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Documentation of the Dentition

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Introduction

There is a growing demand for innovative ways to record the dentition and craniofacial complex. New technologies rely heavily on sophisticated tools and software to accurately capture the dentition. However, in order that these technologies are routinely used in a mainstream practice, a completely digital, highly accurate, and easily portable system needs to be established to create a worldwide information portal. A complete digital workflow will ensure that the appliances delivered are accurate and will be delivered efficiently to the consumer all over the world. Another more important benefit is that if appliances could be digitally built it would promise to reduce cost as the process would require less manual processing, and the transportation time and costs would not delay the fabrication process. It is this drive to create custom lab work that is fueling the next big game changer in orthodontics. The accurate representation of the dentition is by far the most important step to successful orthodontics. Traditional plaster casts are now slowly being replaced by digital models in orthodontics [1]. These digital models are often obtained via an indirect method that requires the transport of plaster casts or impressions of the dentition to a specialized company for laser or computer tomography (CT) scanning [2–5]. It is

a known fact that the process of making plaster casts from dental impression materials such as alginate and polyvinyl siloxane (PVS) impression material has always some degree of dimensional change. During transportation and the period between the impression procedure and the pouring of plaster in the impression, the dimensions of the impression and thus the accuracy of the plaster model can change. Impressions have to be sterilized, transported to a dental lab, and, after fabrication of the plaster models, transported again to the orthodontic office. Plaster dental models have then to be stored in the dental office and retrieved during orthodontic treatment and are prone to fracture. Plaster models and also dental impressions can be scanned with desktop scanners with laser beams and with dedicated CT scanners to transform these models and impressions into digital dental models (Figure 1.1).
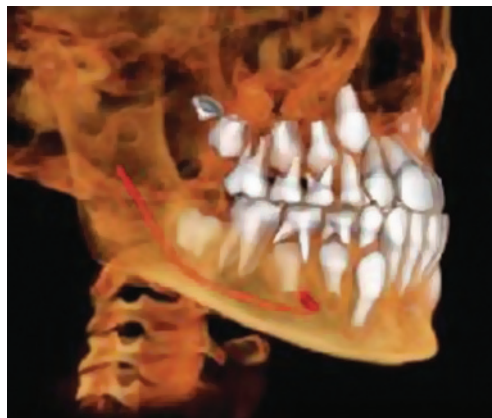
In the literature it is reported that the accuracy of digital dental models scanned directly from impressions when compared to the "golden standard, the plaster cast" is sufficient for orthodontic analysis and treatment planning. But for this method to get a digital dental model an impression or a plaster model is required. As the impression taking procedure and the fabrication of plaster casts is an indirect method to get digital dental models, there is interest in the use of a direct method to copy the dentition.

Figure 1.1 A dental model scanner.
Company: 3Shape.

Figure 1.2 The segmented dentition on a CBCT radiograph.
Company: Anatomage Inc.

A direct method to capture the dentition is by using the cone beam computer tomography (CBCT) radiographs [6]. These radiographs can be used for dental analysis, but CBCT involves exposing the patient to radiation, and the quality of the dentition on the CBCT radiograph is directly related to the radiation dose used (Figure 1.2). Because of the ALARA principle (a radiation dose As Low As Reasonably Achievable), CBCT is not indicated for imaging of the dentition only.

To answer the need for a digital yet economical solution to physical impression materials, several companies have developed intraoral scanning systems to acquire digital intraoral impressions for any type of dental manufacturing. (For more information on the information presented in this chapter, please visit the websites of the companies mentioned.) Only intraoral scanning systems that can scan the entire dental arch can be used to replace orthodontic impression taking. The files of the scanners (stereolithographic (STL) files) can be used to produce digital dental models (Figure 1.3). These digital models can then be used with dedicated software for the diagnosis of a malocclusion, analyzing the dentition, digital treatment planning, and the design of dental, orthodontic, and surgical appliances. During the last decade, several intraoral scanners have been introduced. The first scanners introduced for

Figure 1.3 An intraoral scanner.
Company: 3Shape.

intraoral scanning had some disadvantages, such as the need for powdering the dentition, a slow scanning speed, and a relative large and heavy scanning head [7]. Intraoral scanners have recently come to the technology forefront in dentistry as the new holy grail, with the promise to eliminate the dreaded physical impression. If successfully adopted this is sure to be the next trend. Of course, at the end of the day, it will legitimately only be adopted if dentistry can be made easier, faster, and more precise.

It is easy with the intraoral scanners to scan the interarch relationship. Registration of the occlusion with an intraoral scanner does not require a separate material for bite registration. The occlusion can be quickly, directly, and accurately captured with the intraoral scanner (Figure 1.4). If intraoral scanners are used, the digital dental models are immediately available for diagnosis and analyzing a malocclusion.

Digital workflow using intraoral scanners

The images of the scanner (some scanners can be used to make a scan, color photographs, and an HD video taken at the same time) have the advantage that they can replace traditional plaster models (Figure 1.5) as well as photography of the dentition (Figure 1.6). Because intraoral scanning is a direct procedure, the intraoral scanning procedure could eventually become more accurate than traditional impression taking as intraoral scanning is not prone to some of

Figure 1.4 Scan of the occlusion. Company: 3Shape.
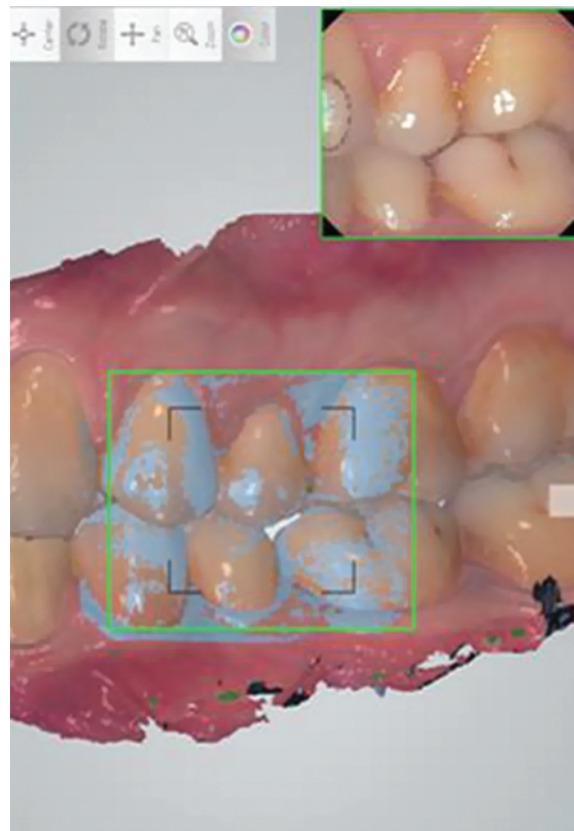
Figure 1.5 A digital dental model scanned with a color scanner.
Company: 3Shape.

the errors that can occur in the traditional impression taking procedure such as air bubbles, rupture of impression material, inaccurate impression tray dimensions, too much or too little impression material, inappropriate adhesion of the impression to the impression tray, and impression material distortion due to the disinfection and transportation procedure.

Inaccurate scanning can be improved by rescanning a specific part of the impression, so the procedure to entirely retake an impression can be postponed. Intraoral scanning could be particularly advantageous for patients with anxiety during impression taking (especially for the upper impression) and for cleft palate patients who could carry an increased risk of impression material aspiration and for whom standard impression

Figure 1.6 A intraoral scan in color.
Company: 3Shape.

trays are not suitable. Intraoral scanning could also be an advantage for patients currently undergoing orthodontic treatment with fixed appliances, for whom a traditional impression will be severely distorted because of the presence of the orthodontic appliances. Currently, the mean time needed for intraoral scanning is shorter than that required for taking traditional PVS impressions (one impression with heavy material and a second impression with soft impression material) but longer than required for the alginate impression taking procedure. Most patients have reported that the intraoral scanning procedure is more comfortable than conventional impression taking, especially with PVS impressions, although some studies have reported the opposite conclusion [8–11]. It can be speculated that the reduction in scanning time as well as the possibility to scan without powdering the dentition will improve the positive experience of the patient with the scanning procedure. It is expected that improvements of the scanners themselves will improve the speed, comfort, and accuracy of scanning. As an example, the advertisement of the recently introduced iTero intraoral scanner mentions a scanning time which is 20x faster compared to the older iTero intraoral scanner. Improvements in the scanning software further reduce the scanning time. A combination of a faster intraoral scanner and improved software and a faster computer (a computer with an Intel Core i7 processor and a fast NVIDIA video card and at least 16 GB of internal memory, can further reduce the scanning time. The technical procedure to scan the dentition, the alveolar bone, and the palate is not difficult. However, inexperienced practitioners will find completion of the first intraoral scans more time-consuming. Therefore, a practitioner's level of familiarity with the scanning system will substantially influence the time needed to complete the scans. Intraoral scanning of posterior teeth,

especially third molars in patients with limited mouth opening, can sometimes be difficult. It can also be difficult to scan the bottom of the oral vestibule. This difficulty is related to the dimensions of the scanning tip and moisture control. The design of a thinner scanning tip may improve comfort during the scanning procedure.

Intraoral scanners generate stereolithographic (STL) files which are universally accepted for software programs and can be used to fabricate digital dental models for analysis and treatment planning. After treatment planning and the acceptance of the treatment plan by the patient, appliances should be selected and discussed with the patient.

These digital models, other digital documentation, and appliance designs can then be transferred to multiple industry platforms (digital labs) all over the world, and orthodontic appliances can be ordered regardless of brand. This new process of appliance manufacturing, known as the digital workflow, surely has the potential to affect all tenants of dentistry, not just orthodontics! For custom appliance fabrication, the quality of the digital impressions sent can be controlled by the dental lab, and after improvement of the digital impressions, production of the selected appliances can be started immediately. So the use of an intraoral scan reduces the time required to manufacture and deliver custom-made orthodontic appliances.

The cost of purchasing an intraoral scanner could be a profitable investment for an orthodontic office, as the intraoral scanning procedure will decrease the need to retake inaccurate dental impressions, as well as the need for impression disinfection and transportation. Additionally, the use of digital dental models will eliminate the need for dedicated space to store dental plaster casts in an orthodontic office. Another advantage is that the digital dental models are immediately available and can be used to discuss treatment with the patient during the documentation visit. It is important to get patients to believe in the quality and state of the art of the dental and orthodontic practice. Patients do understand if the office has invested in equipment that will make their experience of dental and orthodontic treatment better. Patients actually enjoy watching their scans build before their own eyes on screen. The intraoral scanner can be used as a marketing tool for the dental practice: if the patient agrees, the total scanning procedure can be displayed in the waiting room of the dental office and patients and their parents or other accompanying people can witness a life demonstration of the innovative procedures used in this specific dental office. After the completion of the scan, one of the dental staff members uploads the STL files and other digital patient files to the computers of a dental lab, or opens up the records on the computer software installed in their own dental office. Digital dental models can be easily shared with appliance manufacturers, colleagues, dental and medical specialists, and the patient.

Accuracy of digital dental models

Several studies evaluated the accuracy and reliability of digital dental models created with different acquisition methods, such as laser or light scanning of plaster casts, laser scanning of impressions, CT scanning of plaster casts and impressions, and intraoral scanning. These studies use different scanners and different software programs, which limits the ability to compare outcomes. Most of these studies found statistical differences in measurements on digital dental models compared to the same measurements made on dental plaster casts, but few of these measurement differences were clinically significant [6, 11–13].

Differences of more than 0.3 mm for the overjet, overbite, and tooth size (tooth diameter and tooth height), and of more than 0.4 mm for transverse and sagittal parameters, are generally considered clinically significant. For differences in the sum of six anterior teeth in the upper or lower dental arch, a threshold of 0.75 mm can be used. For the sum of 12 teeth in the upper or lower arch, a difference of 1.5 mm can be used to discriminate between statistically and clinically significant differences in measurements of dental models. Inadequate reference point localization may vary between examiners and will directly affect measurement reproducibility. Therefore, direct measurements on plaster casts or digital models are automatically associated with some degree of inaccuracy even when the points are precisely described. As the selected reference points for defining various measurements on plaster and digital dental models vary, the measuring method with calipers or computer software will not necessarily solve the problem of point identification, and so differences in measurements found cannot represent actual differences in measured distances. Point identification on digital models could be more accurate as the digital model can be enlarged and segmented for a better identification of the measuring points. Superimposition of digital dental models with dedicated software such as Geomagic and Maxillim is an alternative to compare the size and volume of the dentition and the alveolar bone on digital dental models. A color scale can then be used to evaluate differences in size and volume of digital dental models (Figure 1.7). Studies have shown that measurements made on plaster models may also not represent the actual dentition, because of possible dimensional changes in impression material and the process of fabricating the plaster cast. However, plaster casts have been used for analysis, treatment planning, and appliance fabrication for over 100 years. It has been reported by many dentists and orthodontists that the occlusion of the
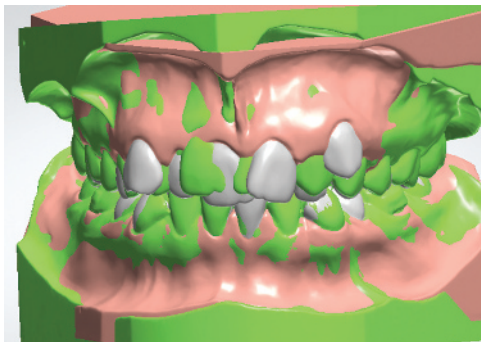
Figure 1.7 Superposition of two digital dental models.
Company: 3Shape.

digital models created by scanning a plaster cast or impression and the wax bite registration with a desktop scanner or a CT scanner can be inaccurate. If intraoral scanners are used, a direct method is used to register the relationship between the upper and lower dentition.

For some custom orthodontic appliances, impressions must be transported to other countries for planning and fabrication procedures. Alginate impression material is not sufficiently stable to be transported for more than a few days, so for fabrication of custom appliances in other countries PVS impressions or intraoral scans should be used as alternatives. The color images produced by this scanner will have a 1 : 1 ratio and could replace traditional intraoral imaging with photographs.

Conclusion

It can be expected that intraoral scanners will soon replace traditional impression taking procedures. The scanning time will decrease and the scanning head will become smaller. The intraoral scanning procedure is hygienic, images are immediately available, no transportation is needed, and storage and retrieval of the models is easy. The digital dental models can be easily shared with other

people, enlarged, and clipped, and dedicated software is available for analyzing a case, planning treatment and appliance fabrication. The files of the scanner can be used in any dental lab. Furthermore, the intraoral color scans can replace traditional intraoral photographs and will have real colors and are presented in a 1 : 1 ratio.

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