

Trepanation or Complete Removal of the Outer Table of the Calvarium for Granulation Induction: The Erbium:YAG Laser as an Alternative to the Rose Head Burr

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Key Words

Erbium:yttrium-aluminum-garnet laser · Periosteum · Burr hole · Granulation · Scalp · Calvarium

Abstract

Background: Large scalp defects devoid of periosteum following tumor excisions are a surgical challenge. In this case, drilling the outer table of the calvarium with a rose head burr is a standard method to induce granulation tissue. **Objectives:** We describe an alternative for trepanation or complete removal of the outer table of the calvarium. **Methods:** We demonstrate the use of an erbium:yttrium-aluminum-garnet (erbium:YAG) laser for the induction of granulation tissue, compare this technique with the standard procedure and evaluate the benefits and limitations. **Results:** The erbium:YAG laser is an excellent method for trepanation or complete removal of the outer table of the calvarium and induction of granulation tissue. **Conclusion:** The use of the laser for trepanation of the calvarium gives results comparable to those of the rose head burr for inducing granulation tissue but has its benefits. Therefore, this method should become a standard alternative to the known procedure.

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Introduction

Non-melanoma skin cancer occurs frequently and is the most common cause for surgical defects of the scalp. In particular, older men with early androgenetic alopecia and long-term sun exposure as well as immunosuppressed patients develop scalp field cancerization with repeated surgeries. Large tumors notably tend to infiltrate the periosteum, resulting in large scalp defects with bare, exposed bone. These large defects can, of course, be closed using local and pedicled flaps or microvascular free tissue transfer [1]. However, patient factors such as old age, comorbidities, oncological prognosis or an inability to tolerate prolonged narcosis are important determinants that often exclude extensive surgical interventions. In addition, the resected periosteum does not allow skin grafting because of the lack of granulation tissue. For this situation, a very old procedure for the induction of granulation tissue on bare bone devoid of periosteum is used. In 1696, Auguste Beloste [2], a French military surgeon, first described the trepanation of the outer table of the calvarium to induce granulation tissue. By drilling or milling the outer table of the skull bone, the diploe with its vessels and fibroblasts is exposed, and granulation tissue can de-

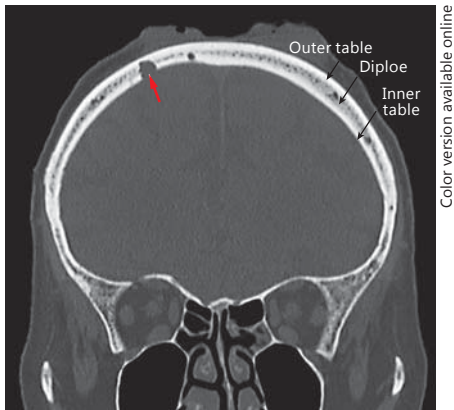


Fig. 1. Preoperative CT scan to exclude malignant bone erosions or calvarium abnormalities before trepanation. Displayed is a CT scan of a patient with a big squamous cell carcinoma of the scalp. The thick arrow marks the loss of the inner table and diploe of the calvarium. The inner and outer table and the diploe are labeled. In this case, the trepanation was canceled, and a large transposition flap was used for closure.

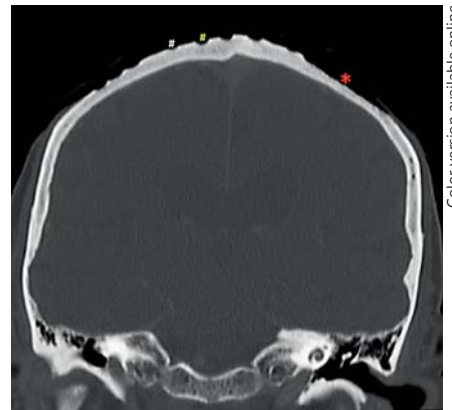


Fig. 3. Postoperative CT scan after trepanation and partial planar ablation of the outer table of the calvarium with an erbium:YAG laser after complete scalp removal. The red asterisk (colors refer to the online version only) marks the planar ablation of the outer table and the exposed diploe. The yellow number sign marks a successful trepanation of the outer table and the exposed diploe. The white number sign marks an insufficient trepanation of the outer table.

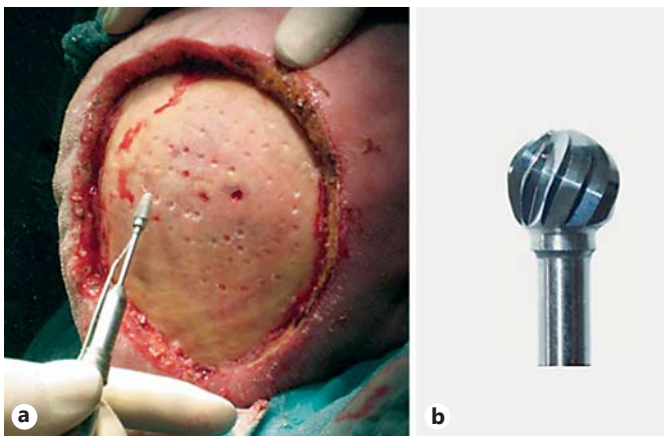


Fig. 2. Trepanation of the outer table of the calvarium with a surgical drill; condition after the excision of an angiosarcoma with resection of the periosteum. **a** Here, a flame head burr was used for the trepanation until discrete bleeding was observed. **b** A rose head burr is displayed.

velop. Normally, it takes a few weeks for the defect to become completely covered with granulation tissue, followed by skin grafting or second-intention healing [3, 4]. The standard procedure for trepanation or complete removal of the outer table of the skull is to use a rose head burr or a chisel to split the outer table. Both techniques use instruments needing sterilization or, in the case of the

rose head burr, a surgical drill, which is not available in every dermatological clinic and even less so in outpatient settings. In addition, use of a surgical drill substantially increases the temperature of the treated regions, increasing the risk of bacterial contamination and deposits of metal shavings [5–7].

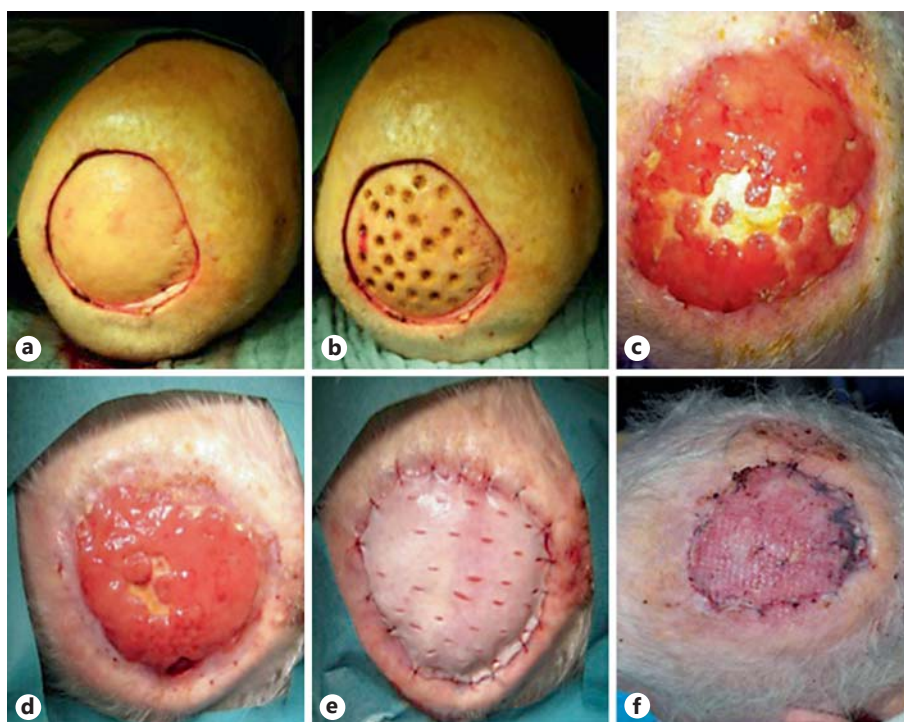
In oral surgery, the erbium:yttrium-aluminum-garnet (erbium:YAG) laser is increasingly used instead of a classic surgical drill for osteotomy. It could be demonstrated in experimental studies that the erbium:YAG laser treatment produces less heat, sharper edges around the openings, no debris or bone fragments and shorter surgical times [8, 9].

Therefore, we investigated the use of the erbium:YAG laser as an alternative for trepanation or complete removal of the outer table of the skull bone and found it to be highly effective in inducing granulation tissue.

Methods and Results

Classical Trepanation Method of the Outer Table of the Skull Bone with the Surgical Drill

For complete resection of a tumor at the scalp, the periosteum must often be resected. If local or free flaps are not applicable and skin grafting is necessary, the induction of granulation tissue is mandatory. The standard procedure requires the use of a surgical drill with a rose



Color version available online

Fig. 4. Trepanation of the outer table of the calvarium with an erbium:YAG laser. **a** Status after micrographically controlled excision of a squamous cell carcinoma in a 94-year-old patient, including the resection of the periosteum (defect size: 12 × 12 cm). **b** Trepanation of the outer table with an erbium:YAG laser (laser settings: 5–10 J/cm², 5 mm, 5–10 Hz). **c** Granulation tissue after 4 weeks. **d** Granulation tissue after 7 weeks. **e** Status directly after transplantation with a split-thickness graft. **f** Successful transplantation after 1 week.

or flame head burr. Before trepanation, a computed tomography (CT) scan of the skull should be routinely performed because sometimes the calvarium is much thinner than the expected 5–10 mm, or the inner table and/or diploe are lacking (fig. 1). The trepanation must be performed under sterile conditions until punctual bleeding is observed (fig. 2). Constant cooling with saline solution is crucial because the rapid rotation of the surgical drill produces substantial heat, which could harm the diploe. Besides trepanation, planar milling of the outer table is also possible. The use of a surgical drill is wet surgery that must be performed with maximum protection using splash-resistant surgical masks and visors for the surgeon and the assistance personnel.

Trepanation Method of the Outer Table of the Skull Bone with the Erbium:YAG Laser

The erbium:YAG laser can be used for trepanation or planar ablation of the outer table of the calvarium to induce granulation tissue [1]. It is very important that the outer table is completely removed and the diploe exposed, as demonstrated in a CT scan of the calvarium after trepanation and planar ablation (fig. 3). We normally use the erbium:YAG laser with a pulse energy of 5–10 J/cm², a spot diameter of 5 mm and a pulse repetition rate of 5–

10 Hz. Particularly at the beginning of the ablation, higher energy and repetition rates are used to thin the outer table quickly. After effective thinning, the frequency and pulse energy are reduced substantially to avoid a heat buildup. As shown in the short movie (online suppl. movie 1; for all online supplementary material, see www.karger.com/doi/10.1159/000368749), it takes only a few seconds to remove the outer table of the calvarium and expose the diploe to effect punctual bleeding. To estimate the thickness of the outer table and the diploe, a preoperative CT scan with a measurement device is very helpful.

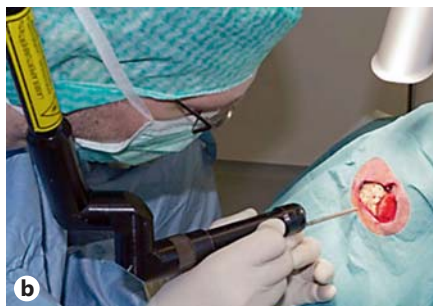
Trepanation must be performed under sterile conditions until punctual bleeding is observed (fig. 4a, b). Finally, a wet wound dressing is applied and changed regularly every 2 days. Normally, after 3–8 weeks, granulation tissue will cover the bone, and the defect can be transplanted (fig. 4c–f; online suppl. fig. 1). For smaller defects, a secondary-intention healing after trepanation can be considered (fig. 5) and is very effective.

Trepanation with sufficient bleeding can be combined with an immediate application of a dermis equivalent, for example Integra™. As shown in figure 6, trepanation with the erbium:YAG laser (fig. 6a–c) is followed by the application of an artificial dermis template (Integra™; fig. 6d). About 4 weeks later, the neodermis can be transplanted

Fig. 5. Secondary-intention healing after trepanation of the calvarium with an erbium:YAG laser. **a** Status after excision of a squamous cell carcinoma (defect size: 2 × 2 cm). The patient refused a flap closure. The trepanation of the outer table was carried out with the erbium:YAG laser (laser settings: 5–10 J/cm², 5 mm, 5–10 Hz). **b** Status 7 weeks after trepanation.



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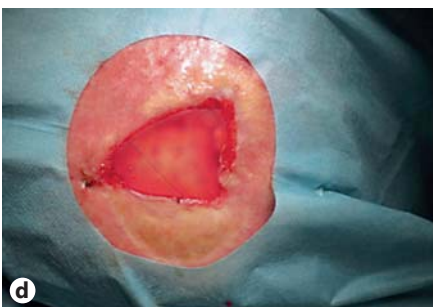
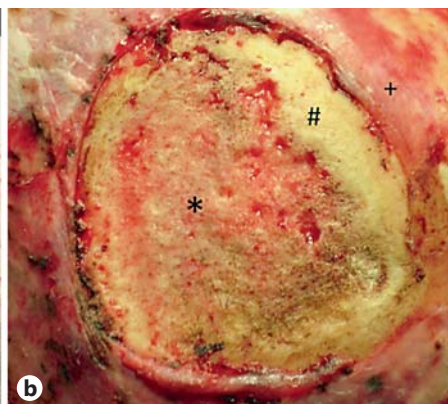


Fig. 6. Trepanation of the outer table of the calvarium with an erbium:YAG laser and immediate application of a dermis equivalent (Integra™). **a** Status after micrographically controlled excision of a recurrent squamous cell carcinoma (defect size: 5 × 3 cm). A flap closure was not possible because of various previous surgeries

in this region. **b** Trepanation of the outer table with an erbium:YAG laser (laser settings: 5–10 J/cm², 5 mm, 5–10 Hz). **c** Status directly after trepanation. **d** Application of the dermis equivalent (Integra™), which was left in place for 4 weeks to establish a neodermis. **e** Status 12 days after transplantation of a split-thickness skin graft.

Fig. 7. Planar removal of the outer table of the calvarium with an erbium:YAG laser. **a** Intraoperative picture (laser settings: 5–10 J/cm², 5 mm, 8–10 Hz). **b** An enlarged picture of the exposed and bleeding diploe (asterisk). In the periphery, the intact outer table (number sign) can be seen. The periosteum (plus sign) around the defect is intact.



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with a split-thickness skin graft. The skin grafting was successful, as shown 2 weeks after the transplantation (fig. 6e).

Besides classical trepanation, the erbium:YAG laser can also be used for the planar removal of the outer table of the calvarium. The same laser settings are used as in trepanation (fig. 7). After planar removal of the outer table, a direct transplantation of the opened diploe is often possible.

Discussion

We have introduced an effective and quick alternative for the trepanation or planar removal of the outer table of the calvarium to induce granulation tissue. Up to now, only a surgical drill equipped with a rose or flame head burr was used for this procedure. The classical method with the surgical drill has some drawbacks compared to the use of the erbium:YAG laser. Many dermatological clinics and outpatient settings do not have a surgical drill at hand. In addition, the sterilization process is elaborate. In contrast, an erbium:YAG laser, because it is used for many other applications in dermatology, is often found in dermatological settings. Sterilization of the laser head is not necessary, because it does not have contact with the defect.

The erbium:YAG laser has a wavelength of 2,940 nm, and its energy is highly absorbed in water and hydroxyapatite, resulting in minimal tissue degeneration and thin surface interaction [10]. Sasaki et al. [11] as well as Hibst [12] explain the 'cold' ablation of the erbium:YAG laser by its maximal energy absorbance in water, which induces rapid steam creation, leading to an explosive destruction of inorganic substances. This property is the basis for the reduced thermal damage in treated bone surfaces

compared to when a surgical drill is used [9]. Sasaki et al. [13] could not find any carbonization regions in bone tissue after erbium:YAG treatment even after high repetition rates (20 Hz). Further analysis by Panduric et al. [8] by field emission scanning electron microscopy and energy-dispersive X-ray analysis of erbium:YAG-treated bone demonstrated a similar amount and distribution of the chemical elements in the treated and untreated areas. Yoshino et al. [14] revealed that erbium:YAG irradiation did not inhibit cell migration and proliferation, which is a prerequisite for the development of healthy granulation tissue. In addition, Panduric et al. [9] demonstrated that the erbium:YAG laser, compared to the surgical drill, does not produce additional bone dust or bone fragments, which increase the chance of local infection, as shown by Stübinger et al. [15]. Furthermore, the same group found that the precision of the erbium:YAG laser in osteotomy is much greater than that of a surgical drill [8]. An additional benefit of the erbium:YAG laser is the lack of development of a wet aerosol as seen with the surgical drill and therefore a reduction in the infection risk for the surgeon and assistance personnel. The smoke aerosol induced by the erbium:YAG laser can easily be eliminated by a medical suction device. In addition, we could successfully demonstrate the combination of erbium:YAG trepanation with the immediate use of a dermal regeneration template, an approach which has not been shown before. We demonstrated that this alternative to the surgical drill is an effective, safe and quick procedure and offers many advantages for inducing granulation tissue on bare bone.

Disclosure Statement

The authors declare no conflicts of interest. There was no funding.

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