Fully guided placement of orthodontic miniscrews – a technical report

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Introduction: Orthodontic miniscrews are used to obtain skeletal anchorage during orthodontic treatment and their application is growing due to the simple method of placement and removal, which invites improved patient compliance without significant impact on function and aesthetics. However, complications and risks are reported that underscore the need for a thorough preoperative assessment to enable accurate placement, especially in confined sites. A novel approach is presented which employs a custom-designed 3D-printed splint to facilitate a fully-guided placement of orthodontic miniscrews.

Materials and methods: The presented splint was virtually planned using coDiagnostiX® software after matching the DICOM data and STL file, to enable fully-guided screw insertion. Insertion depth was defined by a sleeve tube height that provided a depth stop when contact was reached with the head of the hand piece. Additionally, to prevent movement of the insertion instrument, a custom metallic sleeve was designed and 3D-printed by a metallic printer.

Results: Accurate placement was achieved and no complications were experienced during insertion and use.

Conclusions: The insertion approach provides more predictable results and enables accurate placement of orthodontic screws. The procedure avoids associated risks and complications primarily encountered in difficult cases.

OMS are available in a range of diameters and lengths and can be placed in considered locations in the upper and lower jaw. The placement of OMS may be carried out without raising a soft tissue flap under local anaesthesia and is accomplished, in most cases, without predrilling. Nevertheless, there is a risk of damage to adjacent tooth roots and local neurovascular structures. Furthermore, perforation of the floor of the nasal cavity or maxillary antrum is also possible. Damage to the dental roots is usually self-limiting and healing may occur within a few weeks when OMS are immediately removed. However, trauma to blood vessels can cause bleeding, which can be difficult to manage, particularly if it involves the palatine vessels. In addition, premature

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loosening and loss of a miniscrew due to inadequate stability may warrant the interruption of orthodontic treatment, with financial implications.\textsuperscript{7,9}

The accurate placement of an OMS is required for optimal retention, to avoid complications and improve long-term treatment outcomes while enhancing patient acceptance.\textsuperscript{1,12,13} A novel custom-designed 3D-printed splint is presented that allows fully-guided OMS placement.

Materials and methods

Preoperative planning

Preoperative CBCT scans of the upper jaw (Planmeca Promax 3D Max®, Finland) with dimensions of 10 × 5.5 cm (diameter × height) and a voxel size of 200 µm, were obtained. Digital Imaging and Communications in Medicine (DICOM) data were uploaded into coDiagnostiX® implant planning software (Dentalwings GmbH, Germany). Matching an STL file (standard triangulation language) of the corresponding upper jaw model produced from an alginate impression of the teeth, alveolar crest and palatal tissue was performed semi-automatically and fine-tuned by manual adjustment in reference to teeth and adjacent gingivae. The produced plaster model had been scanned with a fully automated optical structured-light scanner (S600 Arti Scanner®, Zirkonzahn, Italy) and digitally saved in the STL format.

Screw positions were virtually planned in the coDiagnostiX® software and focused on correct mesial-distal as well as vertical positions, angulation and insertion depth. In addition, the position of the adjacent dental roots and the maxillary sinus were noted.

Two 14 mm screws (Sterile Dual-Top Anchor System®, Jeil Medical Corporation, Germany) were selected for insertion half way from the mid-palatal suture to the corresponding first premolar, along a transverse line through the premolar’s palatal cusp (M4 site).\textsuperscript{14} Both screws were virtually positioned, as parallel to each other as possible, to facilitate the later application of a planned orthodontic device. A tooth-supported polymer splint was designed for fully-guided screw insertion (Figure 1). As demonstrated in Figure 1 at the polymer splint, a sleeve with an inner diameter (x) of 4.6 mm was designed. The inner diameter was adjusted to the predetermined outer diameter of the insertion instrument (y). Insertion depth was defined by the polymer sleeve height (h) that produced a depth stop when contact with the head of the hand piece was reached. The depth stop was determined by the screw length and the length of the insertion instrument. The custom metallic shaft sleeve was designed and 3D-printed using a metallic printer (Mlab cusing R®, Concept Laser, Germany; Remanium Star CL®, Dentaurum, Germany). This served to provide guidance during placement of the full screw length and helped avoid tilting of the insertion instrument. It was imperative that the outer diameter of the metallic sleeve conformed to the inner diameter of the polymer sleeve (x) and the inner diameter of the metallic shaft sleeve (z) conformed to that of the shaft of the insertion instrument (Figure 1). After polishing and sterilisation, the sleeve was positioned on the insertion instrument and secured in the hand piece (Figure 2).
The virtually-designed surgical splint was saved as an STL file and printed via a digital light processing technique (AsigaPro2®, Dentona, Germany; Pro3Dure GR-10 Guide®, Dentona, Germany). Finally, the 3D-printed guide was cleaned, light hardened (Otoflash G171®, Dentona, Germany) under the presence of nitrogen (N₂) and prepared for intraoperative use.

**Surgical placement**

Local anaesthesia was obtained via palatal infiltration (Ultracain Dental forte®, 1:100000, Sanofi, Austria) and the insertion guide was positioned on the teeth. Two 14 mm miniscrews were inserted using a prosthetic torque-controlled hand piece at 20 rpm. Depth control was dictated by the contact of the hand piece at the insertion guide (Figure 3).

**Results**

Accurate placement was achieved and no complications were experienced during placement of the miniscrews (Figure 4).

**Discussion**

According to preoperative three-dimensional planning, a custom-designed, surgical splint and a custom-fit metallic insertion sleeve have been presented which allowed fully guided palatal insertion of orthodontic miniscrews with sufficient primary stability but without observed complications.

The insertion of OMS as temporary anchorage devices is routinely performed as a soft tissue flapless procedure, often relying on previously published studies that describe average vertical bone height and defined 'safe zones.' Nevertheless, blind screw positioning may compromise the amount of bony support for anchorage and lead to perforation of the sinus or nasal cavity. DICOM data allow individualised planning for optimal screw position and, if matched with STL data from an intraoral scan or plaster model, guided insertion via surgical splints is possible. It is recognised that the use of a positioning aid for OMS has already been reported as well as three-dimensional planning and guided insertion. However, the novel approach presented in the present paper permits a fully-guided application of OMS adapted to a patient’s individual anatomy and the planned orthodontic device.

As a result, a custom-made 3D-printed sleeve has been designed according to the properties of the anchorage system that ensures guidance from the commencement to completion of placement when the final depth and position of the screw is achieved. Corresponding to implant surgery guides, the length of the polymer sleeve is pre-defined by the end position of the intended screw. However, the difference between the presented splint compared with implant surgery splints that allow guided implant bed preparation and implant placement is that the implant-drill is operated at high speed (up to 1500 rpm according to the manufacturer’s protocol) with the splint in direct contact with the guiding structures. Accordingly, abrasion of the splint would occur if a metallic sleeve covering the inner lumen of the polymer splint sleeve was not present. The presented procedure has no need for a metallic sleeve to cover the polymer splint sleeve. This is because only the application instrument and not a high-speed drill nor the screw is in direct contact with the polymer splint. Secondly, the insertion of the OMS is done at low rotations per minute (20 rpm). However, only in combination with the use of the described custom-fit metallic shaft
sleeve on the insertion instrument is tilting avoided as the path of the inserted screw is accurately predefined. A metallic printed guide was preferred to allow for re-sterilisation. However, a polymer-printed sleeve designed for single use might work equally well.

The use of well-established, implant-planning software offers the advantage of great flexibility regarding individual guide design and the preferences of the treating clinician. The described approach relies on the availability of advanced equipment. Artefact-poor DICOM data with an ordinary mode and accurate voxel size (200 μm in this case), covering all essential anatomical structures, are mandatory. Highly accurate devices for 3D printing or milling are required, as are staff skilled to perform accurate matching, planning and fabrication. Nevertheless, the production costs are low, including polymeric resin, metal powder and software related fees.

Conclusion
The presented approach is a safe, effective and a cost-efficient method that allows fully-guided OMS placement, especially in complex cases. Placement is independent of screw material or dimensions; however, further clinical data coupled with the necessary equipment and staff training are necessary to establish widespread application.

Conflict of interest
We declare no conflict of interest.

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References