Evaluation of 3D Technologies in Dentistry

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Quality of service, in terms of improvement in patient satisfaction, is an increasingly important objective in all medical fields, and is especially imperative in orthodontics due to the high numbers of patients treated. Information technology can provide a meaningful contribution to bettering treatment processes, and we maintain that systems such as CAD, CAM and CAE, although initially conceived for industrial purposes, should be evaluated, studied and customized with a view to use in medicine.
The present study aims to evaluate Reverse Engineering (RE) and Rapid Prototyping (RP) in order to define an ideal chain of advanced technological solutions to support the critical processes of orthodontic activity.

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Introduction

In recent years, the use of various Reverse Engineering (RE) and Rapid Prototyping (RP) systems has become consolidated and widespread in industry, predominantly in the design and quality control sectors, and a wide range of these systems, in terms of cost and performance, is now available on the market. This provides an excellent context in which to evaluate the advantages to using such systems to carry out many of the stages in orthodontic processes currently performed by hand, such as the design and manufacture of corrective appliances[1,2],and the

Type of process	Problems with current techniques	Suggestions for improvement
Diagnosis and follow-up of orthodontic treatment	• Space-consuming physical storage of plaster models • Fragility of models	• Digitalization of model and computer storage • The physical model need only be produced as required
Measurement of significant parameters of a plaster model and morphological parameters (definition of occlusion class, discrepancy, Bolton, etc.)	• Strong dependency on operator expertise • Poor precision of measurements due to poorly repeatable positioning of gauge • Time-consuming measurement procedure	• Rigorous definition of measurement procedures • Automation of visualization procedure • Support in filing characteristic measurements
Design and production of corrective appliances	• Strong dependency on operator expertise and time-consuming fabrication procedure • Difficulty in progressive production of transparent aligners	• Design of conventional appliances via virtual positioning of attachments and transferral via RP masks • Progressive production of transparent aligners via free treatment planning
Design and production of protheses -	• Strong dependency on operator expertise • Time-consuming fabrication procedure	• Virtual design of prostheses • Prosthesis fabrication using CNC and RP technologies

Table 1 Results of the analysis of the processes carried out in the odontoiatric sector.

La qualità del servizio, in termini di maggiore soddisfazione del paziente, è un obiettivo sempre più sentito nei vari settori della medicina, ed è accentuato nel campo odontoiatrico, data l'alta percentuale di persone interessate. Le tecnologie informatiche possono dare un notevole contributo al miglioramento dei processi. Esse, però, devono essere rese fruibili da un campo di utenza culturalmente distante da metodi e strumenti propri di settori industriali e manifatturieri, come ad esempio sistemi CAD, sistemi CAM, sistemi CAE. In questo contesto, il presente lavoro di ricerca si focalizza su come i sistemi di Reverse Engineering (RE) e di Rapid Prototyping (RP) possano essere usati con successo per supportare alcuni processi critici del lavoro dell'odontoiatra.

Key words: Reverse Engineering; Rapid Prototyping; Digital model.

production of virtual models of the dental arches[3], and also to determine the feasibility of their use in the planning and simulation of corrective and implantological treatment[4] and in the design and manufacture of fixed and mobile prostheses[5] (Tab. 1).

The plaster model of the dental arches is still the most used tool in orthodontic diagnosis and treatment planning although recent technological advances have made it possible for dentists to consider the alternative of digital modeling and automation of these processes.

The aim of these continuing advances is to realize accurate virtual models and thence to produce simi-

larly accurate physical reproductions where necessary. Reverse engineering is a technique which allows the virtual design and simulation of various orthodontic operations, and rapid prototyping provides manufacturing of physical models which can be used for further treatment planning and functional tests. The three main processes in the RE/RP chain are as follows: the data acquisition system which converts the plaster model into a point cloud data set, the data processing software which carries out elaboration processes such as filtering, decimation, cleaning and matching, and the rapid prototyping system which produces a physical reproduction of the plaster model.
Many companies now offer the digitalization and prototyping of plaster models but a reliable method of evaluation of these services based on criteria deriving from analysis of the processes involved has not as yet been formalized.
This preliminary study presents methodologies established for comparing the various rapid prototyping systems considered and the experimental results obtained; the characterization of the related software and data acquisition systems are currently underway. >

Reverse Engineering Systems

The non-contact systems, prevalently of the optical type, employed for acquisition of three-dimensional shapes have long been employed in industry and their use is now spreading to other sectors after suitable customization. A complete catalogue of these variants has been reported by D'Apuzzo[6], and the vast majority can be classified into two groups, laser projection-based and fringe projection systems. These systems were further developed in the orthodontic field with a view to measurement of plaster models and recently the first systems for intraoral prototyping, based on the study of suitable image analysis algorithms, have started to make an appearance[7]. The need for rapid measurement has led to the development of systems in which all the phases of relative movement between the plaster model and visual apparatus have been automated, for example 3Shape D-200 (www.3shape.com) and hi-Scanμ (www.iof.fraunhofer.de), and the costs of such systems have now been reduced so as to permit their use in the surgery. These systems are generally equipped with software applications which automatically carry out visual acquisition and triangulated surface reconstruction.
The main problems presented by the use of reverse engineering systems in the orthodontic field can be summarized in the following points:

1. It is rather difficult to acquire the curves and edges significant for orthodontic use, for example the tooth necks and borders between teeth, due to the fact that optical systems do not generally possess the resolution necessary to reveal such geometry and tend to 'soften' the edges.
2. Specific expertise is necessary for construction of the point

La qualité du service, en termes d'amélioration de satisfaction du patient, est un objectif de plus en plus important dans tous les domaines médicaux, et est particulièrement impérative dans l'orthodonties du aux nombres élevés de patients traités. La technologie de l'information peut fournir une contribution signicative à améliorer des processus de traitement, et nous maintenons des systèmes tels que le DAO, la CAME et la IAO, bien que conçus pour des buts industriels, mais qui devraient être évalués, étudiés et adaptés aux besoins du client en vue de l'utilisation dans la médecine. La présente étude vise à évaluer le Reverse Engineering (RE) and le Rapid Prototyping (RP) au fin de définir une chaîne idéale des solutions technologiques avançées pour soutenir les processus critiques de l'activité orthodontique.

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cloud data set from several views as it often necessitates cleaning, removal of unnecessary points, and repairing, filling the gaps in the scanned image.

3. The abovementioned automatic image registration systems are only available for a few kinds of rotating table apparatus which do not completely resolve the entire geometry of the plaster model. Systems which rotate and tilt through various axes are more effective in capturing the underhanging areas, but these have only recently appeared on the market.
4. Expertise in the use of CAD systems is also required in order to carry out dimensional analysis of plaster models and to simulate the odontoiatric procedures to be employed.

So as to evaluate the best solution in terms of fulfilling the needs of the Dentistry sector, both specific and general-purpose systems should be compared. From a technical point of view, benchmarking can be arrived at by determination of the resolution and accuracy of these devices[8] using plaster models of various morphologies, but, in order to be comprehensive, this analysis must also be linked to criteria such as cost and ease of use.

Once a single point cloud has been obtained it must be elaborated in order to produce a CAD model via the various phases of image registration, filtering, triangulation, smoothing and so on. Various types of stand-alone software which carry out this process are in commerce, the most well-known of which being RapidForm, Polyworks, Geomagic, or, as previously mentioned, proprietary software of the scanning system can be employed. As the algorithms implemented in the various options differ, they need first to be categorized before proceeding to evaluation of their efficiency and the quality of the results obtained.

Rapid Prototyping Systems

The RP technique involves a series of systems which reproduce an object, irrespective of the complexity in its construction, using additive techniques. The process starts with a specific mathematical definition of an object in a three-dimensional CAD model using rapid, flexible, highly automated processes known as solid freeform fabrication (SFF). SFF processes, typically designed for industrial application, are currently the focus of much attention in the medical field with a view to their employment in a range of applications from the design and simulation of surgical operations to indirect (mould casting) and direct fabrication of prostheses[9]. Unlike conventional machines, which operate by removing material from a solid block, RP systems fabricate layer-by-layer of liquid, powder, granular or laminate material with a deposition thickness of approximately 0.25 mm.

Production via layer tracing is a method which all the various rapid prototyping techniques have in

La calidad del servicio prestados ss un objetivo cada vez más importante en todos los ámbitos médicos, es especialmente en ortodoncia debido al alto número de pacientes tratados, para poder mejorar la satisfacción del paciente. La tecnología de la información pueden aportar una contribución importante para mejoramiento de los procesos de tratamiento, y sostenemos que los sistemas como el CAD, CAM y CAE, aunque si inicialmente fueron concebidos con fines industriales, deben ser evaluados, estudiados y personalizados con miras a su aplicación en medicina.
El presente estudio tiene como objetivo evaluar Ingeniería Inversa (RE) y Rapid Prototyping (RP) con el fin de definir un ideal de procesos de soluciones tecnológicas avanzadas, para de esta forma poder solucionar las situaciones críticas en ortodoncia.

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common, they differ only in the type of material used and the physical principles exploited. The materials employed can be classified into UV sensitive resins, metal granules and powders, wax, ceramics, thermoplastics, sheets of thermoadhesive paper, wax or thermoplastic threads and other materials. Stereolithography (SLA), which uses photopolymers, and powder sintering (SLS) are the most important RP systems commercially available to guarantee high dimensional accuracy of the finished pieces but these, are rather expensive. The systems which employ ink-jet heads, such as 3D-Printing (3D-P), permit more rapid production of finished pieces at a more reasonable cost but unfortunately they are less accurate. Technologies such as fused deposition modeling (FDM) which use the extrusion principle constitute an acceptable compromise in terms of both cost and dimensional accuracy.

The use of RP systems in dentistry currently involves the following applications: manufacture of devices for the dental sector, visualization and diagnosis, surgical design, production of personalized implants and prostheses, anthropological and forensic studies and fabrication of active biological implants[10]. No significant data on comparison of the various RP technologies in terms of the accuracy of the finished pieces have thus far been reported in dental literature, although the authors have previously published a comparative study of the two main RP techniques, SLS and SLA, to establish their accuracy in reconstructing mandibles from cadavers[11].

In this study, however, the four previously cited technologies were examined in order to highlight the cost/benefit ratio obtainable for each in the digitalization and reproduction of a dental plaster model.

Materials and Methods

The parameters to be considered, common to the various types of odontoiatric process were dimensional, morphological and appearance[12] (Fig. 1).

The dimensional errors to be measured were linked to the accuracy of positioning of each tooth and the relative distances between them and may take the form of local errors or errors spread over a wide area where relative positioning is involved (Fig. 2). This information is extremely important in orthodontic treatment where the aim is to obtain a diagnosis based on the positioning of the teeth and to succeed in aligning them.

The morphological parameters refer to the degree of detail captured and reproduced by the scanning system; the teeth present very accentuated morphological characteristics, especially around the neck and in the interstices and occlusal zones of the molars and premolars.

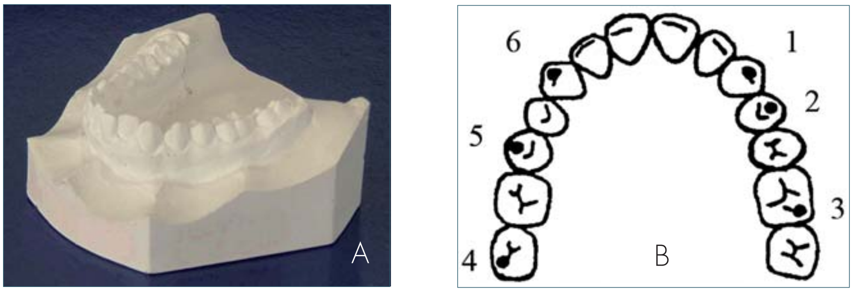
In general, the orthodontist needs to work with a dimensional precision of tenths of a millimeter, which can be evaluated by dimensional parameters. There are, however, processes, for example the design and manufacture of prostheses, which require an accuracy of a few hundredths of a millimeter, and require further evaluation by other parameters.

Finally, as regards the parameters linked to the appearance obtained by the process of reproduction of the plaster model, it is important to evaluate the conformity, in terms of weight and surface finishing, to conventional techniques. As a final criterion, the workability of the material, which can be tested by incision, piercing and insertion of screws or implants, should not be omitted.

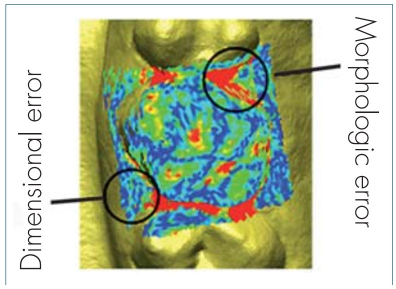
Once the examination parameters were defined, the development of methodologies which would allow us to check and verify the three principal phases (acquisition, elaboration and reproduction) of the prototyping process in order to identify the best RE/RP chain was commenced.

Two types of test were employed to study the acquisition systems, the first aimed at evaluating the system usability and the time required for scanning, and the second designed to compare the resolution and accuracy of the systems. To the former end a standard procedure of measurement which could be employed with both specific and general purpose systems, all used in conjunction with a suitable automatic positioning device, was established. Then ten plaster models were chosen for their high degree of malformation which, upon replication, permitted measurement and comparison between systems of the number of iterations due to an unsatisfactory scanning result, considered as a factor of usability, and the respective time taken.

The environmental conditions of operation were also controlled, in particular the degree of illumination of the room and variation in the surface fi-



Figs1 Plaster model and points used for dimensional/morphological verification.



Figs 2 Colored map of deviations showing dimensional and morphological errors and a local error where the reproduced tooth is rotated with respect to the original.

nishing of the models.

The resolution and accuracy of the various acquisition systems were compared via the acquisition of a single view of a significant portion of the same plaster model. The CAD system was employed to measure the dimensional and morphological parameters directly using the triangulated scatter plot, without further elaboration. The dimensional reference data were calculated from a measurement carried out by a coordinate measurement machine with contact sensors.

The second stage of the process is elaboration of the views obtained and reconstruction of the entire mesh acquired via repositioning (matching) and fusion (merging) of the various views. This is a very delicate stage of the process as significant dimensional and morphological error may occur. A single view is influenced by systematic and accidental errors. Further errors due to the size and quality of the superimposition area and the algorithms used may also arise during the matching phase. It was therefore necessary to compare various types of reverse engineering software as each exploit different matching and merging algorithms. The comparison procedure, and therefore also that of the calculation of the errors induced, was to consider the point cloud data set of a plaster model acquired by the three main types of scanning systems (laser projection, fringe projection and piezoelectric sensors), and to use colorimetric mapping analysis to calculate and highlight any deviation of the reconstructed surface from the single views. The numerical values which contain 95% and 99% of the distribution of the errors, henceforth referred to as the 95^{th} and 99^{th} percentiles, together with the mean variation, the calculated on the 99th percentile, are considered indices of precision of the surface reconstruction process.

Finally, in order to compare the reproduction techniques we chose a plaster reference model which was acquired and elaborated to become the virtual reference model. This was replicated in various versions by the different rapid prototyping machines. The plaster models were acquired and reproduced via a similar means to the reference model by the most repeatable acquisition/reconstruction process possible and the dimensional and morphological parameters were compared in order to determine the best combination of RP machine and production parameters.

The plaster reference model was measured using a piezoelectric system (Roland MDX-15) accompanied by a suitable positioning system. This apparatus permitted us to repeat a similar positioning to the reference model and to replicate the same order of views acquired for each reproduction. The choice of scanning system was made on the basis of its high degree of precision, and due to its insensitivity to environmental conditions despite the protracted measurement times. In order to compare the reproductions in a homogeneous manner, the same three views were acquired for each reproduction.

The acquired views were triangulated using homogeneous parameters (maximum edge length of 2mm and a normal angle of 75° with respect to the direction of acquisition) and then underwent similar matching and merging procedures using RapidForm software (Inus Tech.). This process was carried out by the same operator, in sequence, in the same work session.

The reference models were produced using the following technologies: FDM (Stratasys Dimension), SLA (3D System, using two different resins: Somos WaterClear™ and Accura SI 10™), SLS (3D System, using three different materials: Alpacem™, Duraform™ and Duraform Glass-Filled™) and 3D-P (Z-Corp) (Fig. 3).

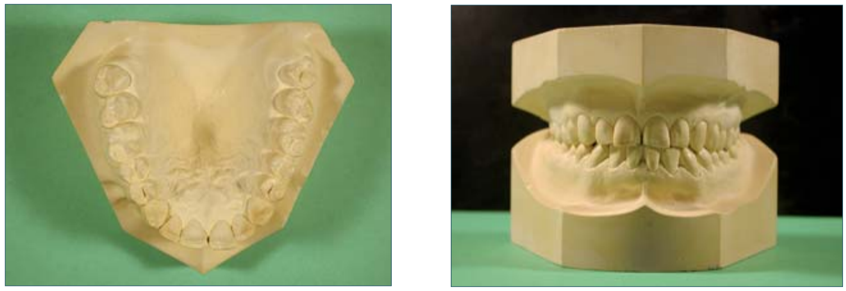
The models were acquired and compared with the original mathematics (Fig. 4). An imaginary line separating the alveolar bone process from the maxillary basal bone was selected as a reference curve to ensure homogeneity of measurement (Fig. 5).

In order to evaluate the quality of detail reproduced by the various RP techniques over a local area, an extremely dense scan of an occlusal premolar surface was carried out (Fig. 6).

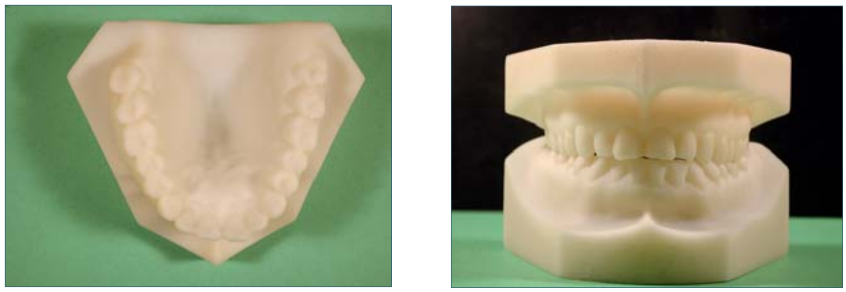
Results and Discussion

Based on the measurements carried out to ascertain the dimensional error (Table 2a, Fig. 7), it can be evinced that:

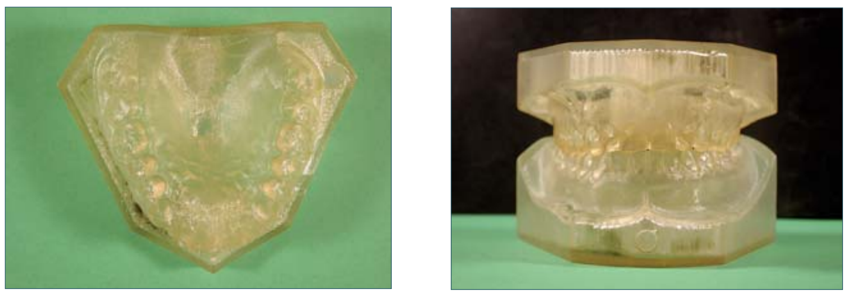
- The dimensional error of the models obtained using 3D-P technology, with respect to the plaster model control, calculated at the 95th and 99th percentiles yielded values equal to 0.267 and 0.43 mm, respectively, while the mean dimensional error calculated at the 99th percentile was equal to 0.103 mm.
- The dimensional error of the models obtained using FDM technology, with respect to the



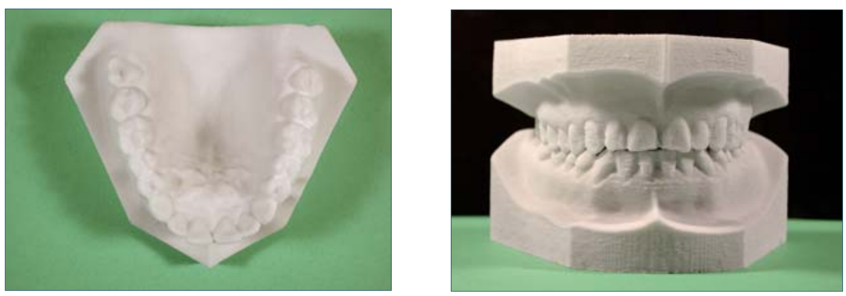
Plaster models



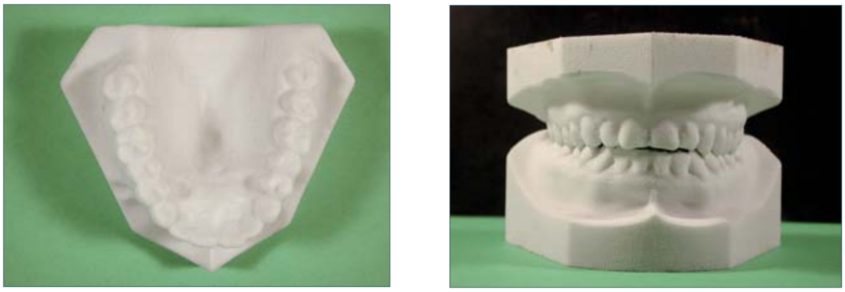
SLA Opaque



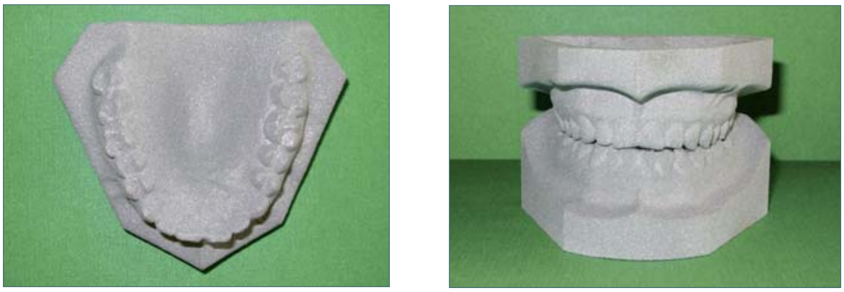
SLA Trasparent



DF



DF-GF



AC-50

AC-90

FDM

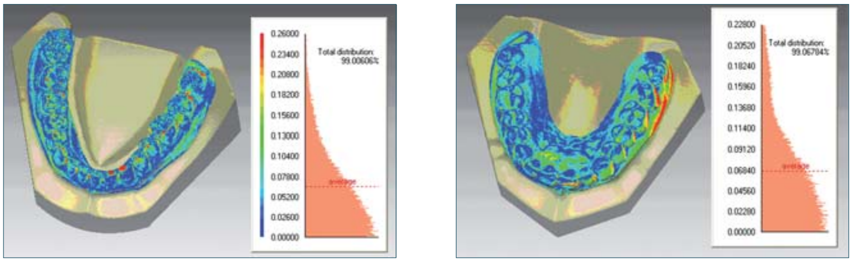
Figs 3 Plaster reference model and reproductions obtained via the various RP techniques.

plaster model control, calculated at the 95th and 99th percentiles yielded values equal to 0.174 and 0.265 mm, respectively, while the mean dimensional error calculated at the 99th percentile was equal to 0.063 mm.

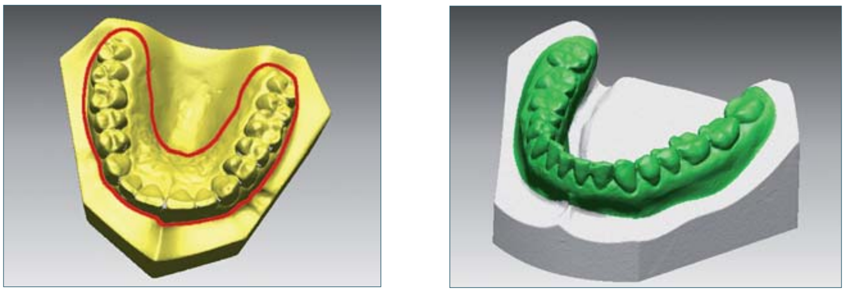
- The dimensional error of the models obtained using SLS technology and AlpaCem™ with mean powder granulometry of 50 μm, with respect to the plaster model control, calculated at the 95th and 99th percentiles yielded values equal to 0.257 and 0.35 mm, respectively, while the mean dimensional error calculated at the 99th percentile was equal to 0.108 mm.
- The dimensional error of the models obtained using SLS technology and AlpaCem™ with mean powder granulometry of 90 μm, with respect to the plaster model control, calculated at the 95th and 99th percentiles yielded values equal to 0.377 and 0.511 mm, respectively, while the mean dimensional error calculated at the 99th percentile was equal to 0.151 mm. As expected, the finer material (AlpaCem™ 50 μm) produced better results in terms of dimensional accuracy.
- The dimensional error of the models obtained using SLS technology and Duraform™ GF (glass-filled), with respect to the plaster model control, calculated at the 95th and 99th percentile yielded values equal to 0.305 and 0.425 mm, re-

spectively, while the mean dimensional error calculated at the 99^{th} percentile was equal to 0.113 mm.

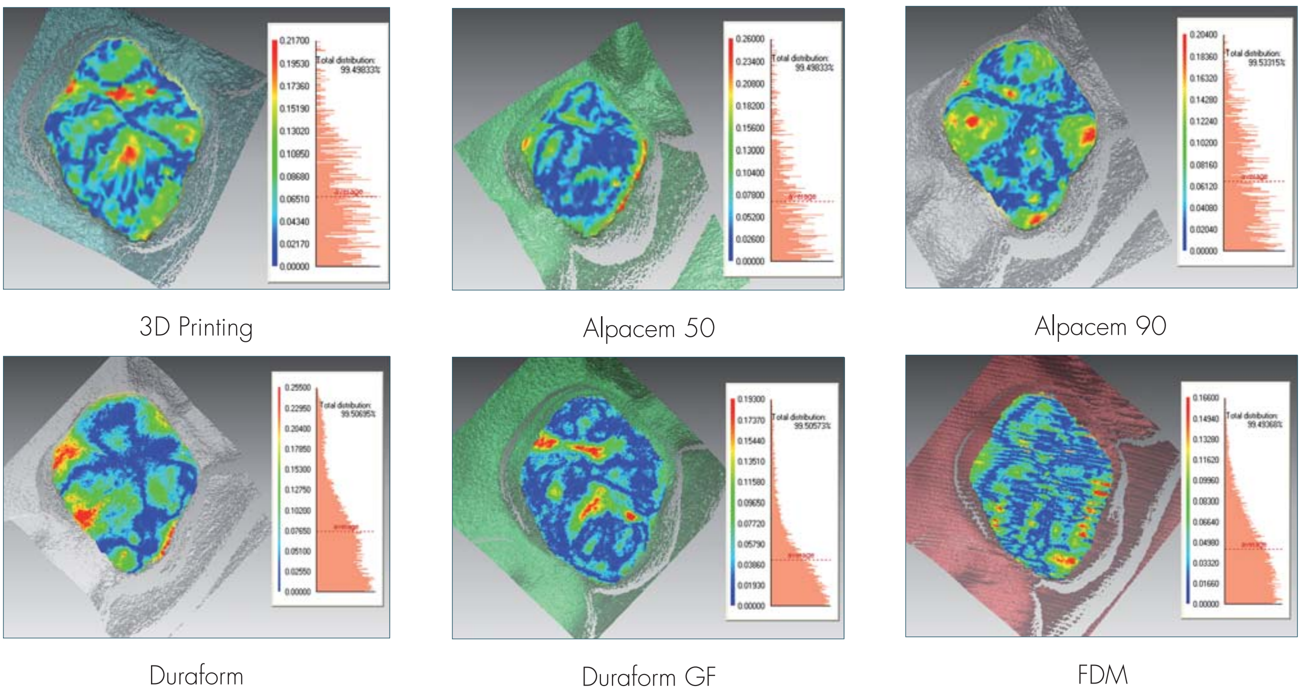
- The dimensional error of the models obtained using SLS technology and Duraform™, with respect to the plaster model control, calculated at the 95^{th} and 99^{th} percentiles yielded values equal to 0.219 and 0.335 mm, respectively, while the mean dimensional error calculated at the 99^{th} percentile was equal to 0.08 mm.

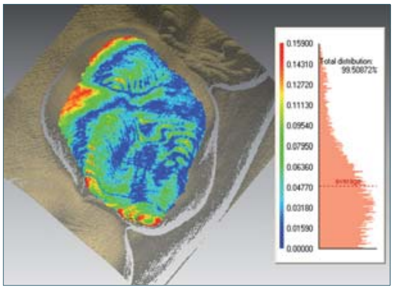


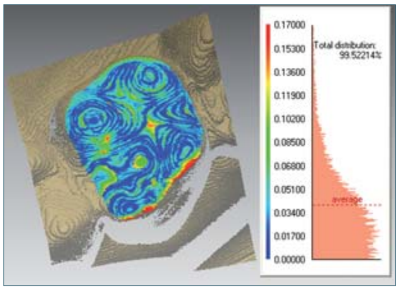
Figs 4 Reproduction of a plaster model of an upper arch using SLA Accura™ and a plaster model of a lower arch using FDM. In the upper figure the resulting error of 0.22 mm applied to 99% of the deviations. The mean error was approximately 0.06 mm. In the lower figure the dimensional error of 0.26 mm applied to 99% of the deviations and the mean error was approximately 0.063 mm.



Figs 5 Definition of the area of reference to guarantee the homogeneity and reproducibility of the measurements carried out.




SLA


SLA Watershed

Figs 6 Premolars.

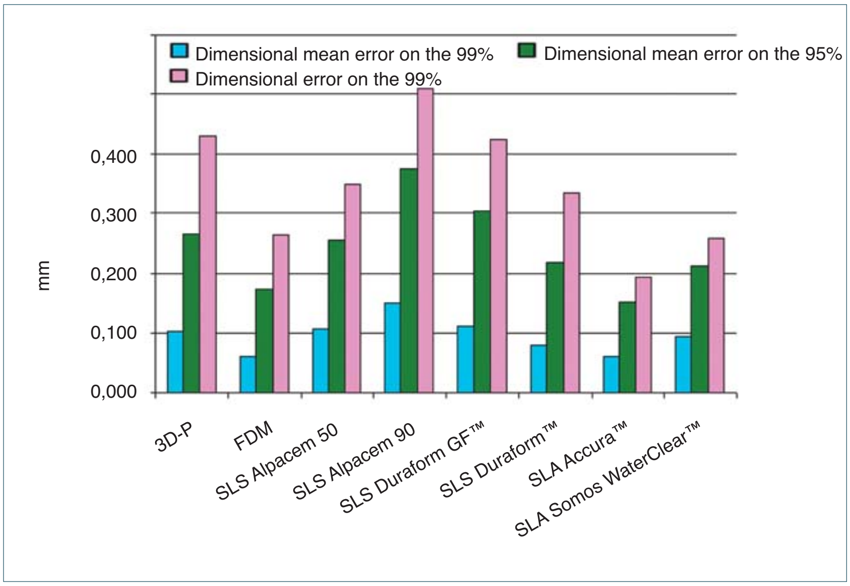


Fig. 7 Graphical summary of results reported in Table 2a.

- The dimensional error of the models obtained using SLA technology and Accura™ resin, with respect to the plaster model control, calculated at the 95th and 99th percentiles yielded values equal to 0.153 and 0.194 mm, respectively, while the mean dimensional error calculated at the 99th percentile was equal to 0.062 mm.
- The dimensional error of the models obtained using SLA technology and Somos WaterClear™ resin, with respect to the plaster model control, calculated at the 95th and 99th percentiles yielded values equal to 0.213 and 0.26 mm, respectively, while the mean dimensional error calculated at the 99th percentile was equal to 0.096 mm. As expected, the SLA models made using a transparent resin (Somos WaterClear™) were less dimensionally accurate than those obtained using an opaque resin (Accura™) as the transparent nature of the mo-

Table 2a Dimensional error resulting from RP of plaster models. The techniques which produced the best results are highlighted in blue.

	Mean dimensional error calculated on 99th percentile (mm)	Dimensional error on 95th percentile (mm)	Dimensional error on 99th percentile (mm)
3D-P	0.103	0.267	0.430
FDM	0.063	0.174	0.265
SLS Alpacem™ 50 _m	0.108	0.257	0.350
SLS Alpacem™ 90 _m	0.151	0.377	0.511
SLS Duraform GF™	0.113	0.305	0.425
SLS Duraform™	0.080	0.219	0.335
SLA Accura™	0.062	0.153	0.194
SLA Somos WaterClear™	0.096	0.213	0.260

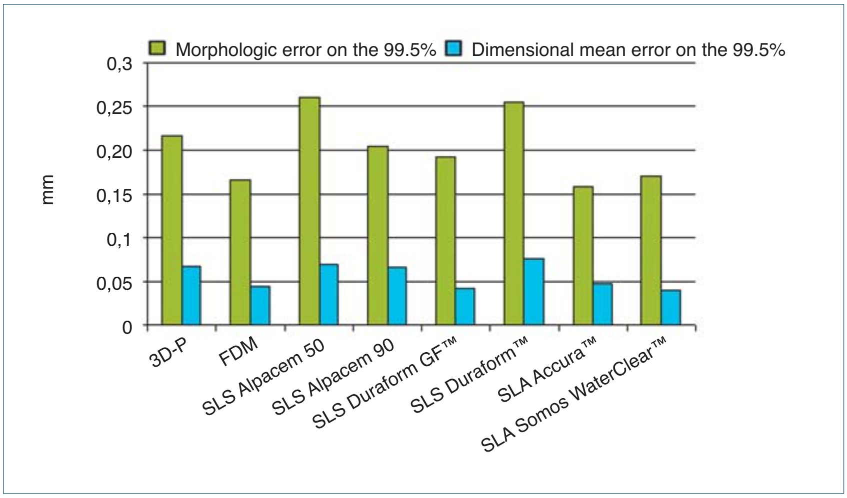


Fig 8 Graphical summary of results reported in Table 2.b.

Table 2b Morphological errors resulting from RP of plaster models.

	Mean dimensional error calculated on 99th percentile (mm)	Mean morphological error on 99,5th percentile (mm)
3D-P	0.217	0.068
FDM	0.166	0.044
SLS Alpacem™ 50 _m	0.260	0.069
SLS Alpacem™ 90 _m	0.204	0.066
SLS Duraform GF™	0.193	0.043
SLS Duraform™	0.255	0.076
SLA Accura™	0.159	0.048
SLA Somos WaterClear™	0.170	0.040

dels created problems during the acquisition phase.

The results obtained show that the two technologies which produce the best results in terms of the accuracy of reproduction of the plaster models were FDM and SLA using opaque Accura™ resin with similar characteristics to the ABS used in the FDM fabrication technique.

Based on the measurements carried out to ascertain the morphological error (Table 2b, Fig. 8), it can be evinced that:

- The morphological error of the models obtained using 3D-P technology, with respect to the plaster model control, calculated on 99.5% of the total errors yielded values equal to 0.217 mm while the mean morphological error calculated on 99.5% of the total errors was equal to 0.068 mm.
- The morphological error of the models obtained using FDM technology, with respect to the plaster model control, calculated on 99.5% of the total errors yielded values equal to 0.166 mm while the mean morphological error calculated on 99.5% of the total errors was equal to 0.044 mm.
- The morphological error of the models obtained using SLS technology and AlpaCem™ with mean powder granulometry of 50 μm, with respect to the plaster model control, calculated on 99.5% of the total errors yielded values equal to 0.26 mm while the mean morphological error calculated on 99.5% of the total errors was equal to 0.069 mm.
- The morphological error of the models obtained using SLS technology and AlpaCem™ with mean powder granulometry of 90 μm, with respect to the plaster model control, calculated on 99.5% of the total errors yielded values equal to 0.204 mm while the mean morphological error calculated on 99.5% of the total errors was equal to 0.066 mm.
- The morphological error of the models obtained using SLS technology and Duraform™ GF (glass-filled), with respect to the plaster model control, calculated on 99.5% of the total errors yielded values equal to 0.193 mm while the mean morphological error calculated on 99.5% of the total errors was equal to 0.043 mm.
- The morphological error of the models obtained using SLS technology and Duraform™, with respect to the plaster model control, calculated on 99.5% of the total errors yielded values equal to 0.255 mm while the mean morphological error calculated on 99.5% of the total errors was equal to 0.076 mm.

- The morphological error of the models obtained using SLA technology and Accura™ resin, with respect to the plaster model control, calculated on 99.5% of the total errors yielded values equal to 0.159 mm while the mean morphological error calculated on 99.5% of the total errors was equal to 0.048 mm.
- The morphological error of the models obtained using SLA technology and Somos WaterClear™ resin, with respect to the plaster model control, calculated on 99.5% of the total yielded values equal to 0.170 mm while the mean morphological error calculated on 99.5% of the total errors was equal to 0.04 mm.
- The results obtained show that the technologies which produce the best results in terms of the accuracy of reproduction of morphological details of the plaster models were FDM and SLA using both resins, but also SLS with Duraform™ GF, which, thanks to its glass particle content succeeded in sculpting the morphological details better.

Conclusions and Future Developments

This comparative study analyzed rapid prototyping systems and defined suitable methodologies of evaluating the fundamental components of an RE/RP manufacturing for application in the orthodontic field.

The preliminary results demonstrate that replication of a plaster model is plagued by problems linked to the size of detail to be reproduced, which is similar to or finer than the fabrication layer of the various additive technologies studied, and therefore results in poor quality reproduction of tooth morphology.

There is a general misconception in the orthodontic field as precision of such a process, although research is highlighting how the chain, upon necessary improvement, is a method which could be extremely useful in dental practice..

Future work will serve to characterize both specific and general-purpose acquisition systems shape and point cloud data management software. Once the ideal chain has been identified, an experimental plan will be developed in order to evaluate its benefits and possible improvements.

References

1. Wong BH. Invisalign A to Z. Am J Orthod Dentofacial Orthop. 2002 May;121(5):540-1.
2. Raffaeli R, Germani M, Mandorli F., "Innovative technologies to support positioning of corrective appliances in orthodontic treatments", in Proc. of XIV IASTED Int. Conf. on Applied Simulation and-ASM 2005, pp. 48-53, Benalmàdena (Spain), 2005
3. Gracco A, Buranello M, Siciliani G, Guarneri M.P. Gipsoteca tradizionale and virtuale a confronto. Mondo Ortodontico-ORI 2005; 5:29-34.
4. Motohashi N.,Kuroda T. A 3D computer-aided design system applied to diagnosis and treatment planning in orthodontics and orthognatic surgery. Eur J Orthod. 1999 Jun;21(3):263-74.
5. Lee MY, Chang CC, Lin CC. 3D image reconstruction and RP models improve defect evaluation, treatment planning, implant design, and surgeon accuracy. IEEE Engineering in Medicine and Biology 2002; 21(2):38-44.
6. D'Apuzzo N, "Overview of 3D surface digitization technologies in Europe", in Proc. of SPIE Thre-dimensional Image Capture and Applications VI, Vol.6056, San Josè (USA), 2006.
7. Yamani M, Farag A, Tasman D, Farman A, "A 3D reconstruction system for the human jaw using a sequence of optical images", in IEEE Transactions on Medical Imaging, IEEE Transactions on Medical Imaging 2000; 19(5):538-47.
8. Tornincasa S, Vezzetti E, "Feasibility study of a reverse engineering system benchmarking", in Proc. of XVII Congreso Internacional INGEGRAF-ADM, Proc CD-ROM, Sevilla (Spain), 2005.
9. Petzold R, Zeilhofer HF, Kalender WA. Rapid protyping technology in medicine–basics and applications. Comput Med Imaging Graph. 1999 Sep-Oct;23(5):277-84.
10. Liu Q, Ming MC, Schmitt SM. Rapid prototyping in dentistry: technology and application. Int Journal of Advanced Manufacturing Technology 2006; 29:317-35.
11. Mazzoli A, Germani M, Moriconi G. Application of optical digitizing techniques to evaluate the shape accuracy of anatomical models derived from computed tomography data. J Oral Maxillofac Surg. 2007 Jul;65(7):1410-8.
12. Bell A, Ayoub AF,Siebert P. Assessment of the accuracy of a three-dimensional imaging system for archiving dental study models. J Orthod 2003 Sep; 30(3):219-23.

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