together and cause a more pronounced buccal bone plate loss. In that case, the flapless surgery is an important factor for the maintenance of the crestal bone. It is important to emphasize that the buccal bone plate in humans is thin,\textsuperscript{49} thinner than in the posterior mandible of dogs, which can affect the results; however, all of the animal studies published in the subject used this same dog model.\textsuperscript{46,47,50}

Another factor that probably contributes to the maintenance of the buccal bone wall is the presence of the synthetic bone graft in the gap. It was observed that the crestal and subcrestal groups with bone graft showed smaller resorption of the buccal bone than did the groups with coagulum (Table 1), when the intragroup comparison was analyzed.

Results from animal experiments revealed that the marginal horizontal gap remaining between the hard tissue and the implant, immediately following its installation, may be resolved with new bone formation and osseointegration.\textsuperscript{24,51,52} However, if the gap width exceeds 1.0 mm, the amount of direct bone-to-implant\textsuperscript{27,53} contact decreases. The jumping gap of 2.0 mm between the implant surface and the alveolar buccal wall is considered a defect of critical size that no implant system has been able to fill without the use of guided bone regeneration. In the present study, the gap of 2 mm remained with a coagulum or was filled with synthetic bone graft. As in the parameter presented in Table 1, the equicrestal and subcrestal groups with bone graft showed a better reduction of the linear distance between implant surface and buccal socket wall. The initial measure was 2.0 mm and after 12 weeks it was 0.06 mm for both groups. The gap with coagulum showed a higher distance between the surfaces for equicrestal and subcrestal groups (Table 2). The differences, however, were
not statistically significant, perhaps due to the small sample size.

It has been postulated that in TCP grafts, the soft tissue components present around the graft 6 months after surgery are filled with osteoblasts and a few osteoclasts and that the resorption of residual particles is not due to osteoclast activity. This feature of TCP may represent a potential benefit for the grafted area because the osteogenic potential is maintained by the presence of osteoblasts and by the scarce osteoclast activity. Thus, the beta-TCP component of the BCP may have a beneficial effect on bone healing and maturation around the graft particles. With BCP, the HA constituent therefore provides a rapid response, while the beta-TCP constituent provides faster remodeling. Furthermore, another study revealed that the BCP concept is based on an optimum balance between the more stable phase (HA) and the more soluble phase (beta-TCP). BCP bioceramics are soluble and gradually dissolve in vivo, providing new bone formation as they release calcium and phosphorus.
phosphate ions into the biologic medium. BCP combinations are osteoconductive, as they support bone apposition and growth, but are slowly degraded in the body. The histomorphometric results of Cordaro et al showed newly formed bone 180–240 days post grafting. There was less residual graft material with “BoneCeramic” and, consequently, more tissue components. Compared to different bone grafts, BCP revealed substantially higher osteogenic capacity, and it also seemed to be as safe and efficient as autogenous bone grafts.

The results of the equicrestal and subcrestal control groups (Table 2) are in accordance with those in the study of Abushahba et al in which the amount of bone-to-implant contact found within the defects grafted with either bovine bone mineral or autogenous bone was greater than that found in the defects where no graft was used. They found remaining defects of 1.35 mm in width in the groups in which no bone grafts were used, but less bone area within threads as compared to grafted sites, and significant differences in the amount of osseointegration and bone regeneration were observed between the augmented sites as compared to defects without augmentation. This is in agreement with the results of Hall et al and Akimoto et al. In our study, the jumping gap is larger, so the resolution of the defects is complicated.

Polyzois et al observed that all implants surrounded by 2.37-mm defects (gap) filled with Bio-Oss integrated successfully. There also seemed to be more bone-to-implant contact and more bone inside the threads compared to the nongrafted sites with defects of the same diameter. In areas with no grafting, limited osseointegration was seen in the defect area. However, the grafted wider defects tended to demonstrate bone-to-implant contact more coronally than sites with gaps of the same magnitude that contained no grafts. They also demonstrated more linear bone-to-implant contact and a greater area of bone included within the threads. In a study by Hall et al, large 3-walled defects next to implants were grafted with canine demineralized freeze-dried bone and bioactive glass. These sites were compared to a nongrafted control. They reported significantly more bone healing when grafting materials were used. These results are in agreement with those of our study that suggest better healing in the defects when grafting is used.

The same augmentation can be applied to the area of the gaps (Table 3) in which it was possible to observe a correlation with the results presented in the linear distances between the implant surface and the buccal socket wall. The area without the presence of new tissue was smaller in the groups where synthetic bone grafting was used, mainly in the ECTG group. No statistically significant differences were observed among all groups, but numerically the differences between the average intragroup and intergroup comparisons are representative (Table 3).
These observations indicate that large buccal gaps (critical size) following immediate implant installation will not be completely resolved without grafting. Hence, in such situations, the use of grafting materials may improve treatment outcomes.

**CONCLUSIONS**

Equicrestally placed implants, in this methodology, presented little or no loss of the buccal bone wall. The subcrestally-positioned implants presented loss of buccal bone, regardless of the use of synthetic bone graft. However, the buccal bone was always coronal to the implant shoulder.

**ABBREVIATIONS**

BCP: biphasic calcium phosphate  
ECTG: equicrestal with bone graft  
ECTG: equicrestal with coagulum  
ECTG: equicrestal implant with bone graft  
GAP-A: radiolucent area between implant surface and buccal socket wall  
GAP-L: distance between implant surface and buccal socket wall  
HA: hydroxyapatite  
IS-BC: distance between implant shoulder and bone crest level  
SCCG: subcrestal with coagulum  
SCTG: subcrestal with bone graft  
SCCG: subcrestal with bone graft  
TCP: tricalcium phosphate

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