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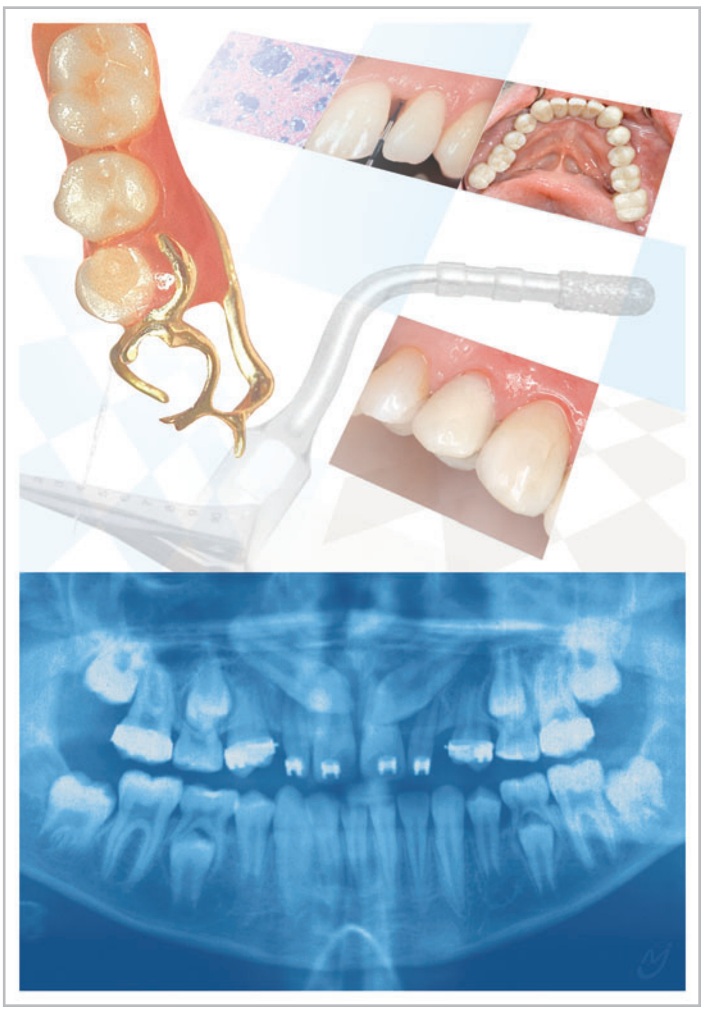

SPECIAL REPRINT

Uses of the operating microscope in minimally invasive implantology

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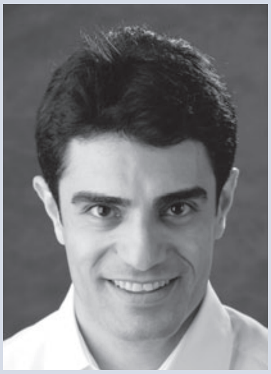

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Key words
Minimally invasive implantology, operating microscope, microsurgery, optical magnification, aesthetic zone, sinus floor elevation, soft tissue management

Abstract
Minimally invasive procedures are ubiquitous in medicine. They will also make an increasing mark in invasive disciplines of dentistry in the future. Therefore in implantology three-dimensional diagnostics, microsurgical instruments and suture materials, but especially optical magnification with axially aligned illumination are required. The operating microscope (OPMI) combines these last two requirements, which are essential for microsurgery, even at high magnification. Customised sterile draping sheets allow the operating microscope to be used even under the aseptic conditions of implant surgery. The advantages of the OPMI in implantology are numerous and are apparent especially in clinical assessment, diagnosis, management of the aesthetic zone, sinus lift, soft tissue management and photo and video documentation. Technical developments such as autofocus, xenon illumination, magnetic fixation, CCD and HD digital cameras enhance the precision of the OPMI, and at the same time improve ergonomy. The following overview article describes in detail the main indications for using the OPMI in minimally invasive implantology

Introduction

Since the development of the operating microscope (OPMI) by Dr. *Littmann* and Professor *Wullstein* in 1953, it is no longer possible to imagine surgery on fine anatomical structures without optical magnification.

The first clinical attempts to use the OPMI intraorally go back to the 1970s. Microscopic magnification was used then for maxillofacial surgical nerve reconstruction[11]. Shortly afterwards, new applications in the early diagnosis of precancerous lesions of the oral mucosa and visualisation of non-tight filling margins were described as useful[10].

A few years later, endodontologists recognised the advantages of the operating microscope. Since the 1990s, systematic use of the OPMI in endodontics has been documented and is now fully accepted scientifically[7,13,24].

Working with the OPMI has become a requirement in postgraduate education in the USA since 1998.

Fig 1 Use of the operating microscope OPMI Proergo (Carl Zeiss, Oberkochen, Germany) in an implantological procedure

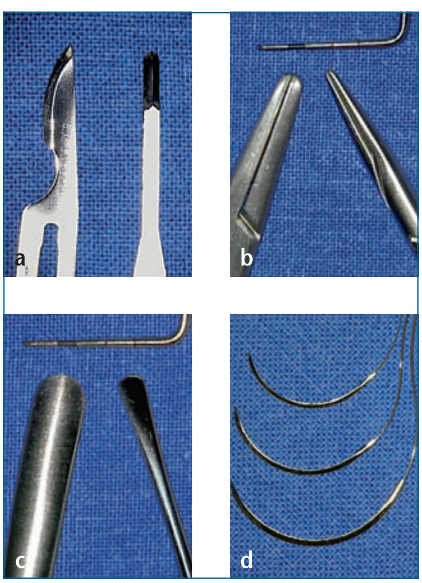


Fig 2a to d Comparison of the size of conventional and microsurgical instruments and needle/suture

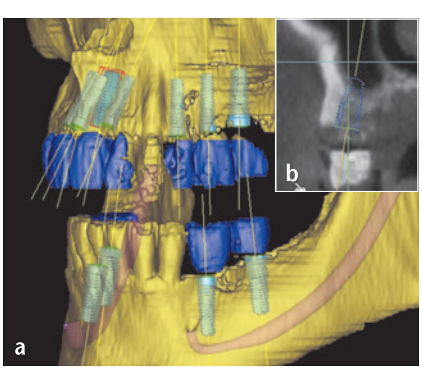


Fig 3a and b Three-dimensional radiography and implant planning (coDiagnostiX planning software, IVS Solutions, Chemnitz, Germany)

Finally, microscopic magnification has also been described as promising in periodontology[17,22,23]. The main indications were listed as mucogingival plastic surgery, papilla reconstruction and connective tissue and mucosal grafts. Fenestration of the sinus floor and implant exposure were also mentioned, but peripherally.

Supported by new technical achievements, minimally invasive treatment methods are the current topic in the operative disciplines of medicine and dentistry.

Minimally invasive surgery means injuring only the amount of healthy anatomical tissue that is absolutely unavoidable. This assumes that the margins of the surgical procedure in the tissue can be precisely determined visually and monitored continuously. The naked eye is no longer sufficient and use of loupes is basically unavoidable. However, these are limited by their usual magnification factor – up to 3.0 – and the lack of axially aligned illumination at their edges.

In minimally invasive implantology, high optical magnification using the OPMI is just one component – though the most important one – of an overall concept (Fig. 1).

Apart from a surgeon experienced in microsurgery and his specially trained assistants, the following are further components:

- Microsurgical instruments and needle/suture combinations (Fig. 2a to d);
- Scientifically documented alloplastic augmentation materials;
- An innovative implant system;
- 3D radiography and 3D implant planning (Fig. 3a and b);
- Equipment for taking and processing digital photographs and video recordings.

The primary aim of minimally invasive treatment is always to minimise tissue trauma while maximising tissue preservation or reconstruction[25].

Assessment and diagnosis

Like all other disciplines in dentistry, implantology increasingly requires precise assessment and diagnosis. The reason for this is the growing importance of predictability of the aesthetic and functional outcome of a planned implantation. This is often the most important criterion for the patient when making a decision on such expensive

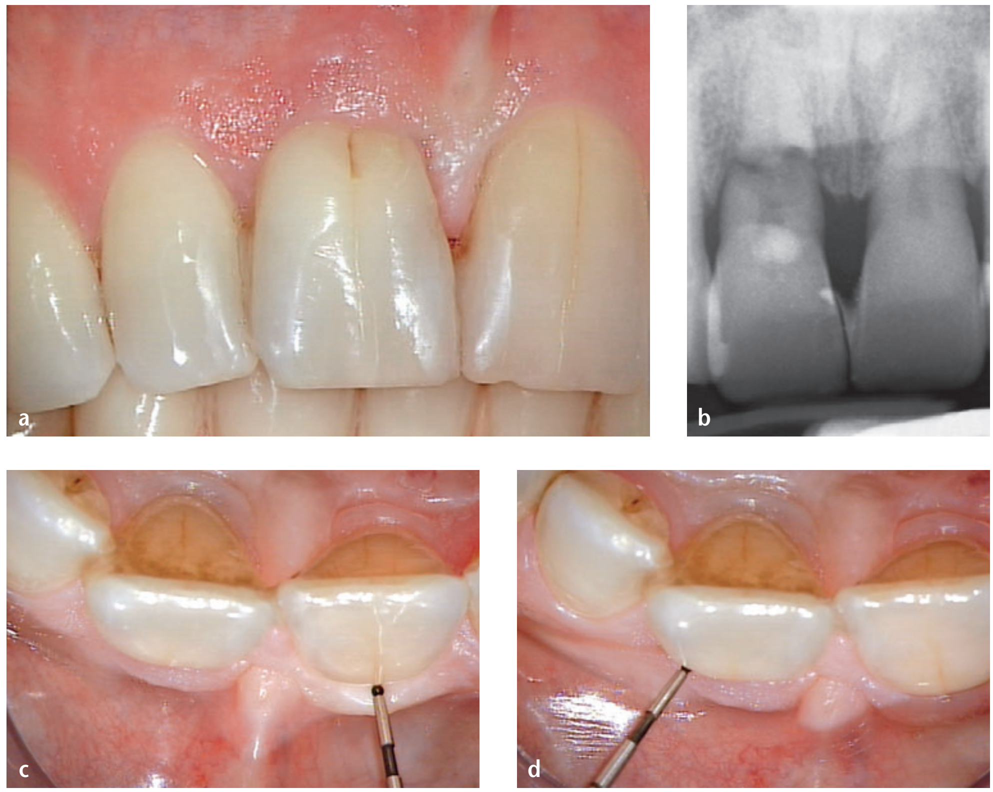


Fig 4a to d Tooth 11 with an internal root granuloma needs to be extracted. On the initial frontal view, one gets the impression of a thick gingiva biotype (B) (a and b). It is apparent only in the incisal view under 8x optical magnification that the healthy tooth 21 with a tissue thickness of 1.5 mm can be classified as gingiva biotype B. Tooth 11 has a tissue thickness predominantly <0.5 mm so it is classified as gingiva biotype A (c and d)

treatment. The aim is to differentiate as exactly as possible the various biological variations of the relevant tissue structures and to distinguish them from pathological changes. Therefore precise visual extra- and intraoral clinical examination is necessary. The optical magnification of an OPMI is very useful especially in pre-implant clinical examination of the aesthetic zone.

Important findings such as different gingiva biotypes (Fig. 4a to d), suspicious discolouration of the dental enamel or soft tissue and the three-dimensional course of the alveolar ridge can be documented precisely and shown visually to the patient (Fig. 5a to e).

In consequence, the indications for tooth extraction or preservation, bone grafting or soft tissue augmentation can be proposed more reliably.

Digital photography and filming

Photographic or video documentation of implant surgery procedures is becoming increasingly important, not least for medicolegal reasons. This type of documentation is the basis of scientific evaluations and is the most important means of monitoring outcome when surgical and prosthetic innovations are incorporated into one's own implant treatment concept. At the same time, complete continuous visualisation of the patient's clinical intra- and extraoral situation in the course of implant-supported prosthetic treatment is also an effective marketing tool. Naturally, preoperative counselling of the patient can be more targeted when one's own case reports are used[2].

High-quality dental digital photography and filming with conventional cameras are time-consuming and require a lot of material.

Optimally, a specially trained photographer is required for this purpose; he accompanies the patient's treatment professionally from the initial assessment, through the surgical procedure, to the concluding assessment.

A special difficulty when a photographer is employed during the operation is that the pictures are not taken from the surgeon's view so that the focus of the image can differ from what he has in mind. The alternative of the

Fig 5a to e Tooth 23 with a coronal internal granuloma is not worth preserving, the red colour transparency at the cervicopalatal aspect of 23 only becomes clearly apparent at a magnification factor of 12 (a-c). Vestibular concavity in the course of the alveolar ridge as a sign of a horizontal bone defect. The dark mucosal discolouration in the crestal region of 21 suggests that the post-extraction gingiva is not yet completely keratinised (d). Determination of the mucogingival margin line by the probe rolling test. In this case, a lack of keratinised gingiva is found at the vestibular margin of 14 (e)

surgeon taking photographs himself often conflicts with the need for intraoperative sterility.

In addition, clinical photos or films taken with a digital camera have to be archived subsequently or transferred to the patient's virtual file.

These difficulties can be minimised or entirely eliminated by using an OPMI with integral 3-chip CCD or HD camera (Fig. 6a and b).

Naturally, sterilisable intraoral reflection-free photo mirrors, soft tissue retractors, a trained assistant and experience are needed for this purpose too.

The images are reproduced as video screen shots with a resolution of approximately 2–3 megapixels. The surgeon focuses and takes the picture himself under sterile conditions by using sterile disposable sleeves or drapes (Fig. 7a and b).

Using suitable dental software such as Evident (Bingen, Germany) the images can be stored directly in the virtual patient file and can be exported and processed if necessary.

The following features are recommended for the operating microscope:

- **Autofocus.** The autofocus saves the surgeon important time during the operation and at the same time it increases the precision of the image.
- **Xenon illumination.** The xenon illumination is very helpful especially when taking pictures of surgical procedures as it is still possible to take pictures despite the high light absorption by blood in the surgical field.
- **Magnet fixation system.** The magnetic fixation system ensures that the OPMI is absolutely free from

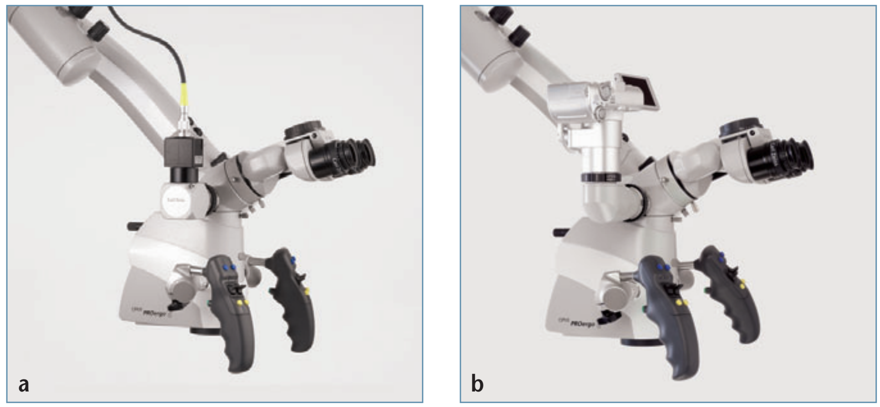


Fig 6 2 versions of imaging documentation using the example of the Proergo operating microscope (on the left with a CCD digital camera and on the right with a digital mirror reflection camera)

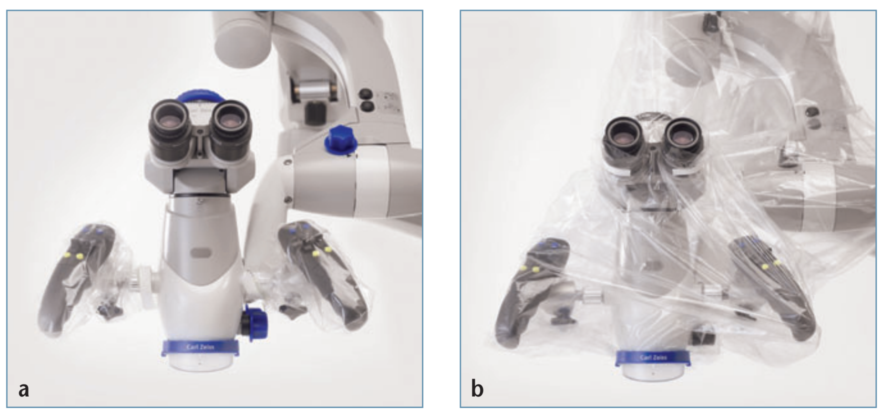


Fig 7 Examples of variations in aseptic draping of the operating microscope for performing implant procedures (OPMI Proergo)

wobble at the touch of a button, which is crucially important especially for photos at high magnification.

Minimally invasive implantology in the aesthetic zone

Most of the scientific achievements in implantology in the last 10 years refer to management of the aesthetic zone[5]. The optical magnification of the OPMI can be used effectively at the following stages of treatment:

1. Minimally invasive extraction;
2. Visual assessment of the bony extraction socket and perialveolar soft tissue to determine whether immediate implantation is indicated;
3. Incision and flap design;
4. Implant bed preparation and positioning;
5. Augmentation;
6. Microsurgical wound closure.

The use of the operating microscope is described in more detail below using the example of immediate implantation in the aesthetic zone.

1. Minimally invasive extraction at 6x to 14x magnification

The indication for immediate implantation is usually decided immediately after tooth extraction. Tissue-sparing extraction is therefore of great importance[8]. For this

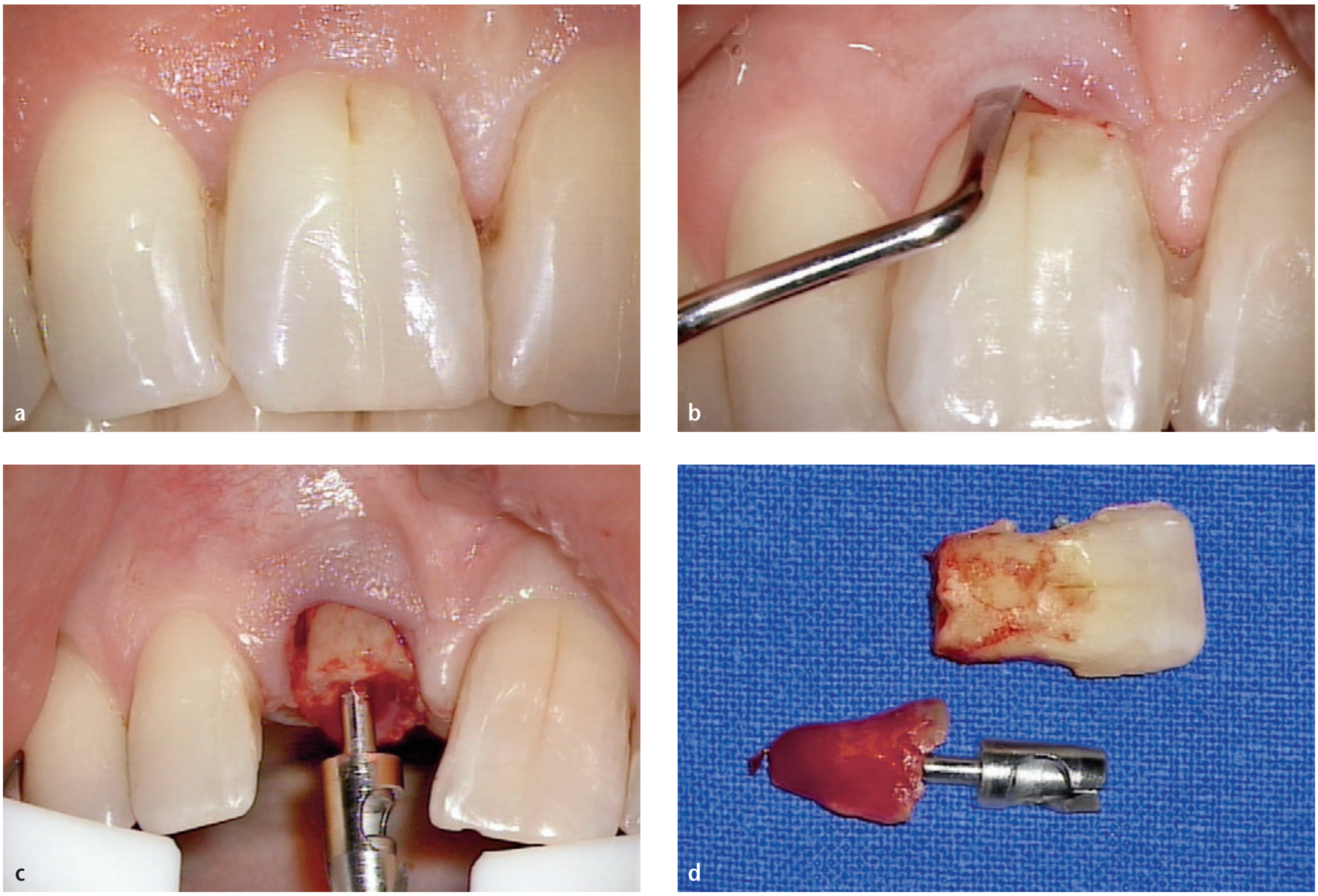


Fig 8a to d Preoperative appearance before starting extraction of tooth 11 because of an internal granuloma (a). Microscopically assisted division of the circular ligament by means of a microelevator at 14x magnification (b). Gentle vertical extraction of the apical root fragment by means of the Benex system (c). Appearance after successful extraction of the two root fragments of tooth 11 (d)

reason, horizontal dislocation of the extraction tooth is increasingly advised against as this increases the risk of fracture of the alveolar margin[21]. Instead, vertical extraction methods such as that using the Benex system (DCV, Seitingen-Oberflacht, Germany) are becoming more and more popular.

The extraction begins with microscopically assisted fine division of the circular ligament by means of a microelevator. After decapping the tooth and securing the Benex root anchor, gradual vertical dislocation of the extraction root with the Benex system can be monitored impressively under the microscope (Fig. 8a to d).

If there is an obstruction to extraction, for instance due to ankylosis of the root, fine movements of the root visible under the microscope would be absent despite the pull of the cable so that the procedure could be interrupted in good time and the extraction could alternatively be continued with fine dislocators such as those of the XTool system (DCV, Seitingen-Oberflacht, Germany).

Even in the case of Terheyden intra-alveolar extraction[21] possible root fragments can be shown indirectly by means of a mirror and dislocated more reliably.

2. Visual assessment of the bony extraction socket and perialveolar soft tissue at 8x to 12x magnification

Following successful tooth extraction the operating microscope proves to be an extremely effective instrument for assessing the (residual) bone structure of the socket. The level of preservation of the vestibular bone and the amount of interproximal bone are crucial aesthetic factors[4] and can be evaluated microscopically (Fig. 9a and b).

If there are bone deficits, a procedure in two or more stages may be needed depending on the morphology of the defect and immediate implantation may be contraindicated.

Any inflamed residual tissue that may still be present can also be removed more specifically using the OPMI.

If immediate implantation is indicated, this can be decided more safely and predictably with optical magnification.

3. Incision and flap design at 5x to 10x magnification

An incision with microsurgical scalpels can be made much more precisely under the operating microscope. Controlled division of anatomical layers such as epithelium, connective tissue and periosteum can be performed. More precise definition of the incision means that it is easier to spare aesthetically relevant structures such as the papillae of the adjacent teeth. Initial flap preparation in the crestal region, where it is important to preserve the fine alveolar margin, is performed under microscope control with microelevators. This is the only way to minimise the risk of iatrogenic fracture of the thin crestal alveolar bone (Fig. 10).

4. Implant bed preparation and positioning at an average magnification of 8x

The main aim of implant bed preparation in the aesthetic zone is reliable positioning of the subsequent implant in the “aesthetically comfortable region“[5].

To do this, the orally directed pilot drill hole and subsequent hole enlargement are monitored microscopically step by step in the horizontal and vertical planes. With intra-alveolar visual control, this means that changes in drilling direction can be made promptly. With the OPMI, the surgeon is better able to maintain the required distance between the implant and the adjacent teeth and can manage this if necessary by adjusting the drilling direction and the choice of implant diameter (Fig. 11a and b).

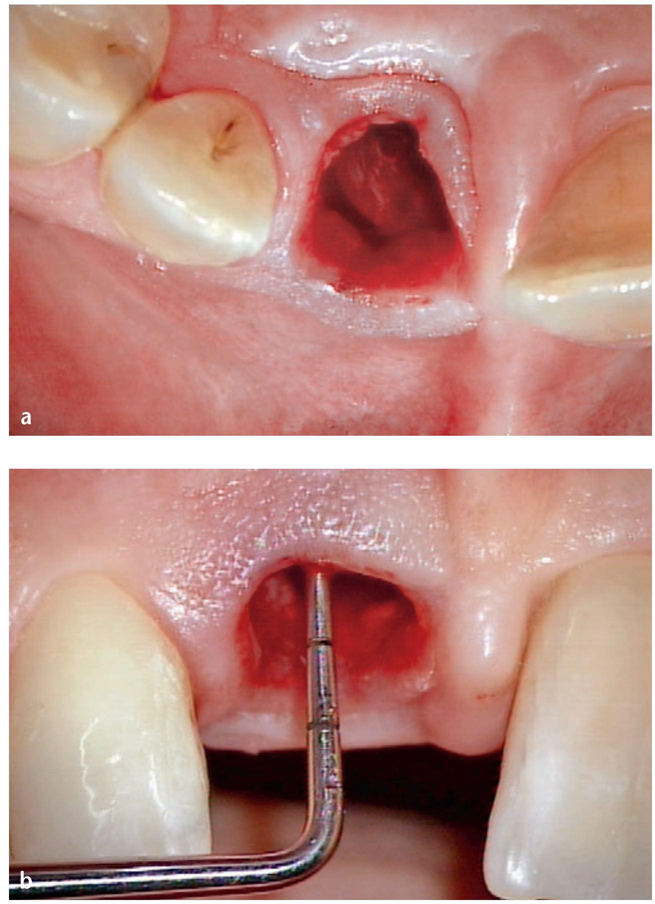


Fig 9a and b Intra-alveolar microscopic evaluation of the vestibular bone and the interproximal bone walls to decide whether immediate implantation or reconstructive measures are indicated at 8-12x magnification

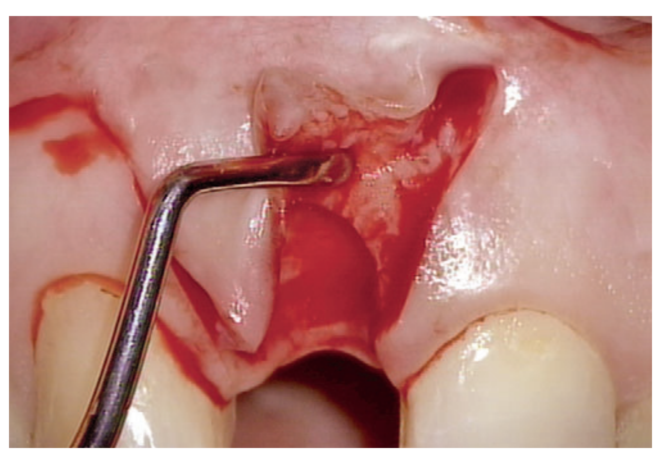


Fig 10 Marginal preparation of the mucoperiosteal flap with a microelevator to avoid microfractures of the aesthetically critical alveolar margin after microsurgical incision at 8x magnification

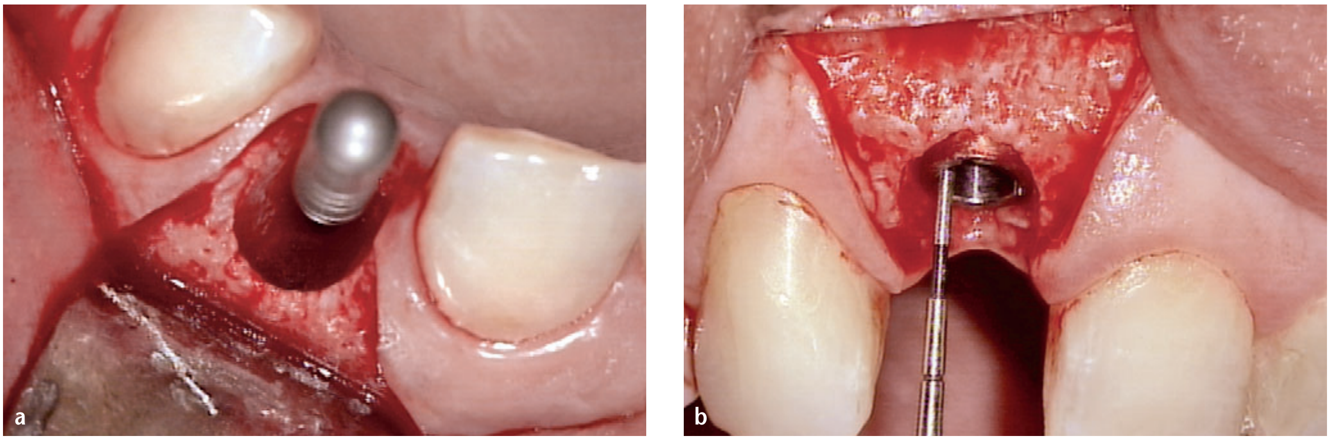


Fig 11a and b Horizontal check of direction after pilot drilling using a Camlog Implant System direction indicator (a). Vertical position check after immediate implantation in region 12 of a Camlog Screwline implant (b)

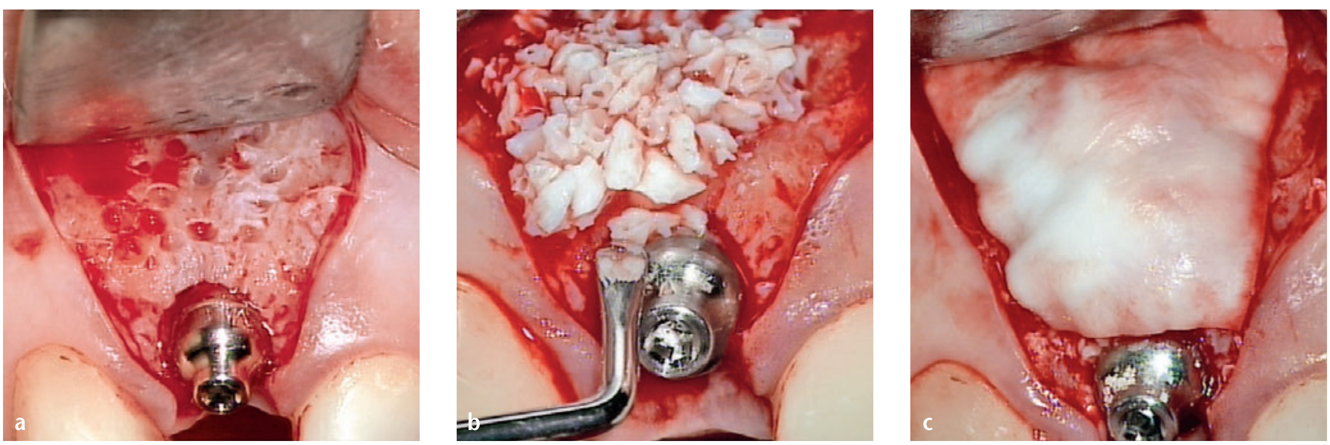


Fig 12a to c Minimal perforation of the vestibular compact bone prior to augmentation to promote perfusion after insertion of a Camlog Bottleneck gingiva former (a). Vestibular augmentation and filling of the "jumping gap" with BioOss granules using a microelevator (12x magnification) (b). Covering the graft with the contoured BioGide membrane for the purpose of GBR (c)

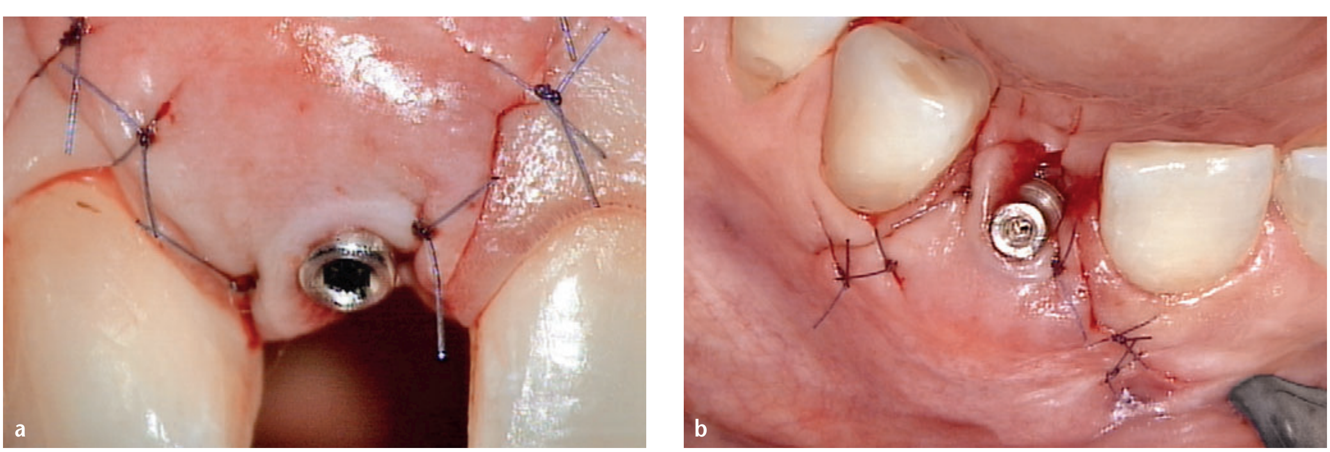


Fig 13a and b Frontal view after microsurgical tension-free wound closure with 6/0 Seralon (14x magnification) (a). Occlusal view after microsurgical wound closure with 6/0 Seralon (b)

5. Augmentation at 6x to 12x magnification

Particularly in the case of immediate implantation in conjunction with vestibular augmentation to prevent future resorption[6], augmentation of the jumping gap (distance between the implant and the vestibular alveolar wall) can be performed by a microelevator and assisted greatly microscopically. A slowly absorbable alloplastic bone substitute is particularly suitable. The microscope can provide great assistance for further augmentation measures in combination with membranes for GBR technique, for instance during membrane contouring and placement (Fig. 12a to c).

6. Microsurgical wound closure at 6x to 14x magnification

Microsurgical tension-free wound closure in the aesthetic zone without optical magnification is no longer state of the art. Naturally, the absence of tension in the wound flap should be checked accurately and if necessary ensured by slitting the periosteum. Assuming good suction, the mucobuccal fold of the periosteal layer can be visualised precisely under the microscope so that it can be divided with one cut to promote subsequent wound healing. Detailed approximation of corresponding parts of the flaps or repositioning of papillary structures requires a minimum magnification factor of 8 (Fig. 13a and b).

Microscopically guided external sinus lift (MGES)

Accidental rupture of the *Schneiderian* membrane is regarded as the complication of external sinus lift with the most consequences[14,20]. In addition, single-step implantation with sinus lift is classified as risky when alveolar ridge atrophy is advanced[12].

The indications for previously described alternative minimally invasive treatment methods such as the *Summers* internal sinus lift[19] or *Benner* balloon dilatation technique[3] are limited because of the need for impact-driven osteoelevation or the lack of visual control of the *Schneiderian* membrane.

In 2008, therefore, *Shakibaie-M.*[16] described a new, minimally invasive variation of external sinus lift using the operating microscope. Using specially developed microsurgical sinus lift instruments (DCV, Seitingen-Oberflacht, Germany) and with 8x to 18x magnification, the external sinus lift access is reduced to a minimum (4–5 mm) and the rate of membrane perforation is significantly reduced[16].

The operation is described below step by step:

1. The rotating osteotomy in the region of the sinus lift window is made under the microscope using size 1.2–1.6 mm round diamond burrs (DCV, Seitingen-Oberflacht, Germany) (Fig. 14a).
2. The dark cuff and the opening of the first subperiosteal sinus vessels signal the vicinity of the Schneiderian membrane so that the osteotomy can be stopped in good time (Fig. 14b).
3. Using the newly developed instruments, which are sharpened, the surgeon is able to fracture the parchment-thin layer of residual bone in the antral direction under control and with little pressure (Fig. 14c and d).
4. Further elevation of the Schneiderian membrane is continued chronologically with the numbered instruments with minimal trauma through the sinus lift window, which measures 5 mm on average (Fig. 14e and f).
5. The subantral space is then augmented with BioOss granules (Geistlich, Wolhusen, Switzerland) using specially developed, miniaturised plugging and filling instruments and covering the sinus lift window with a contoured BioGide membrane (Geistlich, Wolhusen, Switzerland) (Fig. 14g to i).

Apart from reducing the rate of membrane perforation, the primary stability of implants placed simultaneously is increased because of the significant sparing of the bone of the vestibular alveolar process; the nutrition of the subantral graft is improved and the rate of postoperative complications is diminished[16].

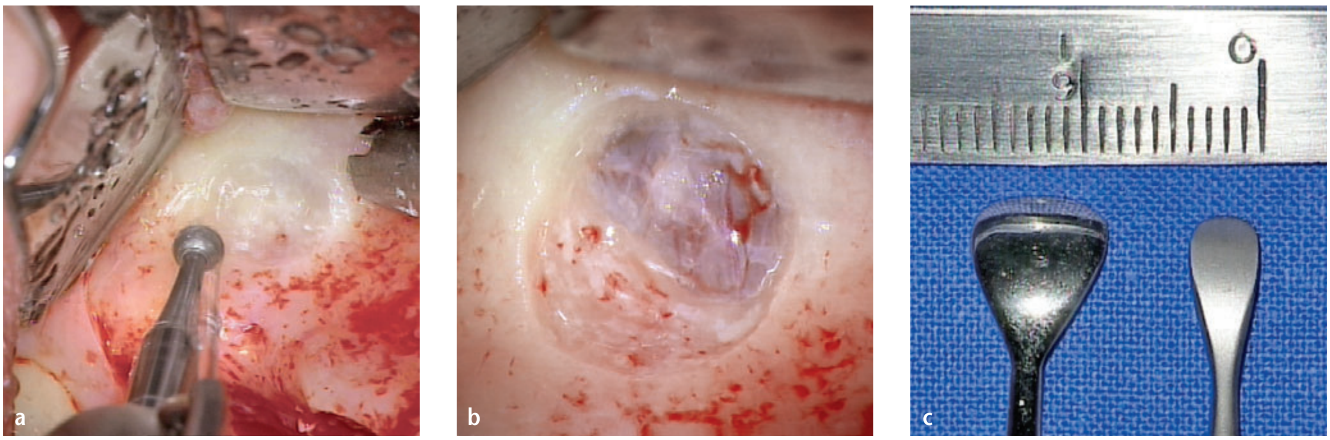


Fig 14a to c Preparation of the external sinus lift window using a diamond round bur with a diameter of 1.2 mm (10x magnification) (a). Prompt conclusion of the osteotomy when the first subperiosteal blood vessels in the sinus are opened (18x magnification) (b). Comparison of the working ends of the instruments. Left: conventional sinus lift instrument, right: microsurgical instrument (c)

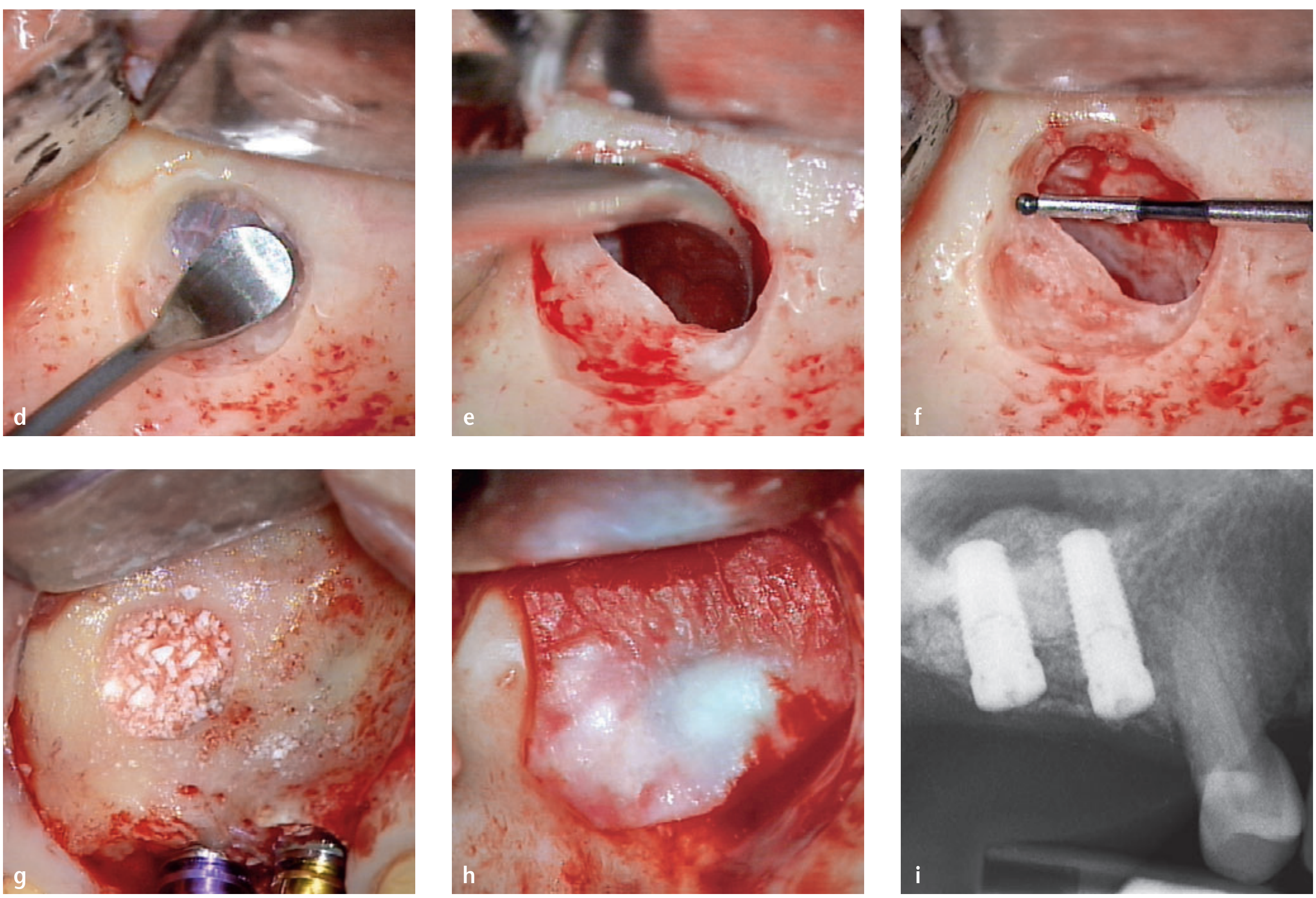


Fig 14d to i Initial circular fracturing of the parchment-thin bone of the sinus lift window in the antral direction (12x magnification) (d). Continuing elevation of the Schneiderian membrane with further angled microsurgical instruments (18x magnification) (e). Appearance after conclusion of membrane elevation through the 4-5mm sinus lift window (18x magnification) (f). Appearance after insertion of 2 Camlog screwline implants in region 15 and 16 and augmentation of the subantral space with BioOss granules (8x magnification) (g). Covering the sinus lift window with the contoured BioGide membrane (10x magnification) (h). Postoperative radiograph with preoperative residual bone height of approx. 2-5mm (i)

Minimally invasive peri-implant soft tissue management

Although there is no consensus in the literature to date on whether the presence of keratinised gingiva around implant-supported restorations instead of alveolar mucosa confers a demonstrable advantage in the long term, a growing number of authors is convinced that attached peri-implant gingiva has the following clinical advantages[1,15,18]:

- Diminished mechanical vulnerability of the peri-implant soft tissue
- Simplified peri-implant hygiene
- Better potential for prosthetic restoration
- Greater resistance to recession
- Greater patient satisfaction with function and appearance.

Plastic reconstructive procedures are often necessary, and these should be performed according to a microsurgical protocol, not least for aesthetic reasons. Precisely in these operations, it makes sense to use optical magnification to minimise tissue trauma and allow better predictability of the treatment outcome[9].

Microscope assistance is effective in the following measures for management of peri-implant soft tissue:

- Dissection of split flaps
- Tunnelling technique
- Soft tissue augmentation with connective tissue grafts or FGG
- Incision for definition of the flap shape for implant exposure
- Flap transfer and insertion of gingiva formers
- Microsurgical wound closure.

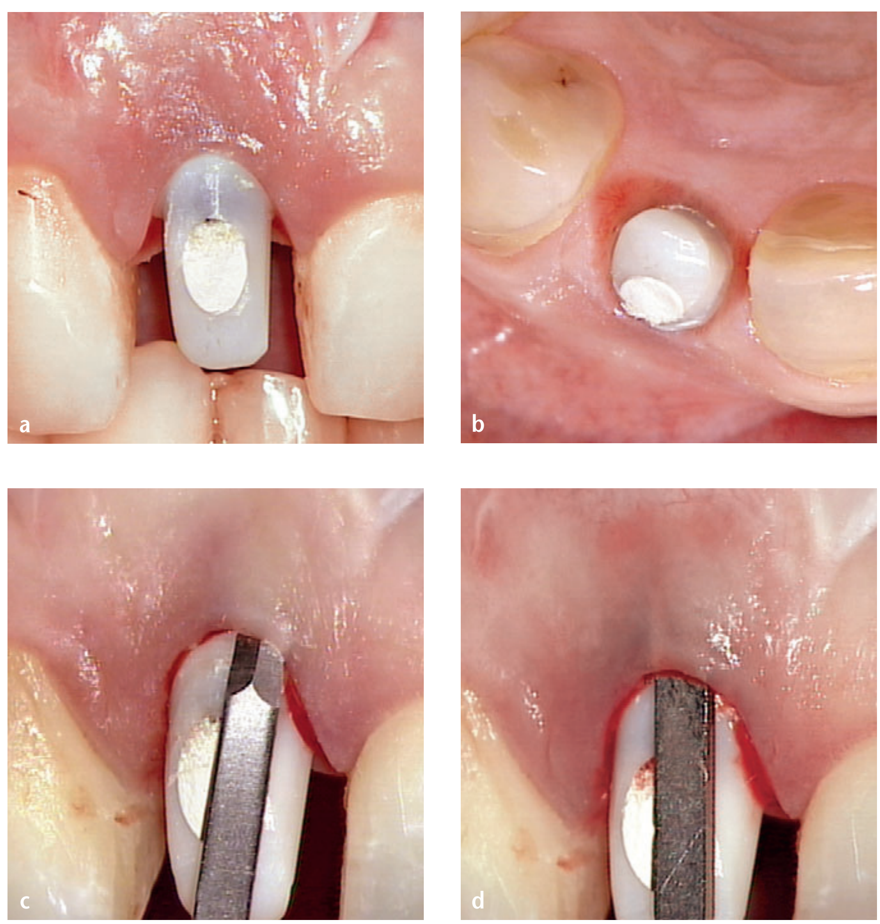


Fig 15a to d Marked vestibulomarginal colour darkening after removal of the temporary crown in region 12 because of horizontal bone atrophy with a thin gingival biotype (A) and good vertical implant positioning, six months after implantation (6x magnification) (a). The incisal view shows clearly the obvious combined hard and soft tissue deficit in region 12 with suboptimal horizontal positioning of the implant (6x magnification) (b). Cautious start of gingiva tunnelling from the marginal aspect using a microscalpel(10x magnification) (c). Apical continuation of gingival tunnelling as far as the mucogingival margin to mobilise the pocket using a microscalpel (12x magnification) (d)

Dissection of split flaps and tunnelling technique at 5x to 12x magnification

Elevation of a purely mucosal flap or sharp dissection in the mucosal connective tissue layer, regardless of the location, requires a lot of experience. Up to now these measures have not been feasible in the case of a thin gingival biotype without appropriate microsurgical instruments and optical magnification. Under the operating microscope the cutting tip of the instrument can move safely and parallel to the periosteal layer in order to avoid iatrogenic perforation of the overlying mucosa (Fig. 15a to d).

Soft tissue augmentation with connective tissue grafts or FGG at 6x to 10x magnification

If the apicocoronal width of the fixed gingiva on the buccal flap is less than 2 mm or if the thickness of the soft tissue encircling the implant is insufficient, soft tissue augmentation should be done, depending on the findings. For this purpose, palatal pedicled or unpedicled connective tissue or free epithelialised grafts have proven effective. The assistance of the microscope proves very useful particularly in the delicate dissection of a palatal mucosal flap of uniform thickness for grafting. Correct three-dimensional placement and fixation of these grafts at the recipient site can be done much more precisely under the microscope (Fig. 16a to h).

Incision for definition of flap shape for implant exposure at 6x to 14x magnification

When making an incision for peri-implant soft tissue management, the existing keratinised gingiva should be distributed as evenly as possible and flap perfusion should be optimal with the aim of minimising scarring and resorption. Optical magnification facilitates precise incision especially where the amount of keratinised mucosa is limited. In conjunction with a microsurgical scalpel, sensitive areas such as the vestibular marginal gingiva or papillae can be deliberately spared (Fig. 17a to c).

Flap transfer and insertion of gingiva formers at 6x to 14x magnification

If the width of the attached gingiva is sufficient for circumferential cover of transmucosal implant structures (at least 3 mm), the flap is dissected without tension using microscope-guided incisions so that an even transfer of the keratinised parts of the gingiva can be achieved.

Especially when replacing implant cover screws with gingiva formers, crushing of the connective tissue between implant and gingiva former can be avoided (Fig. 18a and b).

Microsurgical wound closure at 6x to 14x magnification

Optical magnification during microsurgical tension-free approximation of the peri-implant soft tissues after plastic surgical manipulation should be regarded as the standard in modern-day implantology. An optical loupe with a maximum magnification factor of 3 is very helpful. Further visual magnification of the operation site, as with all the measures described above, leads to greater reproduction of detail. This is often the only way to ensure the correct use and guidance of the microsurgical instruments and needle/suture combinations to promote tissue-sparing wound approximation and more attractive aesthetic results (Fig. 19a to f).

Summary

The optimal illumination and high magnification of the operating microscope take the dentist working in the field of implantology into entirely new visual dimensions, just as in endodontics or periodontics.

The identification of fine anatomical structures of relevance for the implantologist allows much greater precision in diagnosis and during surgery. While this method does require more time and expense and greater surgical skill, this is balanced by greater treatment safety and outcome predictability, depending on the indication. It diminishes surgical trauma, shortens the postoperative healing period and produces better aesthetic and functional results. Photo and video documentation benefits in an unsurpassed authentic manner from a transmission opera-

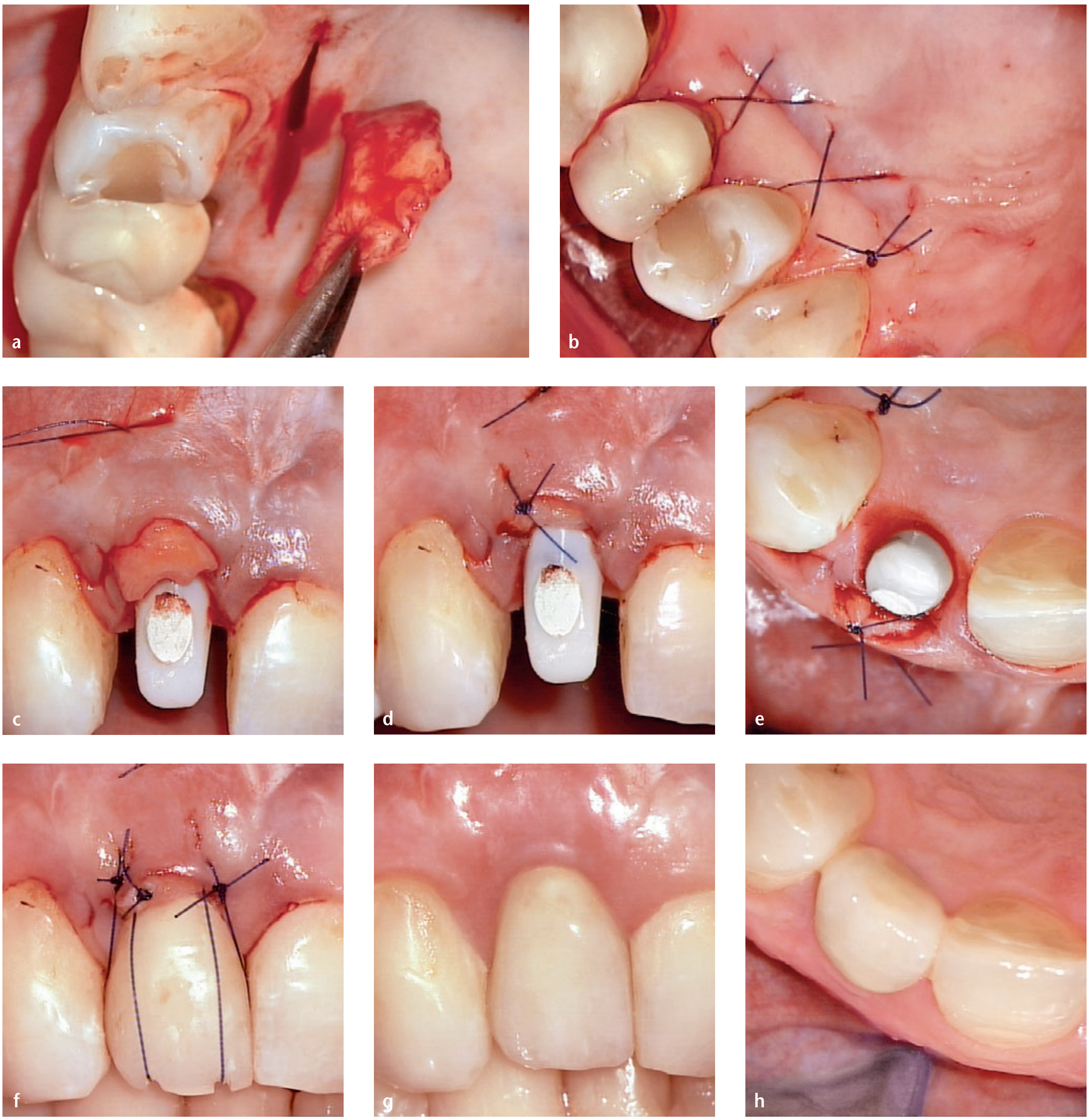
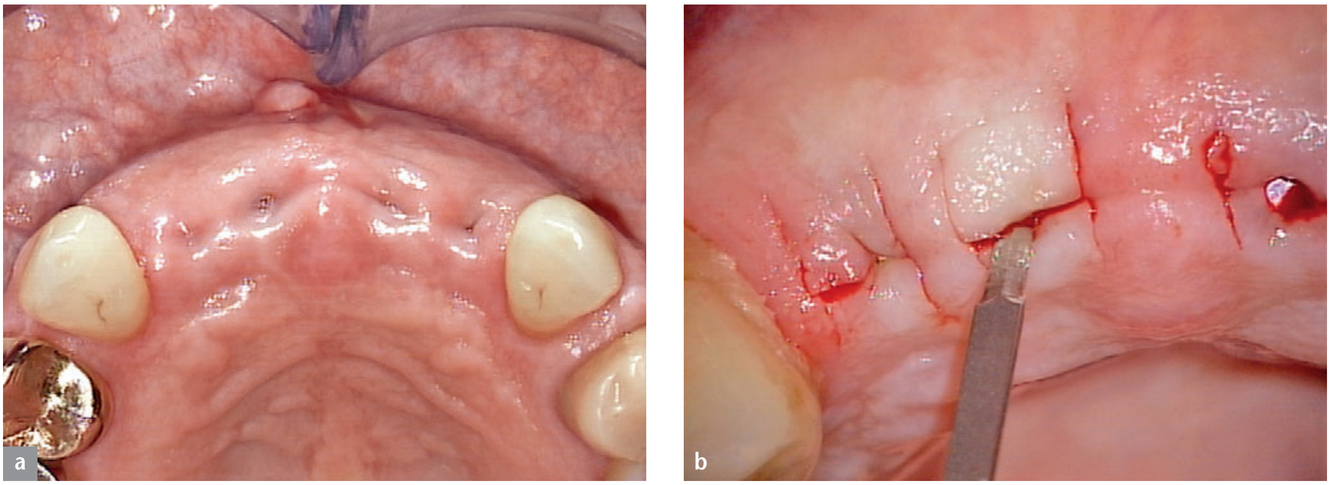


Fig 16a to h Removal of a subepithelial connective tissue graft from the palate in region 14-15 (8x magnification) (a). Appearance after palate wound closure in region 14-15 with 4/0 Seralon (6x magnification) (b). Apical advancement of the looped connective tissue graft into the prepared tissue pocket using 4/0 Seralon (8x magnification) (c). Fixation of the connective tissue graft in the correct position using 6/0 Seralon (8x magnification) (d). The incisal view shows the desired increase in thickness of the vestibular gingiva in region 12 after introduction of the connective tissue graft (8x magnification) (e). Coronal repositioning of the vestibular gingiva after preparation of retention grooves on the incisal aspect of the temporary crown in region 12 with 6/0 Seralon (9x magnification) (f). Appearance 6 months after gingival thickening by means of a connective tissue graft, frontal view (9x magnification) (g). The incisal view shows that horizontal tissue filling is not complete but is aesthetically acceptable (8x magnification) (h)



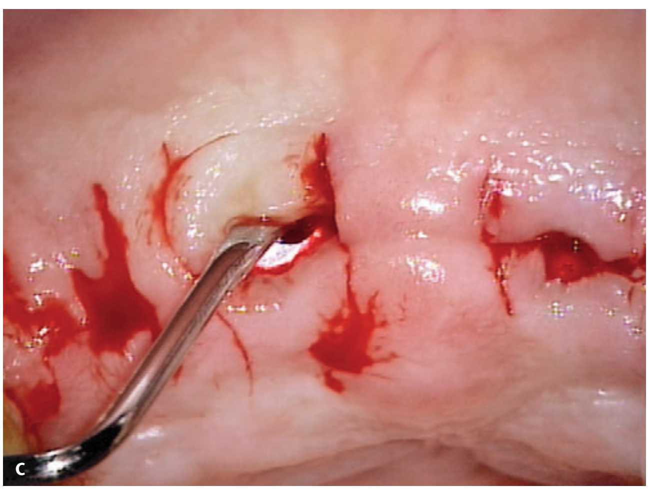


Fig 17a to c Appearance 10 weeks after immediate implantation in region 12, 11, 21, 22 with vestibular augmentation and thick gingiva biotype (B) (4x magnification) (a). Microsurgical incisions to expose the implants using a microscalpel (12x magnification) (b). Targeted orovestibular division and transfer of the keratinised gingiva using a microelevator (13x magnification) (c)

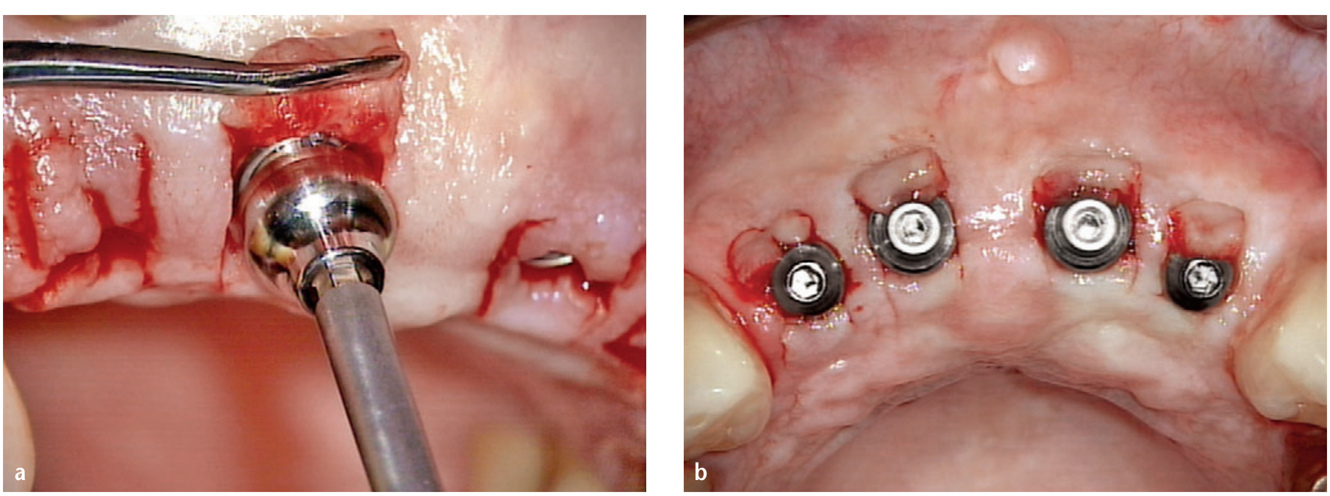
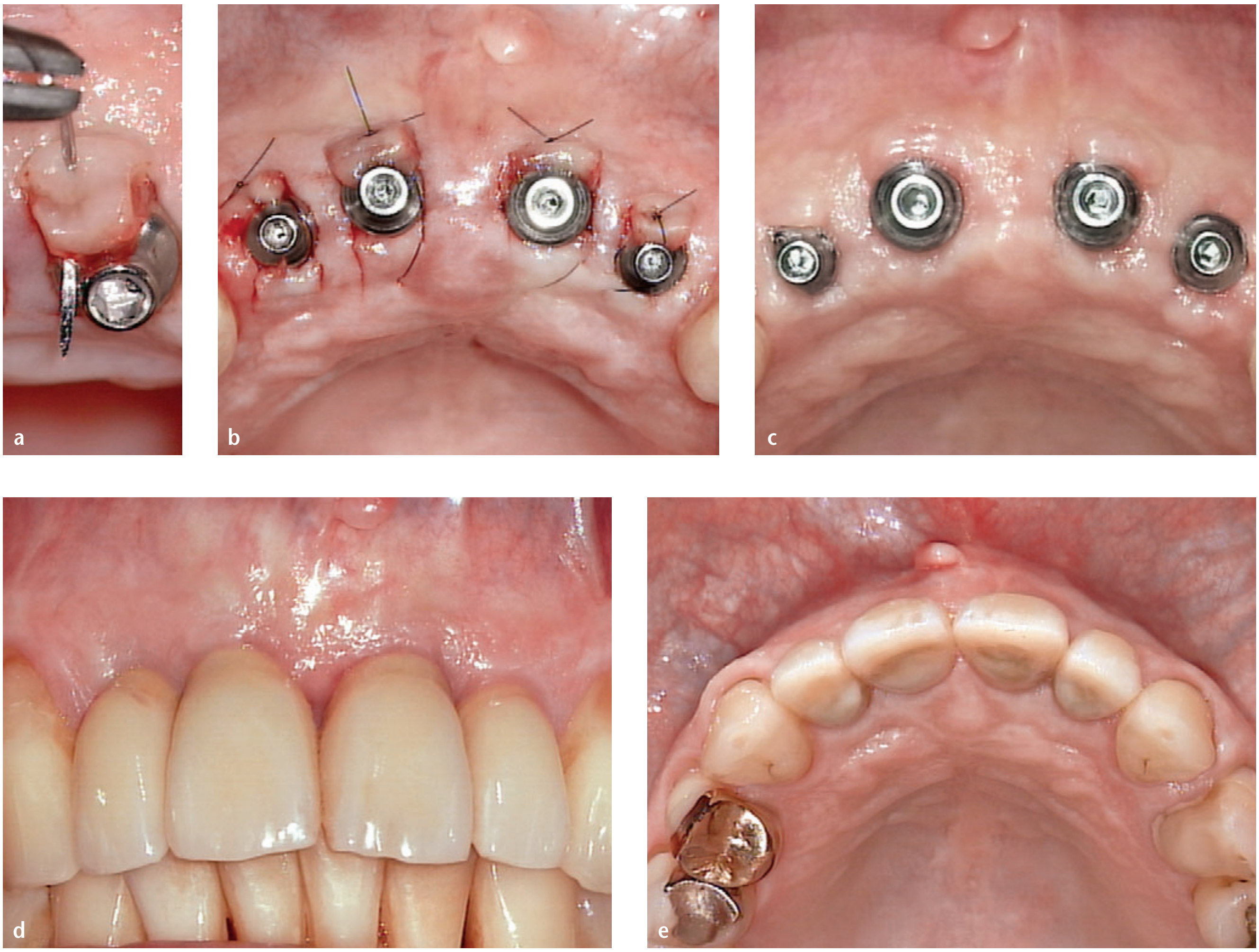


Fig 18a and b Insertion of the Camlog Bottleneck gingiva former without crushing the tissue (14x magnification) (a). Appearance prior to microsurgical roll flap technique after insertion of gingiva formers in region 12-22 (8x magnification) (b)



ting microscope. However, this gradual improvement of the quality of implant outcome by means of an operating microscope is only part of a routinely observed minimally invasive microsurgical treatment concept with a specially trained team.

Acknowledgement

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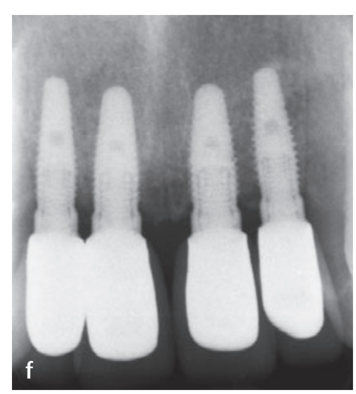

Fig 19a to f Microsurgical suture to fix the rolled flap with 6/0 Seralon (14x magnification) (a). Appearance after conclusion of exposure (8x magnification) (b). Noninflamed, keratinised peri-implant soft tissue profile 3 weeks after exposure (9x magnification) (c). Appearance 1 year after fitting the final implant-borne crowns in region 12, 11, 21 and 22, frontal view (9x magnification) (d). The incisal view reveals negligible vestibular resorption 1 year after the conclusion of the prosthetic restoration (6x magnification) (e). Radiographic follow-up confirms normal peri-implant bone structures 1 year postoperatively

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