Implant Dentistry Curriculum in Undergraduate Education: Part 2—Program at the Albert-Ludwigs University, Freiburg, Germany

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Purpose: The aim of this study was to describe the didactic and clinical undergraduate implant dentistry program of the Albert-Ludwigs University, Freiburg, Germany, with emphasis on the clinical implant experience. ***Materials and Methods:*** A detailed description of the implant curriculum at Albert-Ludwigs University is given with documented exemplary cases and additional flow charts. ***Results:*** All students participate in 28 hours of lectures and approximately 64 hours of seminars with hands-on courses and gain clinical experience. All undergraduate students are eligible to place and restore oral implants. Emphasis is placed on prosthetic-driven planning of implant positions, three-dimensional imaging, and computer-guided implant placement. Implant restorations performed by undergraduate students comprise single crowns and small multiunit fixed dental prostheses in partially edentulous posterior maxillae and anterior or posterior mandibles, implant-retained overdentures (snap attachment) in edentulous patients, and telescopic fixed-removable dental prostheses on remaining teeth and strategically placed additional implants. Over the past 2.5 years, 51 patients were treated with 97 dental implants placed by students in the undergraduate program. Seventy-one restorations were inserted: 60.6% single crowns, 7% fixed dental protheses, 21.1% overdentures, and 11.3% telescopic fixed-removable dental prostheses. The implant survival rate was 98.9%. ***Conclusions:*** Because survival rates for dental implants placed and restored by students are comparable to those of experienced dentists, oral implant dentistry should be implemented as part of the undergraduate dental curriculum. *Int J Prosthodont 2011;24:544–556.*

In part 1 of this study,[1] the literature from 1945 to January 2010 was reviewed to evaluate to what extent oral implant dentistry has been integrated in undergraduate programs of dental schools worldwide. Fourteen surveys reporting on undergraduate implant education at different universities[2–15] and 11 descriptions of undergraduate educational implant dentistry programs at single universities[16–26] were compared and analyzed. Since implants recently have become a more accepted treatment method, this review also showed an increase in the percentage of universities that included teaching implant dentistry in their undergraduate curricula from 51% in 1974 to 100% in 2009.[2,5,15] But just as dental curricula differ from one university to another, great diversity in undergraduate implant curricula can be found. Although nearly 100% of the implant curricula of the surveyed universities include a series of lectures, the overall number of lecturing hours differs, with most surveys reporting 1 to 20 hours of lectures[4,6,7,12] and only a few reporting more than 20 hours.[6,7,12]

The implementation of teaching formats such as laboratory hands-on courses on plastic casts or phantom heads was found in 30% to 42% of the universities analyzed in the research mentioned previously[2,6,9,10]; two surveys reported a higher percentage

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of 62%[3] and 78%.[7] A high percentage of universities also give their students the opportunity to observe implant surgeries and the prosthetic restoration of implants. Analysis of reports on specific implant programs also reveals that, if restoring or placing implants is mentioned as part of the curriculum, in most curricula, it is only performed by a select group of students from the entire semester.[20,22,23] The majority of students only receive lectures or seminars.

The reviewed literature probably does not reflect the actual clinical academic situation, and there was little information available on implant programs in Europe. Hence, the aim of this study was to describe the didactic and clinical undergraduate implant dentistry program of the Albert-Ludwigs University, Freiburg, Germany, with emphasis on the clinical implant experience with the implementation of three-dimensional (3D) imaging and computer-guided implant placement. The standard of care was visualized with three exemplary cases treated by undergraduate students.

Materials and Methods

The implant curriculum of the Albert-Ludwigs University, Freiburg, Germany, is embedded in the 5 years of undergraduate dental education. Faculty of the department of prosthodontics and the department of oral and maxillofacial surgery (OMS) has the main teaching responsibility. Faculty of the department of prosthodontics selects all undergraduate student implant cases and supervises the students through the entire treatment process, from treatment planning and the surgical placement of implants to provisional and definitive prosthetic restoration delivery. The prosthodontic faculty also provides lectures, seminars with hands-on sessions, and treatment planning sessions in the undergraduate implant curriculum. Faculty from the OMS department covers basic surgical techniques, local anesthesia, bone augmentative procedures, and implant placement during general oral surgery lectures.

The undergraduate implant program comprises three levels of experience: lectures, seminars with hands-on courses, and clinical experience (Table 1).

Lectures

From the first to the tenth semester, a total of 28 lecture hours focus on implant dentistry (Table 1). Lectures start in the first semester with implant material science and biocompatibility (prosthodontics faculty) and continue in semester 7 with suturing techniques, indications and contraindications for implants, and internal and external sinus grafting procedures (OMS faculty). Semester 8 contains a series of lectures with the following topics (prosthodontics faculty): definitions, patient selection, indications and contraindications, bone quantity and quality, implant material and surface, implant forms, prosthetic abutment connections, diagnostics, treatment planning, guided implant surgery, prosthetic treatment options (fixed dental prostheses [FDPs]), survival and success rates, occlusion, oral hygiene, recall, and exemplary cases. In semester 9, the OMS faculty covers surgical implant placement, sinus lift and other bone grafting procedures, and navigated surgeries. The last semester includes lectures on technical construction principles of different types of implant-supported prostheses, prosthetic treatment options (removable and fixed-removable complete or partial dental prostheses), exemplary cases, survival and success rates, complex treatment planning, live demonstrations (surgical implant placement, impression taking), maintenance, and peri-implantitis (prosthodontics faculty).

Seminars with Hands-on Courses

The students gain their first practical experiences with implant dentistry in the prosthodontic phantom course (usually semesters 3 or 4) (Table 1). They set up and fabricate a diagnostic template for the mandibular first premolar to first molar region in one quadrant of the phantom head and simulate cone beam computed tomography (CBCT). Students then perform the 3D implant planning on personal computers with an exemplary implant planning software. After receiving the stereolithographically produced surgical template, students perform guided surgical implant placement on plastic-silicone casts and fabricate a provisional FDP. The OMS department provides hands-on courses for suturing techniques in semester 7. The prosthodontics course in semester 8 intensifies with the following subjects: fabrication of diagnostic templates, computer-aided design/computer-assisted manufacturing (CAD/CAM) systems, zirconia FDP framework design with CAD software, CBCT data conversion, and 3D implant planning with implant-planning software. In semester 9, the students practice osteotomies on pig heads (OMS faculty). The semester 10 prosthodontics hands-on courses focus on guided implant surgery, treatment planning with students' implant cases, prosthetic components, 3D imaging and advanced implant-planning software features, and more complex implant cases.

Table 1 Overview of the Didactic and Clinical Implant Program at Albert-Ludwigs University Spread over 5 Years (10 Semesters)*

Semester	Lectures	Seminar with hands-on course	Clinical experience
1	2 h material science, 2 h biocompatibility		
2			
3		~48 h diagnostic template, implant planning, guided implant surgery on plastic casts, provisional FDP	
4			
5			
6			
7	1 h suturing techniques, 2 h introduction to implant dentistry and grafting	1 h suturing techniques	1 wk full-time oral surgery practical course (40 h)
8	6 h implant prosthodontics (FDPs)	1 h diagnostic template; 1 h CAD/CAM systems; 2 h CAD framework design; 2 h CBCT data, 3D imaging software, planning of single implant case	Prosthodontic practical course (~154 h): single implants + crowns, 2-to 4-unit FDPs
9	4 h implant dentistry, 2 h sinus lift, 2 h navigated surgeries	1 h osteotomies (on pig heads)	3 wk full-time oral + maxillofacial practical course (~120 h)
10	7 h implant prosthodontics: (removable and fixed-removable dental prostheses)	1 h guided implant surgery; 1 h treatment planning; 1 h prosthetic components; 1 h student implant cases; 2 h CAD framework design; 2 h CBCT data, 3D imaging software, planning of multiple implant case	Prosthodontic practical course (~154 h): single or multiple implants + FDP, implant-retained overdentures, telescopic crown (on teeth and implants)

FDP = fixed dental prosthesis; CAD/CAM = computer-aided design/computer-assisted manufacture; CBCT = cone beam computed tomography.
*All lectures, courses, and clinical experiences are attended by all students.

Clinical Experience

The clinical experience of dental students starts in semester 7 with a 1-week, full-time practical course in the OMS department (Table 1). This includes anamnesis, diagnosis, and tooth extractions under supervision of oral surgeons. Students also observe implant surgeries and other oral surgeries. Students continue in semester 9 with another 3-week, full-time oral and maxillofacial practical course and practice anamnesis, clinical findings, and diagnosis and assist in oral and maxillofacial surgeries. In semesters 8 and 10, students gain clinical experience in clinical examination, diagnosis, treatment planning, observation of restoring and placing implants, restoration of implants in their own patients, assisting or placing implants in their own patients, and maintenance of implant patients in the department of prosthodontics.

In the prosthodontic outpatient clinic, potential patients for the undergraduate student courses are screened and checked for anamnestic contraindications. Suitable implant cases for the undergraduate implant program are defined as edentulous or partially edentulous patients with adequate bone width and height not requiring bone grafting.

All patients are treated according to the comprehensive dental care concept.[27] Figure 1 gives a step-by-step description of the clinical and laboratory workflow of the prosthodontic practical course for undergraduate students.

The surgical phase includes the prosthetic-driven planning of the ideal implant position with the setup of denture teeth and fabrication of a diagnostic template with gutta-percha markers for the CBCT. The patient and template are scanned using CBCT in a double-scan technique. Data are converted and imported in the Procera Clinical Design software (Nobel Biocare). Cross sections and 3D images are created, and vital structures (sinus maxillaris, alveolar nerve) are analyzed. After the 3D implant planning, data are sent to Nobel Biocare via the Internet, and a stereolithographically produced surgical template is sent back. Surgical implant placement (NobelReplace Straight Groovy, Nobel Biocare) is performed using the NobelGuide (Nobel Biocare) protocol by faculty-student teams, where the undergraduate student assists the tutor or the student places the implant under close supervision of the tutor. If primary stability is ≥ 35 Ncm, implants are left for transmucosal healing with healing abutments. Only when primary stability

Table 2 Type of Prosthetic Treatment

	No. of patients (%)	No. of prostheses (%)	No. of implants (%)
Crowns	26 (48.1)	43 (60.6)	43 (44.33)
Partial FDPs	5 (9.3)	5 (7.0)	11 (11.34)
Overdentures (ball attachment/Locator)	15 (27.8)	15 (21.1)	32 (32.99)
Overdentures (telescopic crown retained on teeth and implants)	8 (14.8)	8 (11.3)	11 (11.34)
Total	54* (100.0)	71 (100.0)	97 (100.00)

*n = 51 patients treated, 2 received multiple treatments.

is < 35 Ncm are implants submerged. Patients are instructed on postsurgical behavior (food restrictions, cooling, no sports, antibacterial mouth rinse) and medications. Provisional prostheses are adjusted to the new situation. After 8 to 10 days, sutures are removed and interim prostheses are relined (Soft Liner, GC). Because of the necessary healing period of between 2 and 4 months, another undergraduate student restores the patient's implants in the next semester. After completion of treatment, all patients join the undergraduate student recall program.

Prosthetic implant rehabilitations for undergraduate students include single-unit and small multiunit FDPs in partially edentulous posterior maxillae and anterior or posterior mandibles, implant-retained overdentures with snap attachments in edentulous patients, and telescopic fixed-removable dental prostheses on remaining teeth and strategically placed additional implants.

Clinical Student Evaluation

Students are evaluated for their preparedness, initiative, and adherence to standards of care and receive credits and grades for the completion of provisional prostheses (fixed/removable) and fabrication of the radiologic template. Others receive credits and grades for the completion of the definitive fixed or removable implant prostheses.

Results

Between 2007 and spring 2010, 51 patients were treated in the undergraduate implant program. They received a total of 97 implants that were restored with 71 restorations: 43 (60.6%) restorations were single crowns, 5 (7.0%) were FDPs, 15 (21.1%) were overdentures with snap attachments, and 8 (11.3%) were telescopic fixed-removable dental prostheses on teeth and implants (Table 2). Two patients received multiple restorations. In the past 2.5 years, 1 of 97 implants failed during the healing period, and none failed after loading. Thus, in this time period, the implant survival rate was 98.9%.

In semester 8, selected treatments for patients were mainly single implants, fixed single crowns, and some small multiunit FDPs. In semester 10, students performed treatments such as single-unit and small multiunit FDPs (Fig 2), implant-retained overdentures (snap attachments) in edentulous patients (Fig 3), and telescopic fixed-removable dental prostheses on remaining teeth and strategically placed additional implants (Fig 4). The following three exemplary clinical cases treated by undergraduate students demonstrate the scope of treatment.

Case 1: FDP in a Partially Edentulous Posterior Mandible

A 63-year-old man visited the prosthodontic outpatient clinic and requested a fixed rehabilitation of the partially edentulous area in his mandibular left quadrant (Fig 2a). The treatment plan of the undergraduate student in his or her 10th semester was to place two dental implants in the mandibular left first premolar and first molar region and to restore them with an FDP. The student provided the setup and produced a diagnostic template. The patient and template were scanned using CBCT (double-scan technique), and the data sets were imported in the Procera Clinical Design software. The student analyzed the data, marked the alveolar nerve, and planned the implants at the mandibular left first premolar and first molar sites (Figs 2b and 2c). The student assisted in placing NobelReplace Straight Groovy implants with the surgical template, according to the NobelGuide protocol. Gingiva formers were screwed on the implants, and 5/0 sutures (Supramid, B.Braun Melsungen) were used for flap adaptation (Fig 2d). After 3 months of healing, another student in his or her 10th semester restored the implants with a three-unit, metal-ceramic FDP (Figs 2e and 2f).

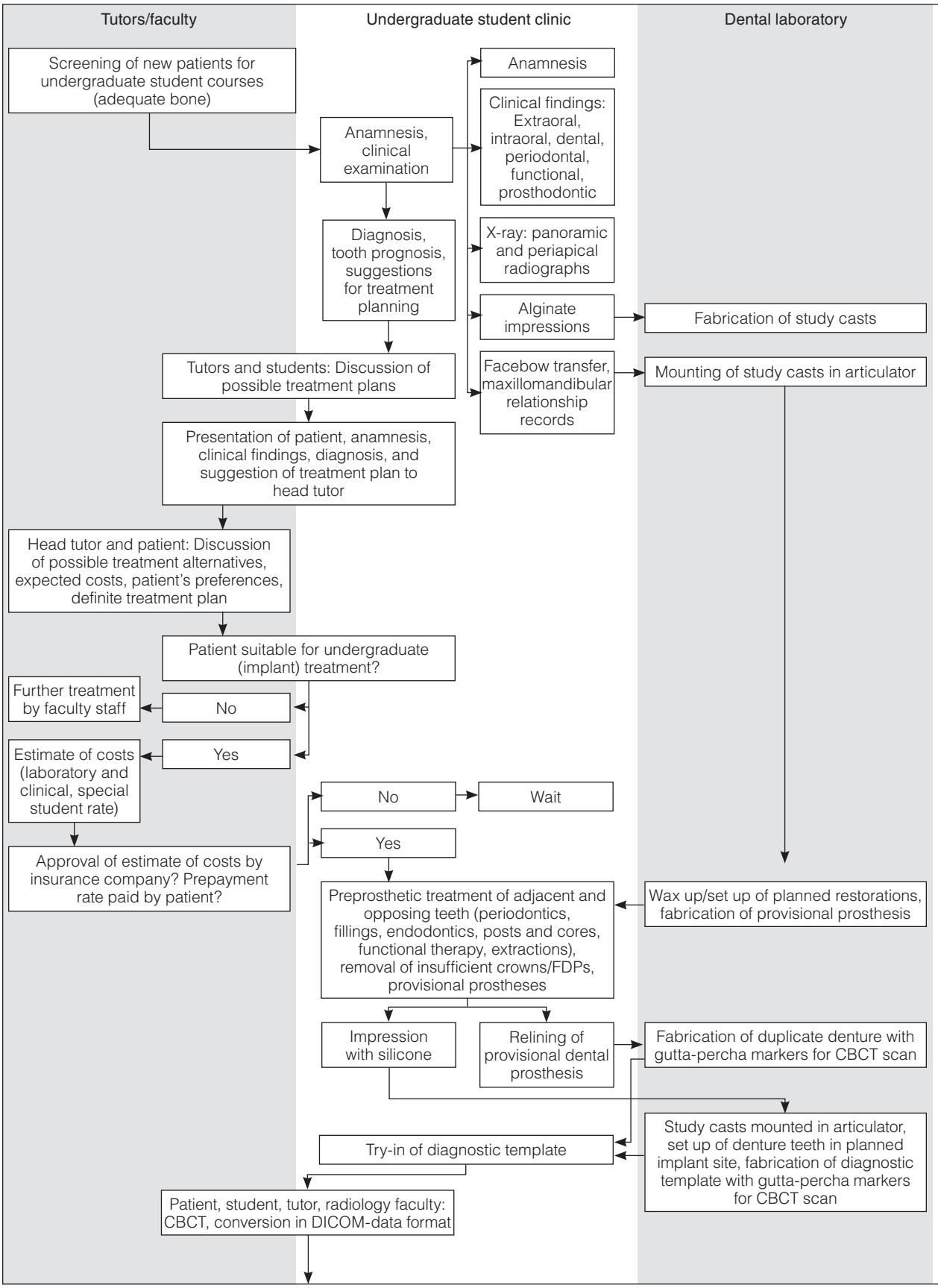
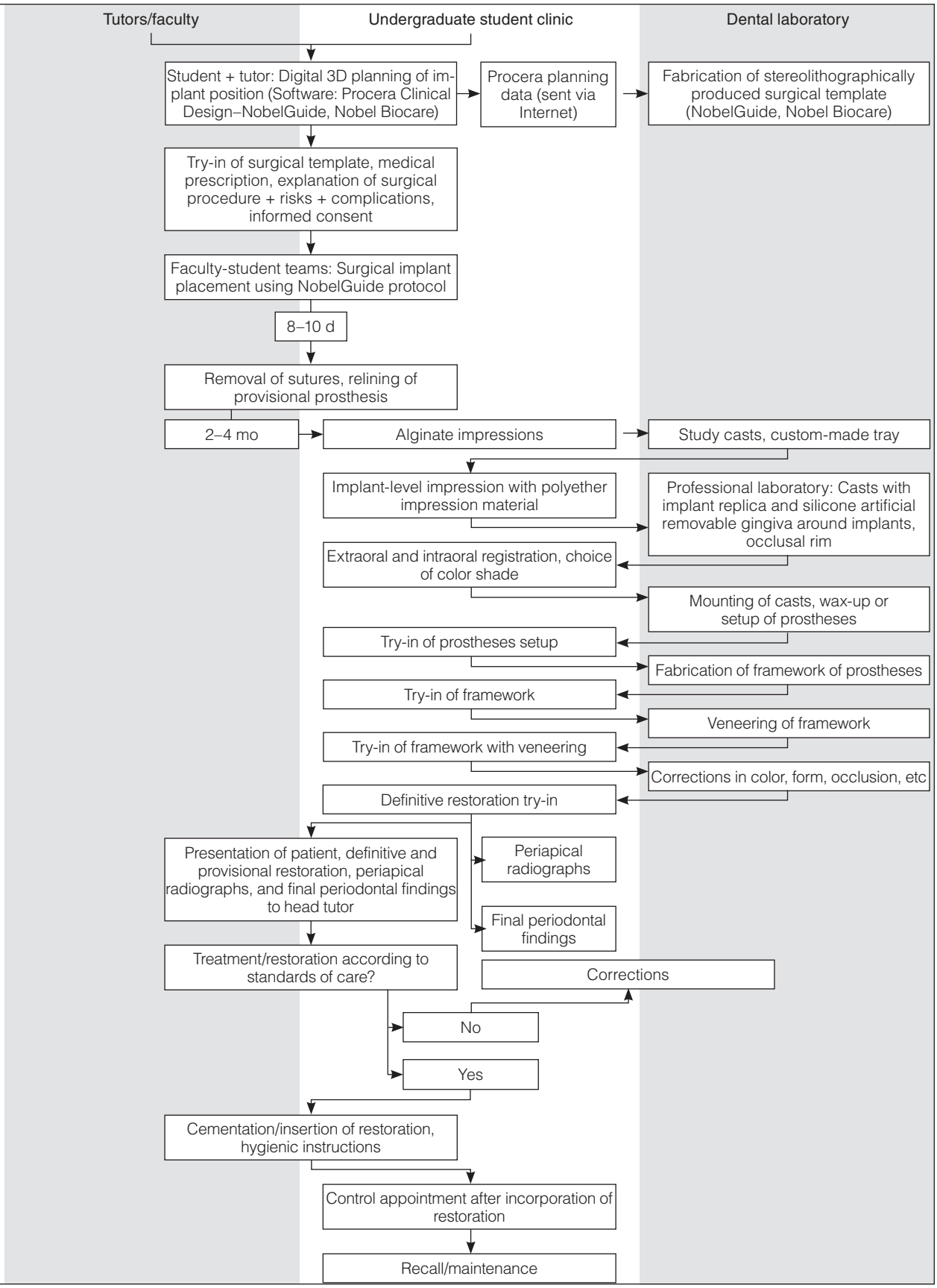


Fig 1 Clinical and laboratory workflow diagram of the undergraduate implant program at Albert-Ludwigs University in semesters



8 and 10 (prosthodontic practical course).

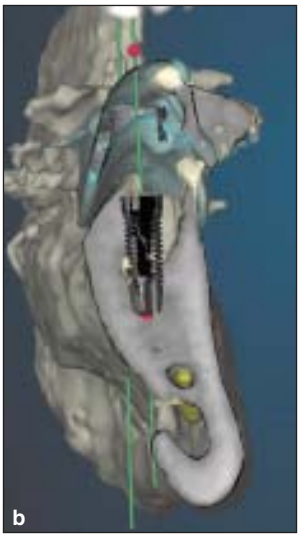


Fig 2a Preoperative partially edentulous posterior mandible. The region of the left first premolar to first molar was edentulous, with a provisional crown at the second molar site.

Figs 2b and 2c Digital 3D imaging and implant planning data for implants at the first premolar and first molar sites (NobelReplace Straight Groovy, TiUnite). Cross sections: first premolar = implant diameter: 4 mm and length: 13 mm; first molar = implant diameter: 5 mm and length: 11.5 mm. Implants are positioned correctly under setup tooth of diagnostic template *(light blue)*.

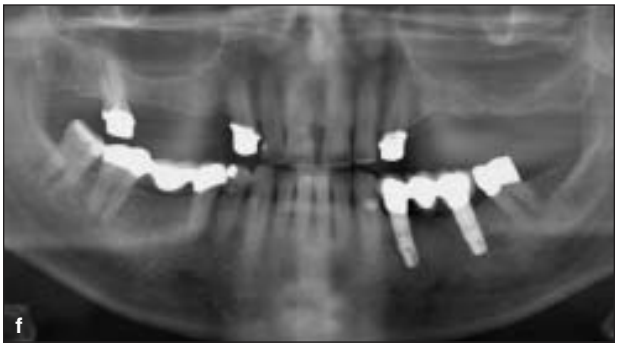


Fig 2d Intraoral situation immediately after implant placement with healing abutments in place. The tissue punch technique was not performed to preserve the limited amount of keratinized gingival tissue.

Fig 2e Occlusal view of the three-unit, metal-ceramic FDP cemented on the implant abutments at the first premolar and first molar sites.

Fig 2f Panoramic radiograph after treatment.

Case 2: Implant-Retained Overdenture in an Edentulous Patient

A 64-year-old woman revealed an edentulous mandible after extraction of her last five hopeless teeth (Fig 3a). The undergraduate student in her 10th semester planned for two dental implants in the interforaminal region (left and right canine sites) and an overdenture with ball attachments. The student relined the immediate provisional complete dental prosthesis and duplicated it for the production of a diagnostic template with gutta-percha markers (Fig 3b). After a CBCT double-scan, the student analyzed the data in the Procera Clinical Design software. She planned the implant placement at the canine sites and three tilted anchor pins for intraoperative fixation of the surgical template (Figs 3c and 3d). The student placed two NobelReplace Straight Groovy implants (diameter: 4 mm, length: 13 mm) in the interforaminal region with the stereolithographically produced surgical template, according to the NobelGuide protocol (Fig 3e). After approximately 3 months of healing, another student in his or her 10th semester restored the implants with an overdenture with two ball attachments (titanium ball abutment, Nobel Biocare) (Figs 3f and 3g).

Fig 3a Healed extraction sites of an edentulous mandible restored with an immediate provisional complete dental prosthesis.

Fig 3b A duplicate denture (diagnostic template) was produced with gutta-percha markers after relining of the provisional dental prosthesis.

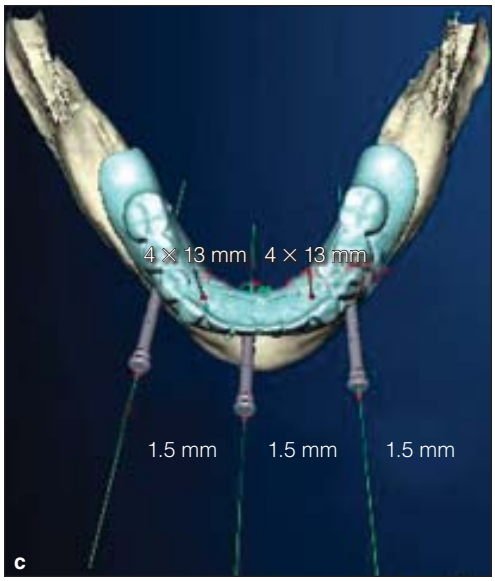


Fig 3c Digital 3D imaging and implant planning data for two implants at the canine sites and three anchor pins for intraoperative fixation of the surgical template.

Fig 3d Surgical template produced from digital CBCT data and 3D imaging by planning software and processed by a stereolithographic production unit. Guide sleeves were made for the chosen implant diameters and for anchor pins.

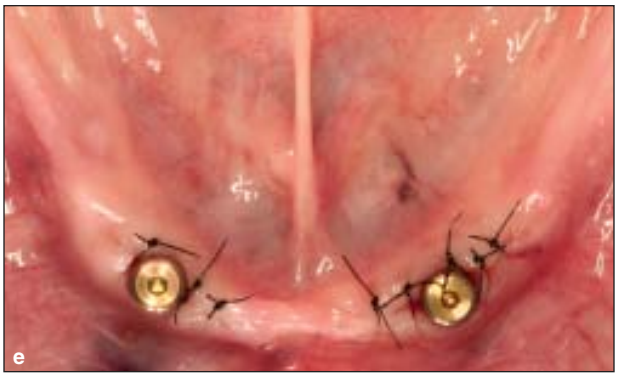


Fig 3e Intraoral situation immediately after implant placement with healing abutments and 5/0 sutures.

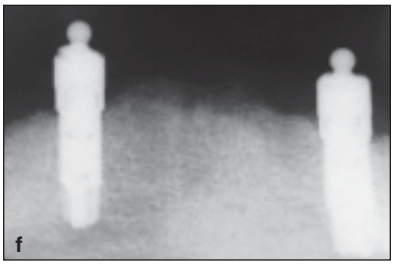


Fig 3f Final periapical radiograph of implants and ball attachments at the mandibular canine sites.

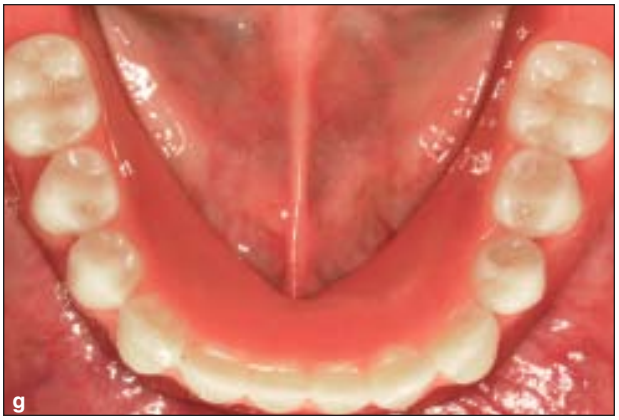


Fig 3g Definitive implant overdenture with integrated metal framework.

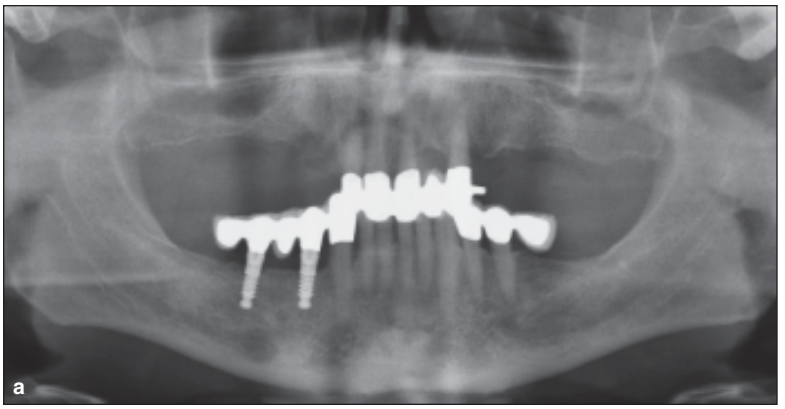


Fig 4a Panoramic radiograph before treatment in the undergraduate student course. Note the hopeless maxillary left central incisor and canine.

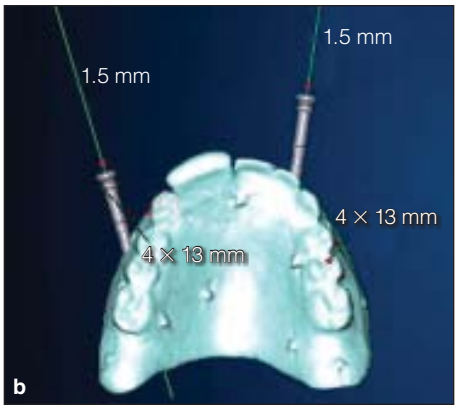


Fig 4b Digital 3D imaging and implant planning data in the left and right premolar region with two anchor pins for intraoperative fixation of the surgical template.

Fig 4c Intraoperative situation after fixation of surgical template with two anchor pins. Note the visible guide sleeves in the premolar region.

Fig 4d Guided drilling procedure with surgical template. Different surgical guides are placed in guide sleeve, which adjusts the lumen to the diameter of the drills. The drill is equipped with a drill stop at the planned implant length plus 10 mm (13 mm + 10 mm).

Case 3: Telescopic Fixed-Removable Dental Prosthesis on Remaining Teeth and Strategically Placed Additional Implants

A 67-year-old man exhibited an insufficient maxillary fixed-removable partial dental prosthesis. Only the maxillary right central and lateral incisors had a good prognosis; the maxillary left central incisor and canine were extracted because of profound caries and severe periodontitis, with probing depths of 7 to 14 mm (Fig 4a). Because the distribution and number of the two residual teeth were statically unfavorable for a removable partial dental prosthesis, the concept of a strategic abutment increase with the help of implants was applied. The treatment plan of the undergraduate student in his or her 10th semester included two dental implants as additional anchoring elements in the maxillary left and right premolar region (Fig 4b) and restoration of the arch with a telescopic fixed-removable dental prosthesis on teeth and implants. According to the NobelGuide protocol, two anchor pins secured the surgical template during the drilling procedure (Fig 4c). The implant drills were equipped with drill stops (screw-retained metal rings) at the desired implant length plus 10 mm (distance from the implant head to the top of the surgical guide). The drilling sequence was guided by a series of tailored surgical guides available for each drill diameter, which were placed in the guide sleeve of the surgical template (Fig 4d). Two NobelReplace Straight Groovy implants (diameter: 4 mm, length: 13 mm) were inserted. After 5 months of healing, another student in his or her 10th semester restored the implants and teeth with a telescopic fixed-removable dental prosthesis (Figs 4e to 4g).

Fig 4e Telescopic fixed-removable dental prosthesis. Telescopic crowns were cemented on the maxillary right incisors, and telescopic implant abutments were used at the premolar implant sites.

Fig 4f Maxillary telescopic fixed-removable dental prosthesis.

Fig 4g Panoramic radiograph after treatment by undergraduate students. Maxilla: fixed-removable dental prosthesis with telescopic crowns; mandible: cantilever FDPs.

Discussion

Constant developments and research are challenging universities to prioritize and continuously adapt dental education in an already overcrowded curriculum. But in education, it must be the aim to educate students to become future dentists who are well prepared for practice and equipped with up-to-date techniques.

Because the use of oral implants proved to be a successful treatment alternative for the rehabilitation of edentulous and partially edentulous arches in comparison to conventional FDPs or complete dentures,[28–31] the concept of integrating oral implant dentistry in the undergraduate program is justified.[16]

The implant curriculum at Albert-Ludwigs University is offered to all students of the entire semester (30 to 40 students per semester, 60 to 80 students per year), but because of limited patient availability, not every student is able to gain clinical experience in treating an implant patient. In the first 2.5 years of the program, an increasing number of patients could be recruited each semester for implant treatment in the undergraduate course. Because 2 of 51 patients first received treatment in the maxilla and then in the mandible, different students were able to treat them, resulting in 53 treated cases. Each patient was always treated in teams of 2 dental students (one as the dentist, one as the dental assistant). In the surgical phase (planning, template, surgery), 106 students achieved clinical experience, and after the healing period, another 106 students performed the prosthetic restorations. With an estimated 35 students per semester, overall, approximately 350 students were part of the implant curriculum (lectures, seminars/hands-on, clinical experience) over the first 2.5 years. The mean percentage of students with clinical implant

experience was 60% (212 of 350): 30% in the surgical treatment and 30% in the prosthetic treatment. Because the number of recruited patients rises each semester, the percentage of students actively treating patients with implants is also increasing constantly.

Many other universities offer the implant curriculum only to a select number (10 to 15) of students.[20,22,23] In those universities, only select students attend special seminars (eg, problem-based learning), hands-on courses, and place and restore implants, while the rest of the class only receives lectures. But other universities also offer didactic and clinical experience to all students, eg, New York University achieved a rate of 91.8% of students having restored single-unit implants or overdentures in 2008.[16]

Like in most universities, the implant curriculum at Albert-Ludwigs University is taught in several years of the students' university studies, with emphasis in the junior and senior years,[4,11,16,23] but the curriculum also includes a lecture and hands-on module in the preclinical course with the following subjects: diagnostic template production, fabrication of a provisional implant FDP, and placement of dummy implants in plastic arch casts with artificial gingiva.

In other undergraduate implant curricula, students are usually assigned to treat straightforward, not-too-complex cases without bone augmentative procedures, such as mandibular overdentures on two implants and one- to four-unit FDPs.[2,5,7] The types of restorations on implants that are performed by undergraduate students at Albert-Ludwigs University are similar, but also include telescopic fixed-removable dental prostheses on remaining teeth and strategically placed additional implants. In partially edentulous patients, the construction of a partial removable dental prosthesis (RDP) is often impaired because of the minimal number and distribution of residual teeth. The favorable quadrangular distribution and support for a partial RDP is often not obtained. The concept of using implants as strategic supplementary abutments combines two intents: it contributes to the maintenance of residual teeth and it enhances denture retention and support.[32,33] In a case control study[32] with 65 dental prostheses supported by 101 root copings, 7 telescopic crowns, 22 molars with clasps, and 93 implants (86 ball attachments, 8 telescopic crowns), the incidence of biologic complications (caries, periodontal/peri-implant problems) was comparable to studies on overdenture abutment teeth.[34,35] More favorable incidences of biologic complications were found in a study with exclusively implant and tooth–supported telescopic crown-retained dental prostheses, without root copings.[33]

For undergraduate students at Albert-Ludwigs University, straightforward cases with single-unit and small multiunit, implant-borne FDPs were selected with adequate bone width and height (no bone augmentation needed) in the posterior maxilla and anterior or posterior mandible. The highly demanding esthetic zone (anterior maxilla) was excluded from the undergraduate course because it usually involves complex bone and soft tissue augmentation procedures, tissue contouring with provisional prostheses, and prolonged treatment time and should be treated by experienced surgeons and prosthodontists. The most common implant restorations of undergraduate students were single crowns (60.6%), which predominantly replaced missing first molars. The second most common treatment was an overdenture in edentulous patients (21.1%) with implants in the mandibular canine area. This is comparable to data reported by Kronstrom et al,[19] with undergraduate student restorations comprising 61.5% single-tooth restorations and 31.7% overdentures, and with the results from the University of Detroit,[20] with 61.4% single-tooth restorations and 15.7% overdentures.

In 2005 and 2008, most universities used Nobel Biocare implant systems, followed by Straumann and Astra, Dentsply Friadent, SteriOss, Biomet 3i, and Paragon.[3,4,6,7] Because of limited financial resources of universities and usually expensive treatment costs in implant dentistry, universities are often financially supported by implant companies for undergraduate implant curricula to offer implant treatment to patients with a limited budget. Petropoulos et al[5] reported that 85% of universities teaching undergraduate implant curricula in the United States receive free implants. In British and Irish universities, only 33% are provided with free implants, 20% receive restorative components, and 46% receive simulation models for the implant curricula.[3] The implant program at Albert-Ludwigs University is supported by Nobel Biocare, with free implants and restorative components, software and surgical templates, surgical sets, and plastic arch casts for simulation procedures. Without this industry-university collaboration, it would not have been possible to integrate the clinical experience in the implant curriculum because of financial limitations. Because students predominantly become familiar with components and software from one implant company in their clinical experience, it is made sure that in lectures, case presentations, and additional hands-on courses, students also familiarize themselves with other implant systems, such as Camlog, Straumann, Xive, and others.

The use of CBCT in combination with a diagnostic template is a modern diagnostic tool used to ideally place implants in a prosthetic-driven position. The 3D imaging allows the clinician to analyze and measure

the available bone in the planned implant site and to preserve vital structures such as the mandibular nerve, the maxillary sinus, and the floor of the nose. Bony defects can be analyzed preoperatively and necessary augmentation procedures can be planned. This gives the patient the benefit of a higher predictability and safety with implant treatment and prevents misplaced implants. A systematic review of the accuracy of computer-guided, template-based implant dentistry reveals mean deviations of 1.07 mm at the entry point of the implant into bone, 1.63 mm at the apex, and 5.26 degrees in angulation.[36] This must be considered when surgeons consider a flapless implant surgery. On the other hand, CBCT has the disadvantage of higher radiation exposure compared to a panoramic radiograph, but less than conventional CT scanning.[37] However, the radiation exposure highly depends on the chosen field of view and resolution and varies widely with different CBCT equipment.[38]

Since the introduction of the clinical undergraduate implant program at Albert-Ludwigs University in October 2007 with 3D imaging and computer-guided surgery, involving undergraduate students in implant treatment has been a positive experience for both students and faculty. The students not only enjoy receiving predominantly theoretic teaching of implant dentistry in lectures and seminars, as it has been in the past, they also appreciate being able to participate in practical hands-on courses with plastic arch casts, for example, to familiarize themselves with prosthetic components or practice implant surgery. Up-to-date techniques such as planning the implant case of a patient from digital imaging (CBCT scan) to 3D modeling and virtual planning of implant positions (Procera software) are integrated. Students that have had the chance to treat their own implant patient, as previously described, give the most positive feedback. When analyzing the studies by Huebner[39] and Maalhagh-Fard et al,[40] it can be expected that those students are more likely to restore implants in their practice after graduation. More than twice as many clinicians with undergraduate implant experience restored implants in their general practice (56%) in comparison to the control group (23%), who had no undergraduate implant training.[39] Clinicians with undergraduate implant experience also surgically placed more implants (14% vs 3%) and referred a greater number of patients to surgical specialists. Maalhagh-Fard et al[40] determined that participation in elective undergraduate implant courses had a weak positive correlation with offering implants and surgically placing implants in private practice. Participants were also more likely to restore implants in professional practice and less likely to refer implant patients to another practitioner. These studies suggest that clinicians with an undergraduate implant experience are positively motivated to implement implant dentistry in future treatment plans.

Conclusions

Because survival rates for implants placed and restored by students are comparable to those of experienced dentists, oral implant dentistry should be implemented as part of the undergraduate dental curriculum.

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References

1. Kroeplin BS, Strub JR. Implant dentistry curriculum in undergraduate education: Part 1—A literature review. Int J Prosthodont 2011;24:221–234.
2. De Bruyn H, Koole S, Mattheos N, Lang NP. A survey on undergraduate implant dentistry education in Europe. Eur J Dent Educ 2009;13(suppl 1):3–9.
3. Addy LD, Lynch CD, Locke M, Watts A, Gilmour AS. The teaching of implant dentistry in undergraduate dental schools in the United Kingdom and Ireland. Br Dent J 2008;205:609–614.
4. Blum IR, O'Sullivan DJ, Jagger DC. A survey of undergraduate education in dental implantology in UK dental schools. Eur J Dent Educ 2008;12:204–207.
5. Petropoulos VC, Arbree NS, Tarnow D, et al. Teaching implant dentistry in the predoctoral curriculum: A report from the ADEA Implant Workshop's survey of deans. J Dent Educ 2006; 70:580–588.
6. Afsharzand Z, Lim MV, Rashedi B, Petropoulos VC. Predoctoral implant dentistry curriculum survey: European dental schools. Eur J Dent Educ 2005;9:37–45.
7. Lim MV, Afsharzand Z, Rashedi B, Petropoulos VC. Predoctoral implant education in U.S. dental schools. J Prosthodont 2005; 14:46–56.
8. Young MP, Carter DH, Sloan P, Quayle AA. A survey of oral implantology teaching in the university dental hospitals and schools of the United Kingdom and Eire. Br Dent J 1999;187:671–675.
9. Seckinger RJ, Weintraub AM, Berthold P, Weintraub GS. The status of undergraduate implant education in dental schools outside the United States. Implant Dent 1995;4:105–109.
10. Weintraub AM, Seckinger R, Berthold P, Weintraub GS. Predoctoral implant dentistry programs in US dental schools. J Prosthodont 1995;4:116–121.
11. Watson RM. The teaching of osseointegrated implant dentistry in the schools of the UK and Eire. Br Dent J 1993;175:201–203.
12. Arbree NS, Chapman RJ. Implant education programs in North American dental schools. J Dent Educ 1991;55:378–380.
13. Bavitz JB. Dental implantology in U.S. dental schools. J Dent Educ 1990;54:205–206.
14. Gowgiel JM. Teaching dental implantology to dental students [abstract]. J Dent Educ 1987;51:26.

15. Chappell RP. Dental school implant survey. Oral Implantol 1974; 5:24–32.
16. Jahangiri L, Choi M. A model for an integrated predoctoral implant curriculum: Implementation and outcomes. J Dent Educ 2008; 72:1304–1317.
17. Kido H, Yamamoto K, Kakura K, et al. Students' opinion of a predoctoral implant training program. J Dent Educ 2009;73: 1279–1285.
18. Klokkevold PR. Implant education in the dental curriculum. J Calif Dent Assoc 2001;29:747–755.
19. Kronstrom M, McGrath L, Chaytor D. Implant dentistry in the undergraduate dental education program at Dalhousie University. Part 1: Clinical outcomes. Int J Prosthodont 2008;21:124–128.
20. Maalhagh-Fard A, Nimmo A. Eleven-year report on a predoctoral implant dentistry program. J Prosthodont 2008;17:64–68.
21. Mitchell DL. Dental implantology at the University of Oklahoma College of Dentistry. J Okla Dent Assoc 2000;90:22–25.
22. Bell FA, Hendricson WD. A problem-based course in dental implantology. J Dent Educ 1993;57:687–695.
23. Simons AM, Bell FA, Beirne OR, McGlumphy EA. Undergraduate education in implant dentistry. Implant Dent 1995;4:40–43.
24. Wilcox CW, Huebner GR, Mattson JS, Nilsson DE, Blankenau RJ. Placement and restoration of implants by predoctoral students: The Creighton experience. J Prosthodont 1997;6:61–65.
25. Richards MD. Educational report on implantology at Temple University School of Dentistry. J Oral Implantol 1980;9:160–171.
26. James RA. Training programs in oral implantology at Loma Linda University. Oral Implantol 1974;5:80–84.
27. Strub JR, Türp JC, Witkowski S, Hürzeler MB, Kern M. Curriculum Prothetik. Berlin: Quintessenz, 2004.
28. Pjetursson BE, Tan K, Lang NP, Brägger U, Egger M, Zwahlen M. A systematic review of the survival and complication rates of fixed partial dentures (FPDs) after an observation period of at least 5 years—I. Implant-supported FPDs. Clin Oral Implants Res 2004;15:625–642.
29. Tan K, Pjetursson BE, Lang NP, Chan ESY. A systematic review of the survival and complication rates of fixed partial dentures (FPDs) after an observation period of at least 5 years—III. Conventional FPDs. Clin Oral Implants Res 2004;15:654–666.
30. Berglundh T, Persson L, Klinge B. A systematic review of the incidence of biological and technical complications in implant dentistry reported in prospective longitudinal studies of at least 5 years. J Clin Periodontol 2002;29(suppl 3):197–212.
31. Salinas TJ, Eckert SE. In patients requiring single-tooth replacement, what are the outcomes of implant- as compared to tooth-supported restorations? Int J Oral Maxillofac Implants 2007;22(suppl):71–95.
32. Kaufmann R, Friedli M, Hug S, Mericske-Stern R. Removable dentures with implant support in strategic positions followed for up to 8 years. Int J Prosthodont 2009;22:233–241.
33. Krennmair G, Krainhöfner M, Waldenberger O, Piehslinger E. Dental implants as strategic supplementary abutments for implant-tooth-supported telescopic crown-retained maxillary dentures: A retrospective follow-up study for up to 9 years. Int J Prosthodont 2007;20:617–622.
34. Budtz-Jörgensen E. Prognosis of overdenture abutments in elderly patients with controlled oral hygiene. A 5 year study. J Oral Rehabil 1995;22:3–8.
39. Mericske EA, Mericske-Stern R. Overdenture abutments and reduced periodontium in elderly patients. A retrospective study. Schweiz Monatsschr Zahnmed 1993;103:1245–1251.
36. Schneider D, Marquardt P, Zwahlen M, Jung RE. A systematic review on the accuracy and the clinical outcome of computer-guided template-based implant dentistry. Clin Oral Implants Res 2009;20(suppl 4):73–86.
37. Ludlow JB, Ivanovic M. Comparative dosimetry of dental CBCT devices and 64-slice CT for oral and maxillofacial radiology. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2008; 106:106–114.
38. Qu XM, Li G, Ludlow JB, Zhang ZY, Ma XC. Effective radiation dose of ProMax 3D cone-beam computerized tomography scanner with different dental protocols. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2010;110:770–776.
39. Huebner GR. Evaluation of a predoctoral implant curriculum: Does such a program influence graduates' practice patterns? Int J Oral Maxillofac Implants 2002;17:543–549.
40. Maalhagh-Fard A, Nimmo A, Lepczyk JW, Pink FE. Implant dentistry in predoctoral education: The elective approach. J Prosthodont 2002;11:202–207.

Literature Abstract

Flapless implant surgery in the edentulous jaw based on three fixed intraoral reference points and image-guided surgical templates: Accuracy in human cadavers

In edentulous patients, the accurate and stable repositioning of a surgical template may be hindered by the mobile or flabby mucosal tissues. This study evaluated the technical procedure and accuracy of flapless computer-assisted template-guided surgery in edentulous human cadaver specimens using three fixed oral reference points (FRPs) for fixation of the registration mouthpiece and the consecutive surgical template. Oral implants placed in edentulous human cadaver specimens were planned using computed tomography (CT). Surgical templates were constructed using a multipurpose navigation system. Both the registration mouthpiece and consecutive surgical template were supported via three FRPs. Study implants were inserted through the guide sleeves, and accuracy was evaluated by fusing the postsurgical data of the cadaver arches and the presurgical CT. A Matlab script enabled comparison of the planned surgical path with the study implants. Thirty-five implants were placed in five edentulous maxillary specimens and 16 implants were placed in three edentulous mandibular specimens (n = 51 implants). The mean ± standard deviation total error (Euclidean distance)/lateral error (normal deviation) was 1.1 ± 0.6 (maximum: 2.4 mm)/0.7 ± 0.5 mm (maximum: 2 mm) at the implant base and 1.2 ± 0.7 (maximum: 3.1 mm)/0.9 ± 0.7 mm (maximum: 3.1 mm) at the implant tip. The mean angular error was 2.8 ± 2.2 degrees (maximum: 9.2 degrees). The authors concluded that FRP-supported image-guided surgical templates might provide similar accuracy on flapless implant surgery in the edentulous arch compared with tooth-supported surgical templates or navigation surgery.

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