New tools for optimizing the implantological workflow

Result-driven 3D implant and bone planning

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Oral implantology has traditionally prioritized the placement of the implants and only then looked for compatible prosthetic solutions. Implant placement itself has now become less of a challenge, so more attention has been drawn to optimizing the individual restorative treatment outcome for a given patient. What is optimal has been defined in functional and aesthetic terms as measured by an imagined ideal situation. In clinical practice, however, problems still persist with regard to the reconstruction of bone defects and with aesthetic and functional implant positions and soft-tissue management. For situations where major rehabilitation is required, implant numbers and positions continue to be the subject of controversial professional discussion.

In addition, the treatment objectives should be achieved as simply as possible, using appropriate and conditionally reversible techniques. Tissue trauma should be kept to a minimum. However, the status quo ante is more easily achieved today. Whether the cost-benefit ratio is favourable will have to be determined individually for each case. We must distinguish between two sets of criteria for implant success – general criteria, valid for all implants, and specific criteria, valid for special indications. The enormous progress made by oral implantology has raised expectations enormously. Even if one goes with the recommendation of the scientific societies that "the best therapy in tooth loss is replacing every single lost tooth by an implant". Even taking into account the oft-cited mantra that we must always aspire to reconstructing the natural situation, one still has to admit that while this may be true for single-tooth replacement and also for the replacement of multiple single teeth, it does not automatically hold for every kind of implant treatment. Less than optimal outcomes can have many reasons, from prerequisites that are not met, which leads to greater treatment risks, to socioeconomic limitations. The highly individual nature of every single case would preclude simple algorithmic solutions.

Prosthetic outcomes depend not only on implant placement but also on the use of bone substitute. Looking at the field of augmentation, we see no general recommendations for any specific method. This is unsurprising, as there are many different methods in clinical use; many of them are used only in a small number of cases and can look back on only a limited time of clinical experience. What amounts to the gold standard for one treatment provider might be considered obsolete by another. Table 1 shows the actual protocol used for augmentations, updated since the last publication (*Ehrl PA*, 2003). In the event of deficiencies in both height and width, a two-stage procedure is invariably used. If only the width is deficient, the procedure chosen will depend on the thickness of the bone, on whether spongious bone is present, in order to decide whether relatively simple techniques such as bone spreading are appropriate or whether bone substitutes must be employed. The transition from one-stage to two-stage procedures is a gradual one.

Materials and methods

Cone-beam computed tomography (CBCT) has been increasingly used at our clinic since 2000; by 2008, it had been used for all implantological interventions. 3D diagnostics by themselves undisputedly provide added insights, increasing the quality of the treatment. But 3D planning also always supports prosthetically based planning in addition to analyzing the anatomical situation, whether using standard plaster casts or – as has been possible for some time – digitally. Even before the introduction of 3D technologies, the so-called "backward-planning" approach (*Kirsch* et al., 2008) had shown visualizations of the

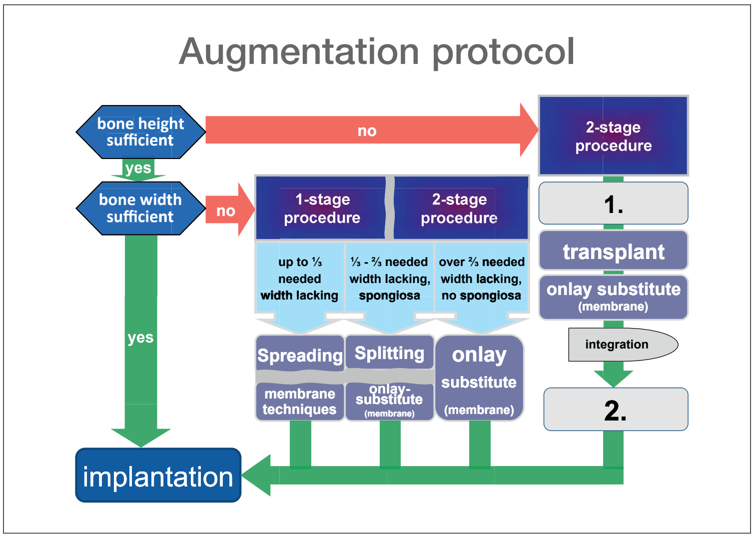


Table 1 Augmentation protocol.

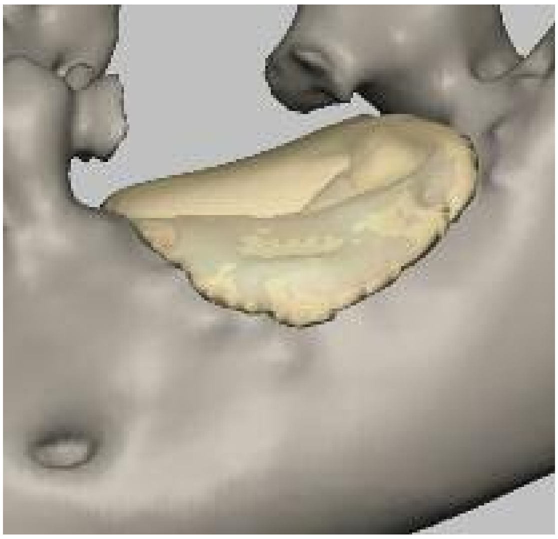


Fig. 1 Individual, digitally planned bone block, individually produced.

desired treatment result to be helpful. Here, too, we began by using 3D techniques and set-ups for more extensive procedures, but we eventually realized that it makes sense to use them even for simpler reconstructions such as single-tooth replacements.

Each of these two modes of treatment planning data – CBCT and analogue – is helpful in its own way, contributing to improve treatment results in the hands of an experienced implantologist. The logical next step now is to connect these two modes. One step that has already been implemented is the transition from the plaster cast and tooth set-up to digital models and digital reconstructions*. But while this approach is available today, it has not yet been sufficiently proven in clinical practice. The question still has to be answered as to which items on the nearly inexhaustible list of digital features are more suitable for the playful in mind and which ones are essentially useful in treating the patient.

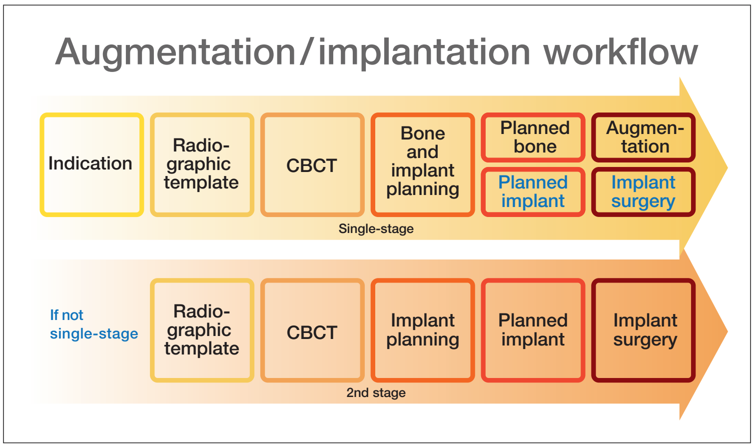


Table 2 Augmentation/implantation workflow.

Another aspect missing from the treatment planning process was that of anticipating the results of the bone augmentation process and – as a consequence – developing a suitable bone substitute in the first place. Today, the first steps in the right direction are being undertaken. It is now possible to create a digital model to calculate the required bone volume, regardless of what material is chosen. Within certain restrictions related to volume, bone blocks can be planned digitally and produced digitally** (Fig. 1).

What are the main features that characterize a 3D-based plan for implant placement and bone augmentation? Only by evaluating three-dimensional data can we anticipate preoperatively how the desired prosthetic result can be obtained. Having the final result firmly in mind constitutes a solid base for decisions related to whether and how to augment. Almost always, bone defects will be present whose extent must be evaluated. These have been described and categorized (*Fallschüssel, Atwood*, Cologne Classification of Alveolar Ridge Defects – CCARD), showing that the horizontal dimension is usually affected first, followed by a gradual loss of vertical height. But defect classifications are beginning to lose their importance, as 3D planning is capable of assessing individual situations. However, they are helpful in recommending certain reconstructive protocols (see Table 1). Table 2 shows the 3D augmentation and implantation workflow for one- and two-stage procedures.

* *Sicat/Cerec, Optiguide procedure*
** *maxgraft bonebuilder (Botiss dental)*

The horizontal component is important for the prosthetic reconstruction in two respects: primarily for aesthetic reasons in the anterior jaw and primarily for functional reasons in the posterior jaw. This also determines the position of the implants. The optimum outcome would be surgical restoration of the original bone volume, possibly even providing a bit of extra volume to compensate for primary bone loss after surgery. In all cases, individual assessments must be made of implant position (e.g. angled abutments, the responsibility of the oral surgeon) and of prosthetic design (the responsibility of the dental technician). Certain design aspects, such as asymmetric crown cervices or ceramic-mucosa interfaces may compromise oral hygiene and are not infrequently associated with aesthetic deficiencies.

If restoration of the vertical dimension is necessary, this will mean having to resort to a more ambitious two-stage procedure in most cases. At this point has to be mentioned, that so far almost all atrophy patterns only refer to one jaw and do not meet functional necessities, primarily striking the more orally situated jaw bone. *Arutinov* and coworkers (2012) assume that this must be compensated for by angled implants. Well-founded planning decisions can be made only based on information about both the three-dimensional anatomy and the planned three-dimensional prosthetic solution. *Kinsel* and coworkers (2007) conclude that implant length alone allows us to reliably forecast the risk of implant loss. This means that available bone volume must be utilized to the utmost extent possible. The EDI guidelines (2011) critically evaluate the placement of short and angled implants. Angled implants, for example, require class III or higher bone quality and 3D planning along with guided implant insertion.

Prosthetic planning on a cast and the fabrication of a diagnostic restoration is the determining factor for a favourable implant treatment result and subsequent rehabilitation. This decides which treatment steps to perform and which objectives to strive for. Quite often, this step does not receive the attention it deserves in daily clinical practice. Treatment planning should be performed by the dentist him- or herself. A special appointment with the patient should be planned to obtain the patient's informed consent. 3D images, planning tools and software as well as try-ins are very helpful. Other imaging modes are also possible planning adjuncts but can be misleading and have to be employed prudently. With two-stage procedures it may be necessary to repeat this step after augmentation and to obtain a second 3D X-ray (see Table 2).

New options for prosthetic planning are available today to replace the use of physical casts. One example is the Sicat/Cerec technique. It offers the classical analogue set-up mode as well as a digital one. For the latter, the surfaces of the neighbouring teeth and soft tissues are scanned and transferred (matched) to the radiological 3D data. This can be done on the basis of a cast or intraorally (Sicat + Cerec + Optiguide procedure). Using the prosthetic planning programme, a digital set-up is performed. These techniques are aimed at simplifying and shortening the workflow. An interesting question is how precise these methods actually are. We have data for the agreement of the Sicat CAD/CAM optical scans with radiograph data. The difference between CBCT data and optical scan surface data has been shown as between 0.03 (0.33) and 0.14 (0.18) mm (*Ritter* et al., 2012). Crowns can be planned with the help of the Cerec crown-and-bridge planning software. The precision of the digital Sicat method depends on the accuracy of the imaging data. For analogue impressions, a precision of 0.1 to 0.2 mm is required (*Luthardt RG*, 2004), and the difference between crowns and natural teeth is 0,027 to 0,101 mm (*Limkangwalmongkol P* et al., 2007 and 2009).

The precision of the two methods – analogue and digital – is therefore within the same range if all potential sources of error are taken into account, such as CBCT, the transfer to the surgical guide, the repositioning of the guide, the seating of the drill in the bore and discrepancies appearing when actually placing the implant. Surface scans improve the precision. The digital way of creating tooth set-ups dispenses with having to fabricate a diagnostic set-up. An important step towards the digitalization of prosthetically driven implant planning has now been realized and is associated with greater reliability and precision of the planning process. Unfortunately, technical restrictions still exist in patients exhibiting partially edentulous jaws or extensive metal artefacts.

The more teeth are missing and the more pronounced the soft-tissue reaction, the more important will be the facial outline and functional criteria. Today we can simulate this only with an analogue set-up, reviewed by the dentist together with the patient.

Different indications – different planning approaches

Single-tooth replacements tend to give rise to high expectations. Where at all possible, the postoperative situation should be the same as before the respective tooth was lost. Expectations in the aesthetic zone are particularly high. The choice of rehabilitation approach must be guided by the existing anatomical situation. For example, immediate or delayed implan-

Fig. 2 Planning an implant in a defect before augmentation (same as Figure 1).

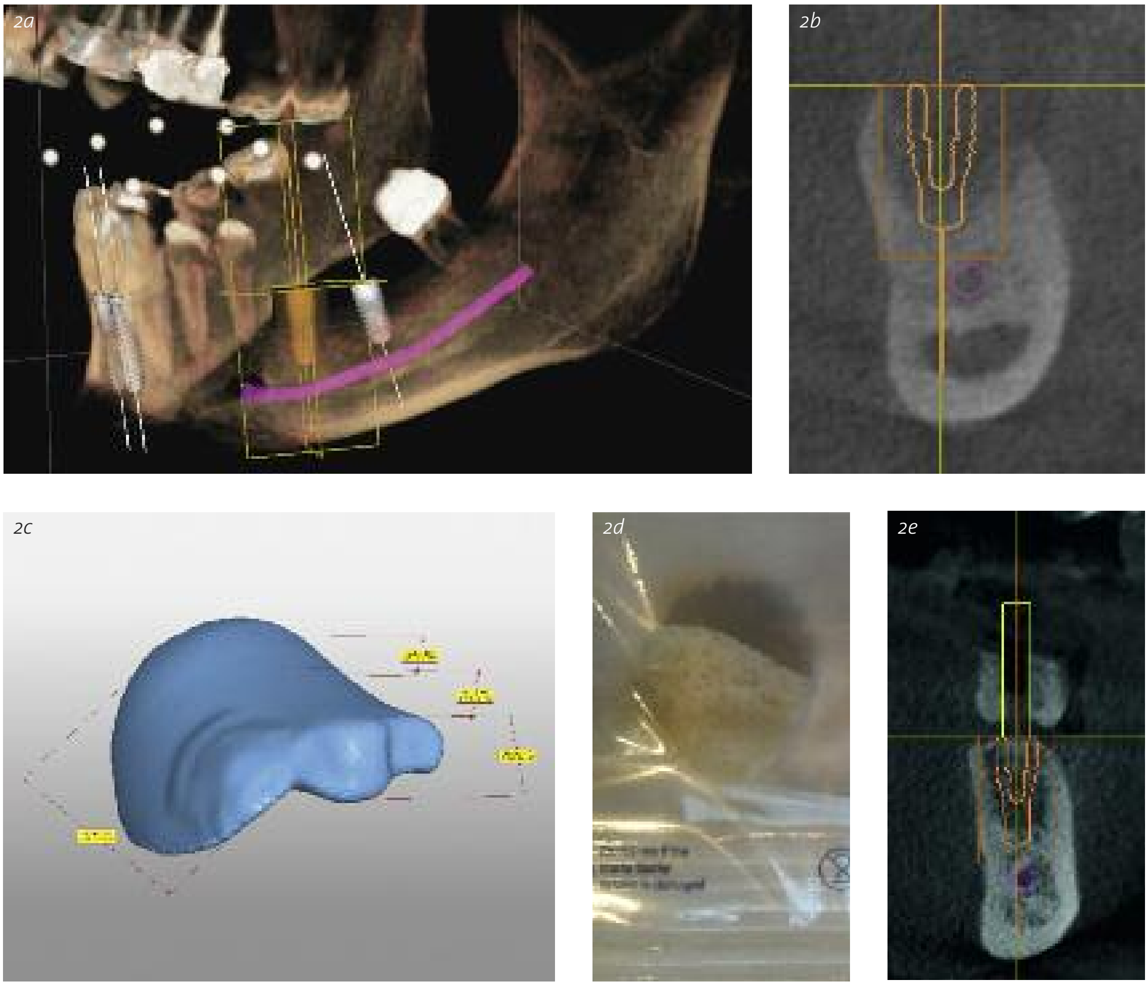


Fig. 2a 3D planning, survey.

Fig. 2b 3D planning, preoperative cross-section of tooth 36.

Figs. 2c and d Human bone block, digital and physical.

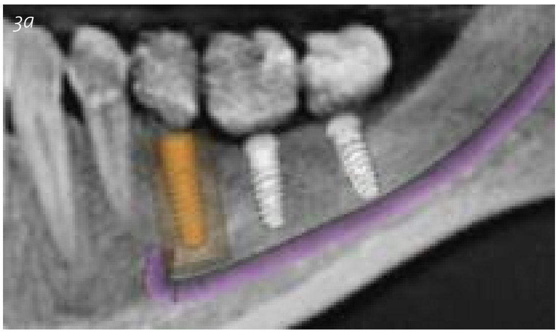
Fig. 2e 3D planning, cross-section of tooth 36, post-operative set-up showing central tooth axis.

tation in an existing socket will be possible without 3D planning. By contrast, diagnostic set-ups and 3D radiographs make sense in delayed implant placement. Appropriately planned axial inclinations will favourably influence the relationship with adjacent and antagonist teeth, emergence profiles and, ultimately, crown positions. Guided implant surgery is particularly helpful in multiple single-tooth implants or in cases of crowding.

When reconstructing a distally edentulous jaw, TMJ function and support are important. There can be no standard answer to the question of how many teeth a person needs. During the past few years, there has been a trend toward more teeth, with fixed bridges for reconstructions to within the first molar, possibly with cantilevers beyond the premolars. In the posterior jaw, the alveolar process will usually atrophy fastest in a horizontal direction, starting from the buccal aspect, mostly with concomitant atrophy in the vertical dimension (Figs. 2a to e).

No or only minor augmentation implies greater technical effort with longer prosthetic reconstructions on shorter implants placed more lingually than natural teeth. The use of short implants in the posterior jaw is subject to several restrictions (good bone quality, primary splinting of crowns or copings, avoidance of cantilevered bridges and no contacts at lateral excursions or during parafunction). Restrictions also apply to the angulation, which is limited at > 20°. The EDI guidelines (2011) do not recommend angulated implants in the shortened dental arch. Where natural antagonists are available, the new implant-supported crowns will not induce functional losses – unlike in cases where the antagonists are not natural teeth or are not located in their natural functional positions. Buccal space must be reclaimed – even if patients sometimes complain of spontaneous cheek bites and bolus retention. In a situation such as the one described, the decision must be very carefully weighed as to whether to take the initially easier path with short angulated implants and long crowns or the harder path with bone augmentation and distally placed implants. 3D planning provides invaluable help with this decision. A typical reconstruction

Fig. 3 Shortened dental arch. 3D planning before and after grafting.



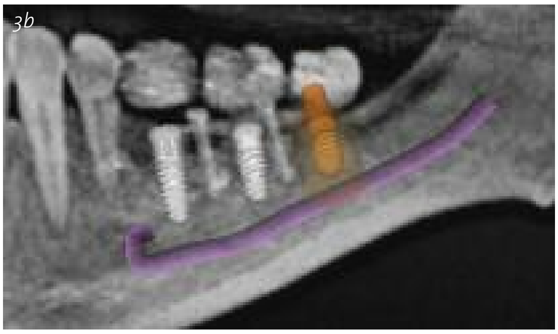


Fig. 3a
Initial planning with set-up.

Fig. 3b
Second planning with set-up after onlay graft.

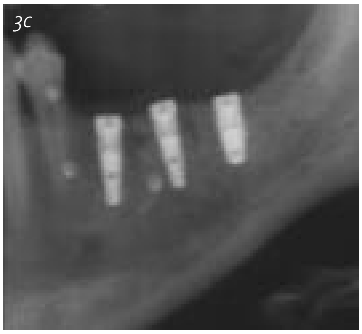


Fig. 3c
The implants have been placed.

Fig. 3d
The crowns have been cemented.

of a shortened dental arch with a favourable baseline situation and a surgical guide used for pilot drillings is shown in Figures 3a to d.

3D planning is even more important when choosing between different treatment approaches to implant-supported restorations for the completely edentulous jaw. Are bone augmentation measures required, and if so, which ones? Is it preferable to provide a removable or a fixed restoration? If the latter: Can multiple implant-supported single-tooth restorations be used or should bridges be provided? Short or wide span? Should the intermaxillary space be filled prosthetically (by longer tooth crowns) or by a mucosa substitute? Usually, answering these questions requires sophisticated functional diagnostics. Digitalized dentistry even with this might help us in the future, making it possible to study mandibular movements in the digital world without the necessity of doing big registration work. Rarely toothless jaws do not require any special augmentation procedure. Extensive augmentations frequently are necessary as this is shown with the patient in Figures 4a to c.

The number of implants recommended for supporting fixed prosthetic restorations has ranged from four (All-on-Four concept) and the Consensus Conference's recommendations of six implants in the mandible and eight in the maxilla all the way to tooth-by-tooth reconstruction up to the sites of the first molars. The many diverse planning data and wide range of therapeutic options available require a particularly diligent planning effort, which is justified by the dire consequences of failure. Planning based on digital casts is not appropriate in these cases as cheek and lip support are so important and can be evaluated only on the patient directly. The advantages of prosthetically driven treatment planning are particularly obvious here.

Even in the case of seemingly simple implant treatment in the edentulous jaw with a view to retaining removable dentures, diagnostic denture planning and 3D planning are reasonable adjuncts – not just to check function and soft-tissue support but also to be able to select implant positions together with the dental technician, who can then can provide adequate space for the box and attachments.

Discussion

The advantages of 3D planning can be subsumed under the concept of more and better information (Table 3). 3D diagnostics provides reliable information about the condition of the alveolar process and important anatomical structures. An additional diagnostic set-up provides additional information about the restoration of function and aesthetics. Both sources of information taken together ensure optimum treatment planning. Digital diagnostic set-ups and augmentation volume analyses are new tools to

Fig. 4 Edentulous upper jaw. 3D planning, augmentation with xenogeneic bone blocks and membrane, at the time of augmentation and at re-entry.

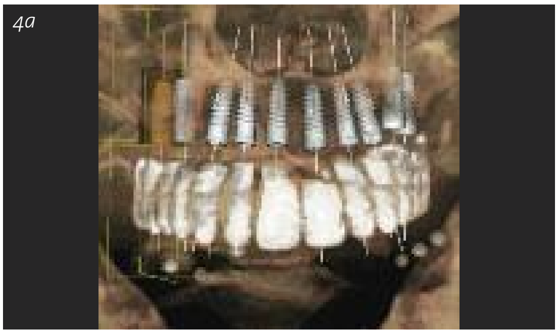


Fig. 4a 3D planning.

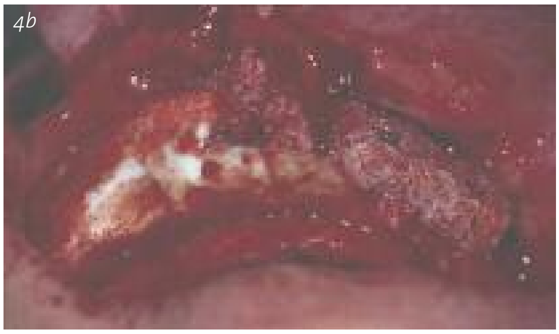


Fig. 4b Augmentation with xenogeneic bone blocks and membrane.

Fig. 4c Situation at re-entry.

be integrated into the implantological workflow. In the past, an experienced surgeon and a bit of patient flexibility could compensate for unpleasant surprises. But this meant leaving the intraoperative procedure prone to spontaneous decisions. Proper preoperative planning using 3D data ensures a well-considered procedure with the specific tools required as well as bone substitutes and suitable implants being ready and at hand. Patients also benefit by gaining a good understanding of the diagnosis, treatment and follow-up and can be assured that everything is being done for their comfort and safety.

The approach described might initially appear more complicated – hence more costly. But knowing exactly what to do and what materials to use actually makes for less complicated procedures and can save money. The planning phase may be longer, but the treatment phase will be shorter, and reworking will be required less frequently. Implant treatment invariably justifies a 3D radiograph. Of course, the introduction of the new techniques is logistically more demanding than traditional procedures and they place greater weight on a team approach, but once introduced, they are extremely helpful.

But despite all precautions, surgery risks can never be completely eliminated. Excessive confidence in methodology can give rise to carelessness. Even in 3D planning, mistakes may occur and failures result, even to the point of further aggravating the initial situation. It is important to be aware of all the different steps and the sources of error from the outset – in other words, one has to obtain expert training in planning techniques. It is still always important to keep an open and critical mind during the procedure and to digress from the envisaged course if necessary. But all in all, the advantages of 3D planning are paramount. ■

Table 3 Advantages of result-driven 3D implant and bone planning.

Higher quality through:

- Identification of risks
- Reliable planning
- Nature-like structures
- Purposeful and fast procedures
- Patient compliance
- Cost transparency

Visit the web to find the list of references (www.teamwork-media.de). Follow the link “Literaturverzeichnis“ in the left sidebar.

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