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RESEARCH ARTICLE

BIOMATERIALS FOR ALVEOLAR SOCKET PRESERVATION

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ABSTRACT

Tooth loss has a direct impact on quality of life by impairing the ability to masticate, speak, and, in some instances, socialize. Bone resorption following extraction presents as a significant problem in restorative and implant dentistry. Socket preservation is a technique by which the amount of bone resorption is limited. This article discusses the scientific literature examining the healing post-extraction and socket preserving techniques.

INTRODUCTION

Tooth loss has a direct impact on quality of life by impairing the ability to masticate, speak and socialize (Gerritsen AE *et al*, 2010). Alveolar ridge resorption refers to bone remodeling which occurs following tooth extraction (Jamjoom A *et al*, 2015). The absence of a tooth in its alveolus triggers a cascade of biological events which in turn results in significant local anatomic changes (Weijden V D F *et al*, 2009). This may lead to esthetic and functional defects. The defects can be so severe that implant placement can be difficult or impossible without using augmentation procedures (Bartee, B.K, 2001, Ashman, A., 1995). Clinical studies have demonstrated that alveolar ridge volume loss followed by extraction is an irreversible process that involves both horizontal and vertical bone reduction (Schropp L *et al*, 2003, Araujo MG *et al* 2009). The aim of this article is to discuss events following extraction and how these can be optimized to facilitate successful implant therapy. The same principles may be applied to edentulous areas in order to enhance aesthetic outcomes for fixed bridges and removable dentures.

Biological Changes Following Extraction

Healing of an extraction socket is characterized by internal changes and external changes. Internal changes lead to formation of bone within the socket and external changes lead to loss of alveolar ridge width and height (Darby I *et al*, 2008). After extraction, initially there is heamorrhage followed by the formation of a blood clot on the extraction socket (Nazirkar G, 2014). This is accompanied by an inflammatory reaction that stimulates recruitment of cells to form granulation tissue.

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Within 48 to 72 hours after extraction, the clot starts to breakdown as granulation tissue begins to infiltrate the clot especially at the base of the socket. By four days the epithelium proliferates along the extraction socket periphery and immature connective tissue is apparent. After seven days the granulation tissue has completely infiltrated and replaced the clot. At this stage, osteoid is evident at the base of the socket as uncalcified bone spicules. Over the next 2–3 weeks (3–4 weeks after extraction) this begins to mineralize from the base of the socket coronally. This is accompanied by continued re-epithelialization which completely covers the socket by six weeks post-extraction. Further infill of bone takes place with maximum radiographic density at around 100 days (Darby I *et al*, 2008). Extraction of teeth follows a three-dimensional resorption pattern. It is apparent that the bone resorption of jaws after the loss of teeth is highest during the first 3 months, even though up to four-fold variations have been reported across individuals over a 14-month period (Nazirkar G, 2014). Alveolar bone resorption occurs in two phases. Initially the bundle bone that anchors the tooth in the alveolar process through Sharpey's fibers is rapidly resorbed and replaced with newly formed immature woven bone (Tan, W.L. *et al*, 2012, Wang, R.E *et al*, 2012, Pagni G *et al*, 2012). Woven bone is then replaced by mature lamellar bone that fills the socket in about 180 days. In the second phase, the periosteal surface of the alveolar bone remodels through an interaction between osteoclasticresorption and osteoblastic formation, leading to an overall horizontal and vertical tissue contraction (Wang, R.E *et al*, 2012).

Factors affecting healing of undisturbed sockets

Size of the socket

Formation of bone in a wide extraction socket as in molars takes greater time than in a narrow socket as in single rooted tooth.

Bone loss pattern

Healing of a socket with horizontal bone loss pattern is quicker since the lower level of the alveolar bone requires less infill (Darby I *et al*, 2008). It should be noted that bone does not regenerate to a level coronal to the horizontal level of the bone crest or to the level of the neighbouring teeth (Schropp L *et al*, 2003).

The need for socket preservation

Generally, implant and restorative procedures are most effective with an enhanced alveolar bone and periodontal support. Adequate height and width of the alveolar ridge plays the most vital role in deciding the success and failure of implant therapy. After extraction, the alveolar bone height and width is decreased. Although ridge resorption cannot be prevented completely, it can be limited to a certain extent.

Factors affecting socket preservation

Minimally traumatic tooth extraction

The application of appropriate instruments with minimal force is recommended to limit damage to the hard and soft tissues. Insertion of fine luxators or periotomes into the periodontal ligament can be followed to sever the coronal fibre attachment, thereby loosening the tooth until forceps can gently deliver the tooth from its socket (Darby I *et al*, 2008). This helps in quick healing of the socket and also enables to maintain the height and width of the crestal bone.

Timing of extraction

Most resorption takes place within the first three months after extraction. Therefore, if possible, the tooth should be retained for as long as possible and the extraction scheduled in accordance with the chosen time for implant placement. A detailed discussion and classification for timing of implant placement after tooth extraction may be found in the proceedings of the 3rd ITI Consensus Conference (Chen ST *et al*, 2004, Hammerle CHF *et al*, 2004). However, it is not always possible to retain all teeth in this manner with pain and infection often necessitating immediate removal of the offending tooth.

Debridement of the socket

Few studies recommend that the sockets should be debrided to remove anything that may interfere with healing, whilst others suggest that a round bur should be used to perforate the socket walls a number of times to allow greater access for blood vessels into the socket and any grafting material in an attempt to improve bony infill (Buser D *et al*, 1993). Opposing this, it has been shown in an experimental study that retention of the periodontal ligament along the socket walls facilitated retention of the clot during the early stages of wound healing (Cardaropoli G *et al*, 2003). Thus, removal of chronically inflamed tissue and foreign materials is sufficient, rather than extensive debridement or perforation of the socket walls.

Soft tissue coverage

Soft tissue coverage procedures may be considered to retain, stabilize and protect grafting materials.

Socket Preservation

Socket preservation is any procedure undertaken at the time of or following an extraction that is designed to minimize external resorption of the ridge and maximize bone formation within the socket. However, there are clinical situations where it is not advisable to undertake ridge preservation at the time of extraction (e.g., in the presence of acute infection). In these situations, preservation of the ridge may be delayed by six to eight weeks (Darby I *et al*, 2008).

Historically, the first therapeutic attempts to prevent alveolar ridge resorption were performed by root retention, with the primary goal of maximizing the stability of removable prostheses (Osburn RC, 1974). Nevertheless, root retention is not always feasible because of fracture, caries, and/or strategic reasons. “Socket grafting” emerged in the mid-1980s as a therapeutic alternative to root submergence. Its use was rationalized on the notion that “filling” the space left by the extracted tooth with a biomaterial would emulate a “root retention effect” conducive to bone preservation, which would subsequently facilitate endosseous implant placement by reducing the need of ancillary grafting procedures (Artzi Z *et al*, 1998). Over the past 2 decades, multiple studies evaluating the efficacy of different socket-filling approaches have been conducted. In these studies, numerous biomaterials has been employed, including autologous bone, bone substitutes (allografts, xenografts, and alloplasts), autologous blood-derived products, and bioactive agents, among others (Darby I *et al*, 2009). Becker *et al*, 1994 compared demineralized freeze dried bone (DFDBA) against autogenous bone in seven paired sites finding that after three months new bone was formed at sites where autogenous bone was placed, but not in six of seven sites using DFDBA. A study using DFDBA (Gajiwala AL *et al*, 2007) showed that DFDBA cannot speed up bone formation. Both Becker *et al*.1994 and Froum *et al*, 2002 showed little new bone formed around DFDBA. However, the use of DFDBA is limited due to the unavailability of quality allografts and high cost of imported alternatives (Gajiwala AL *et al*, 2007). Therefore autogenous bone is considered as the “Gold standard” (Becker *et al*, 1994).

Recently, Artzi *et al*, 2000 used a common porous bovine bone graft (Bio-Oss) in 15 fresh extraction sockets, covering the graft with soft tissue and re-entering nine months later. They reported that there was 82.3 per cent bone infill and all sites allowed ‘‘safe’’ insertion of fixtures. Histologic appearance showed a mixture of Bio-Oss and new bone formation, increasing in bone fraction apically. The use of a xenograft does not require a donor site, thus reducing morbidity following harvesting and simplifying the procedure. Patel *et al*, 2013 examined success and survival rates with maxillary and mandibular teeth within the region anterior to the premolar teeth. This study consisted of 27 patients randomly assigned into two groups. Fourteen extraction sockets were grafted with Straumann Bone Ceramic (SBC) and 13 were grafted with Bio-Oss; both groups were covered with a resorbable collagen membrane (Bio-gide). Both groups had implant placement at eight months post-extraction. At 12 months they had 100% survival and similar success rates according to the criteria of Albrektsson, 1986 –84.6% in the SBC group and 83.3% in the Bio-Oss group. In the two remaining studies, authors observed high degrees of survival and success over observation periods of two to seven years (Norton MR *et al*, 2002, Sandor GK *et al*, 2003). Three randomized studies were identified which compared socket grafting and delayed implant placement with immediate implant placement (Block MS *et al*, 2009, Felice P *et al*, 2011,Van Kesteren CJ *et al*, 2010). Both treatment modalities appeared to have similar implant treatment outcomes after osseointegration, although Felice *et al*, 2011 reported increased difficulty in achieving high insertion torque in sockets grafted with Bio-Oss four months post-extraction. The use of hydroxyapatite in fresh extraction sockets in a series of 23 cases was reported by Nemcovsky *et al*, 1996. They achieved primary closure by rotating split thickness flaps and were followed for 24 months. They showed that there was predictable ridge preservation with minimal postoperative ridge deformation (1.4 mm vertically and 0.6 mm horizontally). This would retain sufficient bone volume to allow implants to be inserted. However, over half the patients experienced some exfoliation of hydroxyapatite suggesting that the flap design was not predictable in maintaining soft tissue closure.

A bioactive glass (Biogran) was investigated in fresh extraction sockets by Froum *et al*, 2002 and compared to control sockets and those with DFDBA. All sites were covered by flap advancement and re-entered six to eight months later. The placement of Biogran resulted in 60 per cent bone vitality, a measure of new bone formation, with the control and DFDBA sites showing approximately 33 per cent. However, it should be noted that all sites were to receive implants, which suggests that there may be little benefit of using a graft material (Darby I *et al*, 2008). Recently, the use of calcium sulfate has been studied. Guarnieri *et al*, 2004 placed calcium sulphate in 10 extraction sockets without a barrier membrane and re-entered the sites at three months. The graft material had readily resorbed with 100 per cent bone infill and implants were able to be placed at all sites. It should be noted that there is again a general lack of studies reporting on the use of calcium sulphate, with which the authors of the above paper concur. Another product that was used to graft extraction sockets is BioPlant HTRTM. It is a biocompatible microporous composite of methacrylate and calcium hydroxide. Haris *et al*, 1998 reported that after a period of 8 to 12 months there was sufficient hard tissue to place implants. Recently, a combination of hydroxyapatite and calcium sulfate known as the biphasic calcium phosphate is available. But, the authors are not aware of any peer-reviewed papers investigating its use in ridge preservation.

Use of membranes in socket preservation

It is also possible to cover the socket to prevent ingress of soft tissue, thereby promoting maximal bony healing. Generally, there are two types of membrane used, resorbable and non-resorbable. Lekovic *et al*, 1997 investigated the use of a non-resorbable expanded polytetrafluoroethylene(ePTFE) membrane to maintain the alveolar ridge after extraction. Two sites each in 10 patients were used, one site receiving a membrane and the other site as a control. All sockets were debrided and flaps displaced to cover the membrane and socket. Reassessment took place at six months, with significantly greater loss of bone height and width in the control group and more infill in the ePTFE group. However, 30 percent of membranes became exposed and this resulted in similar results to the control group. Giving the high rate of exposure, this paper suggests the use of ePTFE membranes should perhaps be avoided. A later paper by the same group (Lekovic V *et al*, 1998) looked at the use of a resorbable membrane compared to a control site in 16 patients. A polyglycolide⁄ lactide membrane (Resolute, WL Gore & Associates) was placed and reassessed at six months. The experimental sites showed significantly less loss of alveolar bone height, more internal socket fill and less horizontal resorption of the ridge. Importantly, there were no exposures. Therefore, it seems that resorbable membranes should be preferred over nonresorbable. Some studies have evaluated the use of bone grafts along with membranes. A study by Panq *et al*, 2014 suggested that the deproteinized bovine bone graft and absorbable collagen membrane were beneficial to preserve the alveolar ridge bone and had no influence on the osseo integration of delayed implant. Iasella *et al*, 2003 reported on the use of tetracycline hydrated freeze-dried bone allograft and a resorbable membrane (Bio-Mend) compared to extraction alone in 24 patients. They replaced the flap without complete socket coverage and reassessed four to six months later. Both groups lost ridge width, although the experimental group lost less width and had more bone infill. The test group sites were more suitable for implant placement, but all sites were still able to receive implants. In a case report, Fowler *et al*, 2000 used DFDBA and an acellular dermal graft for ridge preservation. An acellular dermal graft is an allograft harvested surgically and with all cellular material and epidermal layer removed. The authors found the height of tissue to be acceptable for implant placement and suggested this technique be used where primary closure couldn't be achieved. Fugazzotto PA, 2003 in a report on a comparison of resorbable and titanium-reinforced membranes used with Bio-Oss found that ''significant bucco-lingual ridge collapse was noted upon re-entry''. The findings of this paper are supported by the work of Zubillaga *et al*, 2003 who showed that tacked membranes in place results in less loss of augmented bone than non-tacked membranes.

"Space fillers" may be used to help in the preservation of socket. Serino *et al*, 2003 placed in 36 patients a commercially available bioabsorbable sponge of polylactide-polyglycolide. The teeth were surgically extracted, sockets debrided, the sponge inserted and flaps replaced with no primary closure. Six months later all sites were reassessed and implants placed. There were 26 test sockets and 13 control. All test sockets healed with less bone resorption than the controls especially in the mid-buccal region. The authors suggested that the sponge served as a support to prevent the collapse of the surrounding soft tissue into the socket during the healing process. Collaplug may also be used. This sponge can be placed into the socket without raising a flap, but there is little research in this area and the materials may only act to stabilize the clot and not to preserve the ridge.

Immediate implants in socket preservation

The third ITI consensus report showed that immediate implants are a very successful form of therapy (Chen ST *et al*, 2004). However, it has been reported that implants do not ''preserve'' the ridge they are placed into (AraujoMG *et al*, 2005, Botticelli *et al*, 2004, Chen *et al*, 2005). Araujo *et al*, 2005 demonstrated that immediate implant placement in a dog model failed to prevent resorption of the socket walls, especially buccally.

They suggested that this may be due in part to the early disappearance of the bundle bone and also disruption of the blood supply buccally due to elevation of a flap. Bundle bone, in the presence of a tooth, occupies a larger fraction of the marginal portion of the bone wall in the buccal than lingual and has a large number of fibres from the periodontal ligament inserting. It seems that when a tooth is removed bundle bone is resorbed rather than replaced. If one thinks in terms of solely being able to place an implant then this may not matter at all as long as there is enough bone initially, but this may cause problems later especially in aesthetic areas if there is buccal tissue loss (Araujo *et al*, 2006).

Current advances

Given the current advances in stem cell technology we may in the future be able to place tooth buds in sockets to regrow teeth or place a cellular scaffold in the socket to maintain the bone. Cultivated scaffolds from bone marrow mesenchymal stem cells have been placed into fresh extraction sockets with results that ‘‘show promise’’ (Marei *et al*, 2005).

Complication

Any surgical procedure may have complication such as post-operative pain, swelling and occasionally infection. Any surgery on the gingival tissues will cause recession. It is well known that in guided tissue regeneration procedures up to 70 percent of non-resorbable membranes may become exposed to the oral environment, severely reducing the amount of new tissue formed (Cortellini P *et al*, 2000). In addition, Girard *et al*, 2000 reported a case of a foreign body granuloma following placement of a graft into an extraction socket with pain and sensation disturbance. It should be noted that the site was already compromised by previous infection and may serve as a reminder to debride sockets fully or not to undertake preservation in the presence of infection.

Limitation

Socket preservation has been developed recently. There are a great number of techniques that have been presented, but with only few research reports to support. The influence of the general health and habits of the patient makes it difficult to adhere to a particular technique for socket preservation.

Conclusion

Preservation of the extraction socket plays a vital role in deciding the replacement options for the lost tooth. This aids healthy conditions for the patient to undergo best replacement modalities. Although ridge resorption cannot be prevented completely, it can be limited to a certain extent. Further long-term studies are required especially to assess the ridge dimension following preservation and implant placement.

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