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The Accuracy of Bone Mapping and Guided Flapless Implant Placement using a Novel Surgical Guide A Human Cadaver study.

Submitted in partial completion of a D.Ch.Dent (Prosthodontics) Trinity College Dublin.

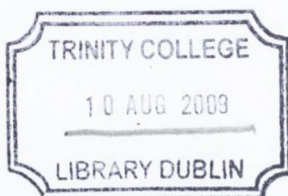
2008

Maurice Edward Fitzgerald

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Dedication

This thesis is dedicated to my wife Ciara, for her support, patience, encouragement and love.

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1. Summary

The Accuracy of Bone Mapping and Guided Flapless Implant Placement using a Novel Surgical Guide: A Human Cadaver study

Dental Implants are a predictable way of replacing missing teeth. However in some instances the position of the implant is a hindrance to providing a functional and aesthetic restoration. The problems associated with sub-optimal implant placement are numerous and include biomechanical, aesthetic, economic, and functional issues in addition to iatrogenic damage. Many techniques have been developed to help optimise the positioning of dental implants. Most use the restorative driven approach where the final result is visualised and the implant placed according to the restorative parameters. Guided surgery such as CT based stereolithographic guides have been developed to aid in precise implant placement and these have proven reliable and accurate. In some less complex cases however the radiation dose and expense of such systems may not be justified. The model based NobelGuide™ uses bone mapping data to visualise the bone morphology and implant placement takes place on a stone cast from which a stent is fabricated to facilitate accurate spatial placement of the implant. This technique may have advantages in terms of reduced radiation dose, expense and simplicity over the CT based systems. The accuracy of this technique however is unknown. The aims of the current study were to measure the accuracy of the model based NobelGuide™ and evaluate if the bone mapping data are sufficient for implant placement.

Materials & Methods: 13 implant replicas were placed in 9 human cadavers bounded edentulous spaces. Highly restrictive stents were fabricated using pre-operative bone mapping data. A stone cast was modified to represent the bone at the implant site. The manufacturer's instructions were followed regarding surgical placement of the implant replicas. Post operative impressions were taken for comparison with the planning model used to generate the stents. Mucoperiosteal flaps were raised over each implant site and the area inspected for fenestrations, thread exposures or dehiscences. A coordinate measuring device was used to obtain positional and angular information from each implant placed in the planning and the post surgery cast. These were compared and analysed for clinical and statistical significance.

Results: The mean accuracy for the model based NobelGuide™ was 0.67 mm (SD +/- 0.55 mm) with an angular mean deviation of 3.473 degrees (SD +/- 2.51 degrees). The greatest measured errors were still within acceptable limits set out in the previously published literature for similar techniques. Sites with small bone volumes (ridge width less than 5mm bucco-lingually) preoperatively led to thread exposure without exception; however the accuracy of the transfer of implant position was independent of bone volume. As such the bone mapping is of sufficient diagnostic value for implant placement in cases with large preoperative bone volumes (greater than 5 mm bucco-lingually), in small bone volumes the need for grafting (simultaneous or otherwise) should always be suspected.

Conclusion: The use of the model based NobelGuide™ encourages adherence to the restorative driven approach. The accuracy of the method is within acceptable limits for guided surgery set out in the literature and the use of the bone mapping is sufficient in cases with large bone volume. The technique can also be used in cases with small bone volume but a flapped procedure is recommended. Its use in free end edentulous areas requires further research.

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Table of Abbreviations

1. CTBN : Computer Tomograph Based Nobelguide TM
2. MBNG : Model Based Nobelguide TM
3. CT : Computer Tomograph.
4. 3D: Three Dimensional
5. FEA: Finite Element Analysis.
6. IGTP: Image guided template production.
7. PVS: polyvinylsiloxane addition silicone impression material.
8. R/P: Regular Platform implant.
9. RPM: Revolutions Per Minute.

2. Literature Review

2.1 History of Implants

2.1.1 Brånemark and the early pioneers

The first dental implants can be traced to the Mayan people circa 600 AD. Here pieces of shell were shaped and inserted into the jaw bone and achieved a form of bone integration¹. However the controlled use of this process was not refined until the 1970s.

No discussion of dental implants is complete without reference to PI Brånemark's work². Prior to the modern concept of bone integration many researchers had looked for a way to stabilise dental prosthesis in an edentulous area. These "implants" were more mechanical than biological and had varied success. Subperiosteal, blade, endodontic and other implants were used but often led to catastrophic failure³.

Brånemark in the early 1960's was researching blood flow in bone⁴. In the course of his experiments he noticed that the titanium viewing chambers inserted into rabbit tibias were tenaciously attached to the bone. This phenomenon was discovered to be a predictable integration of the oxide surface of titanium to the healing bone. Later work was commenced into using this osseointegration⁵ to support and stabilise dental prostheses.²

Initially it was thought that only the bone between the mental foramina in the mandible was suitable to support implants. The original protocol was used only in the edentulous mandible to support a fixed prosthesis. The implants were smooth machined commercially pure titanium in a cylindrical root form configuration. The implants were placed via a open mucoperiosteal flap procedure and submerged for 6 months of unloaded healing⁵.

Literature Review

Even though implants as we know them today were basically available in the late 1970's their popular usage did not start to develop until the 1990's. The publication of the Toronto study and others⁶⁻¹⁰ provided much needed long term clinical data as well as pushing the limits of the original Brånemark protocol. It was found that implants could be placed in the maxilla and posterior mandible. Single tooth implants showed good success rates above 90%⁹. Both fixed and removable prostheses showed biological success and patient satisfaction¹¹. Most importantly the bone to implant interface seemed to show stability over time.

As the volume of literature and experimental evidence grew, the root form, commercially pure titanium, two stage implant was showing very consistent success rates¹². This was in stark contrast to Linkow's³ vent blades and other earlier implants which had relatively poor success. As confidence grew, the priority started to change from merely survival of the implant (which now was 95% assured¹³) to overall clinical performance.

2.1.2 Survival versus Success

Success, in general terms, can be defined as the gaining of what is planned. Therefore, to be considered successful, an osseointegrated implant has to meet certain criteria in terms of function, tissue physiology and maintenance of osseointegration, absence of pain and other pathological processes and user satisfaction (aesthetics and comfort)¹⁴.

Consequently, a failure may be defined as the first point at which the performance of the implant, measured in some way, falls below a specified, acceptable level. This definition of implant failure includes a great deal of ambiguity and encompasses a large variety of clinical situations, ranging from all symptomatic mobile implants to implants showing more than 0.2 mm of peri-implant bone loss after the first year of loading or bleeding pockets exceeding 5 mm of probing depth. As such the definition of success or failure is of the utmost importance. An implant that is still present in the patient's bone but is not fulfilling the success criteria can be seen as surviving rather than successful.

Literature Review

A uniform definition for implant success versus survival has been difficult to determine, because of the unclear predictive measures of conventional periodontal techniques (for example, periodontal probing of implants). Substitute measures such as probing around implants only measure local inflammation, which may or may not relate to implant outcomes. Equally important, a study should provide information on the patient's aesthetic outcomes and prosthetic complications.¹⁵

While criteria for implant success have been published¹⁶, their focus often has been implant system-specific, which has resulted in greater emphasis on implant survival rather than success. Diagnostic technologies, such as resonance frequency analysis, may play a useful role in assessing the longitudinal integration of an individual implant¹⁷.

One of the first attempts to evaluate in an objective way the clinical performance of osseointegrated oral implants was made by the Swedish National Board of Health and Welfare in 1975. Periodontal (gingival index, plaque index and pocket depths), prosthetic (type of occlusion) and radiographic parameters (absence of peri-implant radiolucency), together with the patients opinion on treatment, were used. Albrektsson proposed more strict criteria which have been generally accepted. The minimum success criteria proposed by Albrektsson et al ¹⁴ are set out in Table 2.1.

1. An individual, unattached implant is immobile when tested clinically.
2. Radiographic examination does not reveal any peri-implant radiolucency.
3. After the first year in function, radiographic vertical bone loss is less than 0.2 mm per annum.
4. The individual implant performance is characterised by an absence of signs and symptoms such as pain, infections, neuropathies, paraesthesia, or violation of the inferior dental canal.
5. As a minimum, the implant should fulfil the above criteria with a success rate of 85% at the end of a 5 year observation period and 80% at the end of a 10 year period.

*after Albrektsson et al. *IJOMI* 1986; 1:11

Table 2.1 Suggested minimum success criteria for dental implants.

Literature Review

At that time conventional periodontal indices were not included, because they were not considered to correlate to implant success, and this opinion was supported by Smith and Zarb¹⁸ who did not consider it necessary to include any measure of mucosal health in their proposed criteria for implant success. In 1988, at the second NIH Consensus Conference¹⁹, it was concluded that different success criteria should be applied to different implant systems. Consensus was expressed on excluding probing depth, as this measurement might be related to the thickness of the mucoperiosteum and consequently might not be correlated to implant success or failure. Recently, at the 1st European Workshop on Periodontology, it was agreed that an absence of mobility, an average radiographic marginal bone loss of less than 1.5 mm during the first year of function and less than 0.2 mm annually thereafter, and absence of pain and/or paraesthesia, were to be considered success criteria for implants. It was also suggested that probing depths related to a fixed reference point and bleeding on probing should be measured. Periodontal parameters were introduced to better describe the state of peri-implant tissues in order to provide clinical tools to identify failing implants.

From a research point of view these success criteria may allow meta analyses of several studies. However on a patient by patient basis they are of little use. The patient generally wants a tooth or teeth rather than an integrated implant. Hence a perfectly integrated implant which is not fulfilling aesthetic demands or is placed where it is of no prosthetic use is a failure and the corollary, a implant which has lost 5 mm of bone since being placed may function to retain or support a prosthesis successfully for the patient.

2.2 Modern Advances in Implant Dentistry

With the growth in implant dentistry, coupled with the high success rates, the profession started to look to expand the indications for implant dentistry. Research has moved from the now highly predictable mandibular interforaminal implants to more challenging uses.

The advances since Brånemark's early work can be divided into:

- Earlier Integration.

- Earlier prosthetic loading.
- Integration with high success in poor quality bone and in smokers.
- Comparable success with long and short implants.
- Bone augmentation.
- Less traumatic surgery.
- Single tooth implants and improved gingival aesthetics.
- Partially edentulous cases.
- The restorative driven approach.

All these advances are aimed at improving success, not just from a biomechanical viewpoint but also from a patient acceptance, convenience and aesthetic perspective.

2.2.1 Earlier Osseointegration

Much research has lead to a myriad of implant surfaces all designed to enhance the osseointegration process. Each implant company has its own patented surface however their differences can be generally divided into:

- Implant Macro topography.
 - Implant length and taper.
 - Solid or hollow implants.
 - Thread geometry, thread pitch and cutting efficiency.
 - Connection geometry and design (internal connection, Morse taper, external connection)
 - Presence of stress breaking components.
- Implant Micro topography.
 - Surface Roughness (minimally, moderately or highly rough)
 - Nano topography (sub micron scale)
- Implant Chemistry.

- Bioactive Surface.
- Ionic Surface
- Implant Biomechanics
 - Composition of implant (commercially pure titanium, titanium alloy, ceramics etc.)

While each implant company professes the advantages of their combination of chemical, surface modification and prosthetic connection there is little research which distinguishes one implant system from another.²⁰ However the most important advance which has been universally adopted by all the implant companies is the idea of the moderately rough implant surface.

Roughness of the implant surface in the $1.51\mu\text{m}$ range²¹ have shown stronger bone response than the original minimally rough Brånemark turned titanium surface ($0.5\text{--}1\mu\text{m}$)²². Some have suggested that this is due to fibrin attachment which can resist the contraction of the initial clot, and provide a pathway for migration of osseogenic cells to the implant surface. This enhances bone disposition very close to the implant surface, called contact osseogenesis. This meets the ossifying front away from the implant (distance osseogenesis) and these together are faster and more stable than distance osseogenesis alone²³.

Roughness in higher ranges has shown poor results such as with the hydroxyapatite coated implant²⁴ (although this may also be due to delaminating of the surface coating). While the original Brånemark implant has the greatest long term data and high success rates, the newer moderately rough implants show comparable success rates but more importantly these rates are high even in the more classically high risk areas such as the posterior maxilla, type 4 bone and grafted bone²⁰. The method of achieving this rough surface varies from company to company. Some methods are acid etching, grit blasting, ion beam deposition, titanium plasma spraying and anodization, however the method seems to have little clinical relevance.

2.2.2 Earlier Loading

Earlier types of implants, such as blade, subperiosteal and vitreous carbon implants²⁵ were subjected to immediate loading and their higher incidences of failure formed the basis for concerns about immediately subjecting titanium root form implants to loading. The earlier implants exhibited an implant-fibrous tissue interface. The fibrous tissue interface with inflammatory cells was felt to be the cause of the bone loss and higher failure rate associated with these implants.

With faster osseointegration due to the modern surfaces and less dogmatic adherence to the original Brånemark protocol, the time until prosthetic loading had been reduced and sometimes eliminated. Also the time from tooth extraction to implant placement has reduced²⁶.

- Time from Extraction to Implant Placement

Various descriptors such as immediate, early and delayed are used to describe whether the implant is placed at the same time as tooth extraction, after complete healing or in a partially healed site respectively. However these terms are imprecise and lead to problems when comparing studies and performing meta analysis. The ITI consensus statement in 2004 gives a rational 1-4 classification system given in Table 2.2²⁶.

Classification	Definition	Advantages	Disadvantages
Type 1	Implant placement immediately following tooth extraction and as part of the same surgical procedure	• Reduced number of surgical procedures • Reduced overall treatment time • Optimal availability of existing bone	• Site morphology may complicate optimal placement and anchorage • Thin tissue biotype may compromise optimal outcome • Potential lack of keratinized mucosa for flap adaptation • Adjunctive surgical procedures may be required • Procedure is technique-sensitive
Type 2	Complete soft tissue coverage of the socket (typically 4 to 8 wk)	• Increased soft tissue area and volume facilitates soft tissue flap management • Resolution of local pathology can be assessed	• Site morphology may complicate optimal placement and anchorage • Treatment time is increased • Socket walls exhibit varying amounts of resorption • Adjunctive surgical procedures may be required • Procedure is technique-sensitive
Type 3	Substantial clinical and/or radiographic bone fill of the socket (typically 12 to 16 wk)	• Substantial bone fill of the socket facilitates implant placement • Mature soft tissues facilitate flap management	• Treatment time is increased • Adjunctive surgical procedures may be required • Socket walls exhibit varying amounts of resorption
Type 4	Healed site (typically more than 16 weeks)	• Clinically healed ridge • Mature soft tissues facilitate flap management	• Treatment time is increased • Adjunctive surgical procedures may be required • Large variations are present in available bone volume

Table 2.2 Suggested protocols for implant placement in extraction sockets and their advantages and disadvantages

When reading literature regarding immediate placement one should carefully check the materials and methods for the exact timing of placement as some confusion exists, and the same chronology may not follow the same nomenclature between papers.

- Time from Implant Placement to Loading

Terms such as immediate, early, early delayed and delayed are used with some variability. The early restoration of the implant does not necessarily mean the implant is occlusally loaded. There has been no consensus to date regarding terminology. However as a rule of thumb:

- Immediate Loading = implants placed into full occlusal load on the day of surgery or within 24 hours.

- Early Loading – implants placed into full occlusal load within 20 days of implant placement.
- Delayed Loading – implants placed into full occlusal load after a period of time commensurate with osseointegration.
- Immediate Restoration – Implant restored to aesthetic function at the time of surgery or soon after but not placed into occlusal contact.
- Progressive Loading – the placement of the implant into incrementally higher occlusal load over time after the initial bone interface has been established.

It is wise to remember the bone to implant contact curve over time for an implant ²⁷(Fig 2.1)

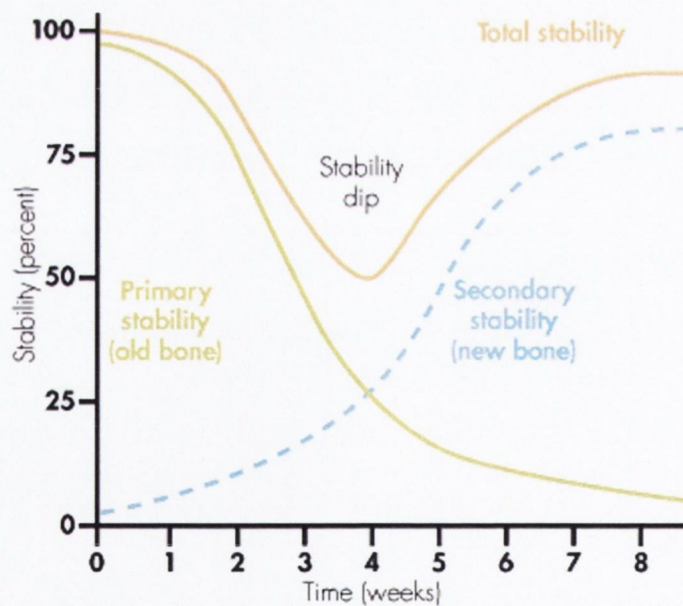


Figure 2.1 implant Stability as a percentage of the final osseointegrated level against time since placement.

It is evident that in order to avoid excessive micromotion²⁸ and possible fibrous encapsulation of the implant, loading should be confined to times of high stability; as such early loading may be less advisable than immediate loading. This has been borne out by research slightly favouring immediate (95%) rather than early loading (93%) as seen by 3 year survival rates of implants²⁶.

2.2.3 Bone augmentation

From the work of Atwood²⁹ and Tallgren³⁰ it has been identified that the alveolar bone resorbs at a predictable rate after tooth extraction. The associated ridge defects can limit the availability of bone for primary stabilisation of dental implants. With advances in grafting materials and protocols many of these limitations can be overcome. Implants placed in association with internal and external sinus lifts and particulate allografts show a 95% success rate at 3 years^{31,32}. Distractions osseogenesis, block grafting, alveolar nerve repositioning, localised grafting, soft tissue grafting, ridge splitting, short implants and wide implants have been added to the implant surgeons armamentarium to give more predictable results in less than ideal anatomic presenting circumstances.

2.2.4 Less traumatic Surgery

As dental implants became more commonplace, the focus shifted from thoughts of pure surgical sterility and maxillofacial facial surgery skill sets, to a periodontal skill set. Immediate placement at the time of extraction, placement with simultaneous grafting in conjunction with resorbable membranes, and flapless surgery have become more acceptable. With the bone/implant interface now most likely to be formed and maintained over time, the patients experience of the procedure becomes more important.

Immediate placement means that now patients are without teeth or a tooth for a shorter time period and possibly never without some support or retention for a prosthesis. Simultaneous grafting leads to fewer visits until the patient received their prosthesis and flapless surgery lead to less subjective post operative swelling and pain³³, and certainly short term soft tissue advantages³⁴.

2.3 The Restorative Driven Approach

It can be seen that dental implantology has been refined to an extent where not only can successful osseointegration be expected in most cases, but those cases on the fringes of surgical possibility 10 years ago are now routinely undertaken ³⁵. However as discussed above the implantation and osseointegration are only one part of any comprehensive definition of success.

Patients want teeth not implants. As such the focus of good implant surgery has shifted from merely placing the implant in the greatest volume of bone to one where the implant is placed to be in the best position for the definitive restoration ³⁶.

As the indications for implants have expanded the prosthetic challenges have increased exponentially. Not only do patients demand a stable and functional prosthesis but aesthetics, durability and maintainability are mandatory. The Brånemark style "high and dry" prosthesis in the mandible was functional and showed excellent long term results, but the challenges of a single tooth replacement are very different.

Drago ³⁷ in 1994 was the first to publish on the problems of improper implant placement with regards to the final prosthetic outcome. Unfortunately this work was published in the Journal of Oral and Maxillofacial Surgery and received little attention in restorative circles. Drago maintained that "In order to predictably achieve optimal placement, visualisation of the final restoration is necessary prior to beginning treatment".

This notion was refined and popularised by Garber and Belser ^{36,38,39} a year later. The term 'Restorative Driven' treatment planning was coined to identify this process. Garber published an algorithm to predictably place and restore implants in prosthetically ideal position. The final restoration is mocked up on diagnostic casts and transferred to the mouth temporarily. Once judged acceptable the implant is placed using a stent derived from the planning. The ideal position of an implant is not necessarily exactly where the root of the missing tooth was. In the case of a central incisor, the placement of the implant in the same angulation (labially inclined) as the natural root would necessitate an angulated implant component and cement retained

restorations. Figure 2.2⁴⁰ shows an implant placed where a:) the natural root was requiring cement retention, b) labially placed and c) more vertically placed with screw retention. The screw retained prosthesis is usually more favourable as it has fewer components, costs less and has a high degree of retrievability.

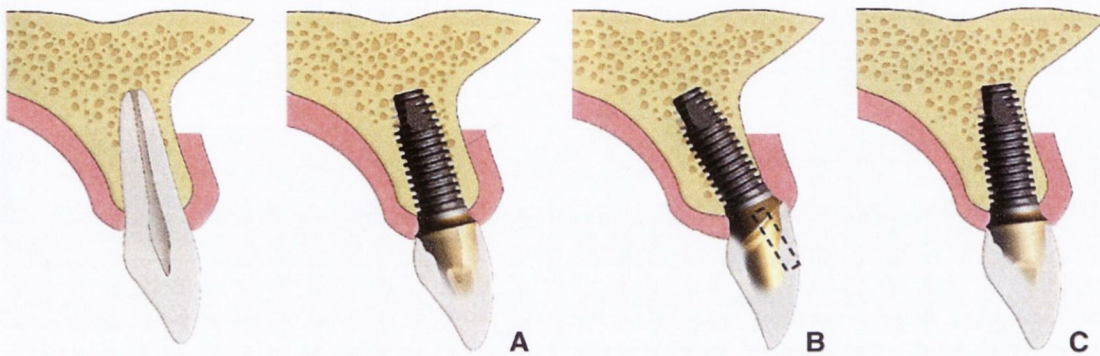


Figure 1.2: Placing an implant exactly where the natural root was (a) often is too labially inclined for retrievable screw retention of the crown. (b) shows a implant too labially and (c) shows an ideally placed implant where the fixture is more vertical than the natural tooth.

Here was a paradigm shift from a surgical emphasis where the final restoration was secondary to the survival of the osseointegrated interface, to a situation where the prosthetic demands of the restoration were the overriding factors in implant placement.

Unfortunately the multidisciplinary resources needed to produce ideal results are not always available, and most clinicians have many cases where implants are placed in sub-optimal positions. Many factors can cause this, some avoidable and some unavoidable:

- Lack of prior planning.
- Local confounding anatomical factors.
- Patient being unwilling to undertake grafting procedure.
- Following natural root anatomy in immediate placement sites.
- Poor appreciation of the effect implant depth has on the restoration by the implant surgeon.
- Surgical error.

- Lack of prosthetic knowledge on the surgeon's part.
- Lack of surgical knowledge on the prosthodontists part.
- Unavailability or unwillingness to use surgical stent.
- Overemphasis on "placing the implants" rather than the final outcome for the patient.

A malpositioned implant is more than a mere inconvenience; it has repercussions for the patient than will effect treatment for the lifetime of the patient or of that implant, whichever is shorter.

2.4 The Problems with Sub-Optimal Placement.

The problems introduced by a poorly placed implant are numerous and they are the difference between successful osseointegration, and a successful restoration.

- Biomechanical.
- Aesthetics.
- Economic.
- Poor utilisation of bone.
- Iatrogenic damage
- Functional

2.4.1 Biomechanical.

- **Cantilever arms-** while a certain amount of cantilever extension is commonly used⁴¹⁻⁴³ excessive cantilevers have been associated with increased prosthesis failures.⁴¹
Cantilevers can not only be created by extending distally. Anterior restorations can have a "bucket handle" cantilever effect if the prosthetic teeth have to be placed anterior to the implants.

- **Non axial loading** – the biomechanics of dental implants are very different from those of teeth and the stress of function are not distributed and dissipated as efficiently as in a natural tooth. Non axial loading not only has a detrimental effect on restorative materials (setting up of damaging tensile forces) but may have a role in bone loss around the implant itself.⁴⁴⁻⁵²
- **AP Spread** – Related to cantilever length, the antro-posterior spread of implants helps to favourably load the implants and support the restoration. Poor AP spread can limit the potential length of a cantilever⁵³, for fixed restoration and choice of the restorative materials.
- **Retention** – differential angulations between implants, and between the implants and the occlusal plane can have a deleterious effect on retentive mechanisms in removable prosthodontics such as ball and socket attachments. Gulizio⁴⁹ showed that angulations exceeding 20 degrees difference had a significant effect on retention for such attachments. Also the adjustment required to abutments for fixed restorations can lead to an unretentive, overly divergent geometry with little retention and resistance form.

2.4.2 Aesthetic.

- Implants placed too far buccally look long in comparison to the adjacent teeth, Fig 2.3.
- Implants placed too far lingually can look short or have unaesthetic and unhygienic ridge laps Fig 2.4.
- Implants placed at excessive depth can have implications for hygiene, cement removal, soft tissue stability and soft tissue height.
- Implants placed superficially can have unnatural emergence profiles, gingival height discrepancies and metal show from the implant. Fig 2.5.

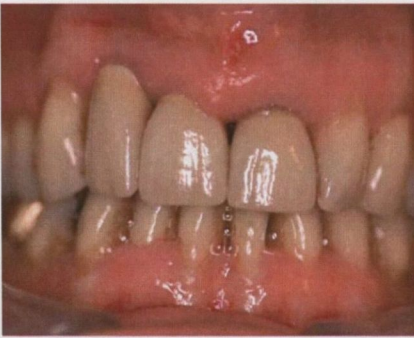


Figure 2.3 Implant 1.2 is buccally placed and appears long.



Figure 2.4 palatally placed implant required excessive cantilever



Figure 2.5. Superficial implants with metal platform of fixture showing.

2.4.3 Economic.

Premachined or standard implant components are less costly to purchase and require less laboratory time (casting, scanning, and adjustment) than custom abutments. Misplaced implants nearly always require the outlay of expense to provide custom abutments, multi-unit angulated abutments, prosthetic screws, and multi-unit prosthesis. Even with these devices the final aesthetic and prosthetic outcome may remain less than ideal. Secondary soft tissue grafting may be necessary to achieve a harmonious soft tissue profile or a stable gingival level. An extra expense is involved in revision surgery such as implant removal, block resection, and the placement of extra implants to support a prosthesis.

These costs may not be apparent at the planning stage, as such often the restorative dentist is faced with higher costs than expected which can either be borne by the clinician, or passed to the patient. This revision of the cost more often than not is unacceptable to the patient and can cause loss of confidence from the patient's viewpoint.

2.4.4 Poor Utilisation of Bone.

The classical surgical approach to implant placement is to raise a mucoperiosteal flap and expose the underlying bone. This direct visualisation if the bone allows the placement of the implants in positions where primary stability is most likely. However while this method has

advantages over a flapless procedure with regard to inspection of the implant site as it can underestimate the volume of bone available.

With some form of presurgical imaging (Computer tomography, linear tomography etc) the volume of bone beyond that superficially visible bone is revealed. This allows implant placement in sites that may on superficial inspection appear to be narrow or anatomically unsuitable, and also gives a quantitative measurement of the implant length that can be placed.

An example of this is placing distally angled implants along the anterior wall of the maxillary sinus. This method engages more of the available bone and increases the AP spread of the implants.

Implants placed without a three dimensional preoperative assessment tend to be placed in the safer areas such as the anterior mandible and be shorter due to surgical caution near anatomical landmarks.

Conventional radiography is helpful, however, magnification factors and the two dimensional representation derived, limit its use as an exact guide.⁵⁴

2.2.5 Iatrogenic Damage.

Probably the most worrying complication for implant placement is encroachment on a delicate anatomical structure. Damage to the inferior alveolar or mental nerves can cause temporary or permanent paresthesia, anaesthesia or chronic pain⁵⁵. Maxillary sinus perforation, nasal floor perforation, incisive canal violation and encroachment on vascular bundles (e.g. lingual artery) are other possible complications however the less serious complications can cause prosthetic and surgical complications also. These can be: devitalisation of adjacent teeth, surgical trauma to previously placed implants, bony dehiscences, and fenestrations.

2.2.6 Functional.

One of the aims of any implant restoration is to provide occlusal surfaces or guiding surfaces for the opposing teeth. While an implant does not behave like a natural tooth the goal of any restoration should be to load the restoration along the implants long axis. Finite element analysis (FEA) studies⁵⁶ have shown that large angular loads can cause local bone stress around the first four threads of an implant and many cite this as a factor in late implant failure. Sub-optimal placement can lead to cases where axial loading of the fixture is impossible and the implications are not only in implant to bone stress but to increased risk of screw loosening, prosthesis fracture and cement failure.⁵⁰

Having an implant in a prosthetically undesirable position has the effect of limiting the retentive mechanism for the restoration. Screw retention may be desirable but not achievable; as such the retrievability of the restoration suffers. In large span prosthesis, screw access holes may emerge through the marginal ridge areas or through the functional cusp. This decreases the amount of area available the development a functional occlusal scheme or places areas of high stress in a plastic restorative material. (Fig 2.6)



Figure 2.6: The screw access emerges through the embrasure space; this may cause phonetic and occlusal problems.

Phonetic problems are seen with many types of restorations albeit thankfully temporarily. However the most likely causes with implant restorations can be avoided with correct implant placement avoiding over contoured palatal surfaces of connectors with anterior teeth and long teeth with open embrasures that can cause air escape.⁵⁷

Oral hygiene access is often compromised by bulky restorations without proper emergence profiles or with poorly cleansable pontic or ridge lap portions. Poorly placed implants can lead to problems of cement removal after definitive luting of the restoration with is known to have deleterious effects on gingival tissues.⁵⁸

2.5 Restorative Driven Treatment Planning – Methods

The problems associated with poorly planned and placed dental implants are many. As such every effort should be made to idealise each patient's treatment. The placement of an implant is a once off procedure with little scope for future revision. Planning should always start by visualising the final result.

Firstly the patient should be assessed for each implant. Ideally this is carried out with the aid of a multidisciplinary team. The implant site is examined for height and width of bone and soft tissue. The position of the proposed prosthesis is found with regard to the patients intra and inter arch static and dynamic factors of occlusion. Diagnostic records are needed such as study casts, radiographs both panoramic and periapical. Bone sounding can be used to detect any difference between the soft tissue volume and the underlying bone. The need for pre surgical grafting or concurrent placement and grafting can be estimated using these records.³⁹

Next the restorative dentist can create a facsimile of the final tooth. Many methods exist such as diagnostic wax ups, trial dentures, Kesling setups, model surgeries or computer planning.

However this is done, the position and form of the final prosthesis should be evaluated and approved from an aesthetic and functional viewpoint. The use of tooth coloured material placed in the mouth with an impression or pull down of the wax-up is useful. It allows the patient to approve the waxup and allows the dentist to more clearly identify the problems, angulations and soft tissue concerns of the final prosthesis.

This information must then be accurately transferred to the implant surgery. Techniques are available to suit the many types of clinical cases which may present. In general terms the surgery can be strictly guided by the stent, or the stent can act as a less directive surgical guide.

- Unguided Implant Surgery: Here the pre planning data is used to create a template that is used intermittently during surgery. The surgeon can choose to place the implant in a number of positions within the broad scope of the stent. Here a compromise is reached between the availability of bone and the prosthetic tooth position.
 - Copy Denture: clear copy dentures can be drilled to allow access for surgical drills and still allow the surgeon to visualise the prosthetic teeth (Fig 2.7.)
 - Simple Acrylic Stent: The diagnostic waxup is used to create a removable stent supported on the teeth adjacent to the surgical site. Holes or slots are placed in the stent to allow surgical access (Fig 2.8.)
 - Pulldown: A simple vacuum formed pulldown can act as a guide. (Fig 2.9.)

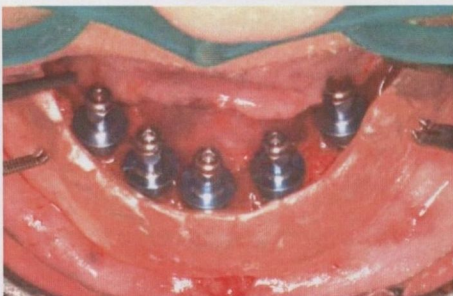


Fig 2.7. Copy Denture as Stent, labial surface of stent transfers position of the final teeth.

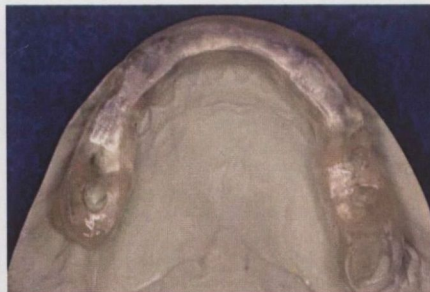


Fig 2.8. Custom Acrylic Stent, with restrictive drilling holes.



Fig 2.9. Vacuum Pulldown Stent from a diagnostic waxup.

more :
 e prosthetically ideal position for implant placement) than free hand implant placement, many factors limit their usefulness. Choi in 2004⁵⁹ put forward the following disadvantage of the simple surgical stent:

- Excessive freedom of angulations, depth and location. Most stents allow a degree of freedom that may be too great. Angulation problems may not be evident and certainly these stents give no concept of the depth at which each implant should be placed.
- Stents are often constructed without any knowledge of the anatomical limitations. The diagnostic waxup, while invaluable, is based on a cast of the dental arch that may bear no relation to the quantity of the underlying bone. As such the restorative dentist may suggest unsuitable locations for implant placement.
- Difficult to use during surgery. Stents which are quite restrictive limit the surgeon's view of the implant site, the location of the flaps and the presence of blood may deter the surgeon from using them effectively.
- Many decisions have to be made during "stressful" surgical time. The three dimensional position of the implant has to be decided along with patient management, complex instrumentation, anaesthesia and time management pressures.

2.6 Guided Surgery

The problems and inadequacies associated with conventional stents have led to the development of guided surgical systems. Here 3D planning data is used to place the implants precisely. The surgeon has little scope to change the position of the implants from the pre-surgical data. The guide system is used continuously during surgery.

- Computer Bur Tracking. Here sensors on the bur and patient relate the position of the drill head to a CT scan of the patient in real time on a computer monitor. The pre-planned implants on the computer are shown and the bur positioned until it coincides with this planned position. (Fig 2.10.)⁶⁰

- Stereolithographic Surgical Guides derived from CT computer planning data are constructed with restrictive implant placement guides. (CT based NobelGuide, Simplant guide) (Fig 2.11.)⁶¹
- Acrylic Stent with Restrictive implant placement guides derived from bone sounding data. (Model Based NobelGuide) (Fig 2.12.)⁶²

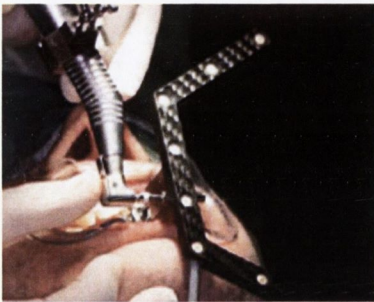


Fig 2.10 Computer Bur Tracking



Fig 2.11. NobelGuide™



Fig 2.12 Model Based NobelGuide™

Certainly the use of data regarding the bone volume (CT scan, bone sounding etc.) to plan and place the implants is in line with Garber's³⁶ ideas on the "restoratively driven" approach. And such guided stents and computer navigated systems overcome many of the disadvantages of the unguided stent. However they are not without their disadvantages. The question of accuracy of each method is often raised, a problem which surgeons may find most important because it is removing their ability to make decisions during surgery. As such the uptake of such systems are reliant on the accuracy of the planning data and the surgeon's confidence in each system.

The data that commonly can be used for guided surgery are Computer Tomography and Bone sounding. Any discussion on accuracy must first start with a discussion of the suitability of these data to guide implant placement. Many systems also advocate a flapless approach to placement and this too will be discussed.

2.6.1 Computer Tomography.

Computed tomography (CT) is a medical imaging method employing tomography. Digital geometry processing is used to generate a three-dimensional image of the inside of an object from a large series of two-dimensional X-ray images taken around a single axis of rotation. The word "tomography" is derived from the Greek words tomos (slice) and graphein (to write).

Computed tomography was originally known as the "EMI scan" as it was developed at a research branch of EMI, a company best known for its music and recording business. It was later known as computed axial tomography (CAT or CT scan) and body section roentgenography⁶³.

CT produces a volume of data which can be manipulated, through a process known as windowing, in order to demonstrate various structures based on their ability to block the X-ray beam. Although historically the images generated were in the axial or transverse plane (orthogonal to the long axis of the body), modern scanners allow this volume of data to be reformatted in various planes or even as volumetric (3D) representations of structures.⁶³

Types of CT scan include: Dynamic volume CT, Axial, Cine, Helical/spiral, Electron beam CT, Helical or spiral CT, Multislice CT, Dual-source CT, Inverse geometry CT, Peripheral Quantitative Computed Tomography (pQCT). Regardless of the type, modern dental CT scans produce computer files that can be printed on x-ray film but more usefully, can be manipulated in a personal computer to produce a three dimensional representation of the area of interest. (Fig 2.13.)

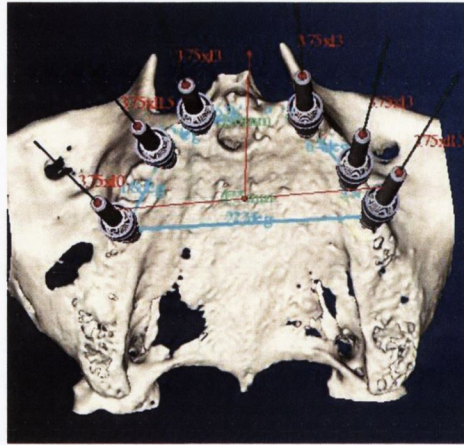


Figure 2.13: CT scan of a patient maxilla manipulated in the NobelGuide™ software.

Several Systems exist which allow the importing of CT data (Digital Imaging and Communications in Medicine or DICOM files.) and the virtual placement of dental implants. However questions may be asked as to how accurately the CT scan represents the true topography of the patient's bone? ⁶⁴

In general, the quality of CT data depends on the slice thickness and the influence of possible artefacts. The thinner the slice thickness and the smaller the voxel size, the higher the resolution and accuracy of measurements of delineated structures.³⁵ Movement and metallic dental restorations may lead to geometric distortions and invalid data acquisition.

Reddy and associates⁶⁴, using glass sphere reference markers placed in the mandibular plane, found the mean accuracy of vertical and horizontal measurements on 2D reformatted CT views (slice thickness 1.5 mm, fixed slice spacing 1.0 mm, and 0.5 mm overlap of each slice) varied from 0.07 to 0.15 mm. The results were significantly better than those observed on even the best-positioned panoramic radiographs, where accuracy ranged from 0.15 to 0.24 mm following 25% magnification correction. The difference was strikingly higher for panoramic radiographs when patient positioning during exposure was not optimal, which indicates that the standard

practice of assuming a consistent 25% magnification for dental panoramic radiography may need reconsideration.

2.6.2 Radiation Dose.

One problem levelled at all systems that use CT radiography is the exposure to ionising radiation. In comparison to other forms of dental radiography, the CT scan delivers a high dose.

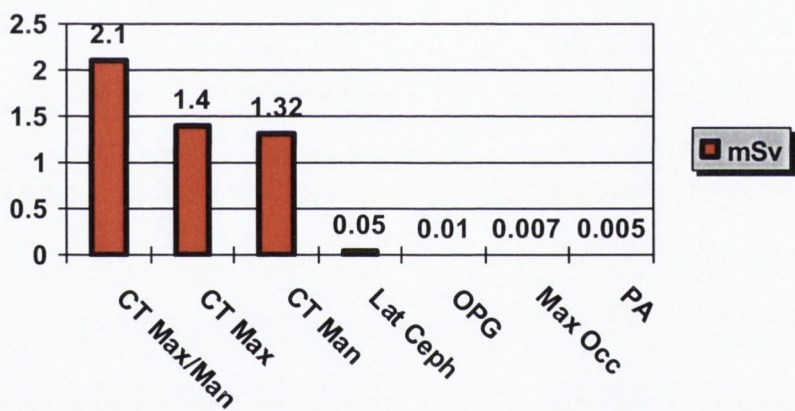


Table 3.3: Relative radiation dose of standard dental exposures in millisieverts.

While the stochastic effects of such a dose are insignificant, the non stochastic effects of radiation should never be forgotten. Ngan⁶⁵ published the data in Table 2.3 which clearly shows that a CT scan is an order of magnitude greater than other dental exposures. As such the benefit of a CT scan must offset the considerable biological burden.

2.6.3 Bone Mapping.

Bone mapping or bone sounding is a method where, under local anaesthetic, a probe is used to measure the thickness of the soft tissue overlying the bone. By then subtracting this thickness from a stone cast of the same area (Fig 2.14-2.16) ⁶⁶, the clinician can assess the most suitable areas for implant placement (with regard to the final restorative outcome). This method does not expose the patient to any extra radiation or require expensive equipment or personnel.



Fig 2.14 – Mapping Guide with Guide Holes

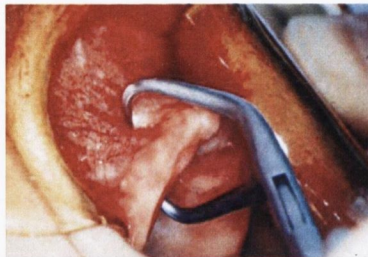


Fig 2.15 – Mapping Intraorally with a callipers

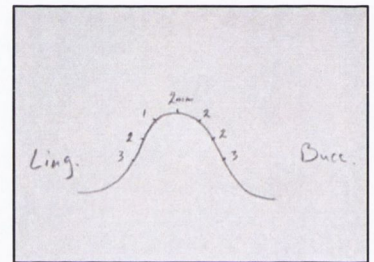


Fig 2.16 – Mapping chart for transfer to stone cast.

Little research exists as to the relative use/accuracy of this method and any research available is conflicting. ten Bruggenkate ⁶⁷ in 1994 presented a research paper on a ridge mapping technique using a specially designed calliper, that suggest that the technique is reliable and easily performed. Advocates of the technique are also Wilson ⁶⁸ and Traxler ⁶⁹ who showed that this technique compares favourably to ultrasound measurements however both methods were judged to be somewhat inaccurate.

Perez in 2005 ⁷⁰ compared the accuracy of linear tomography and direct ridge mapping for determining alveolar ridge dimensions. One site in the posterior mandible was selected for evaluation in each of five cadaver heads. Vacuum-formed stents made from models of the

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cadaver ridges were used to identify three sets of measurement points for each specimen: coronal, middle, and apical. An imaging stent that contained 2-mm metal balls at each point was also constructed, while the ridge mapping stent had holes drilled at corresponding locations. Linear tomograms and periapical radiographs were taken of the selected sites. Ridge mapping measurements were made with callipers. Five blinded examiners measured the ridge width at the designated measurement points with both lateral tomographs and ridge mapping as well as distance from the ridge crest to mandibular canal. Mandibles were then sectioned and an independent examiner made direct measurements. MANOVA was used to determine whether lateral tomography and ridge mapping differed significantly from the direct measurements.

There were no significant differences between lateral tomographs and ridge mapping for ridge width measurements. However, both techniques underestimated ridge dimensions compared to direct measurement ($p < .05$). Measurement of mandibular canal height was accurate when determined by periapical radiographs but not by lateral tomography. It was concluded that neither lateral tomography nor ridge mapping proved to be completely accurate in determining ridge width in the posterior mandible.

Allen in 2000⁶⁶, used ridge-mapping to assess bone levels available for implant placement in the anterior maxilla. A modified surgical stent was designed to locate the ridge-mapping calliper at the same points on the jaw before and after flap reflection. Eleven subjects were included in the study. Measurements ($n = 100$) were made at 25 implant sites, 50 "pre-operative" (before surgery) and 50 "intra-operative" (during surgery) at 3 mm and 6 mm distances from the crest of the ridge. There were statistically significant differences between pre- and intra-operative measurements. Based on pre-operative measurements, clinical judgements were made as to whether supplementary procedures such as guided bone regeneration would be required. Unanticipated supplementary procedures were required at 10 sites. The findings indicate that ridge-mapping alone may not be sufficient to accurately predict the bone available for implant placement in the anterior maxilla. It is suggested that ridge-mapping may provide reliable information about bone levels when the labial aspect of the anterior ridge is not markedly concave.

Rocci in 2003⁷¹ presented a 3 year clinical study to evaluate an immediate-loading treatment protocol, which included flapless surgery, implants placed in predetermined positions and connected to prefabricated provisional restorations. A total of 97 Brånemark System Mk IV implants with a machined surface were inserted in the maxillas of 46 patients. A presurgical three-dimensional model of the patients' soft tissue and underlying alveolar bone anatomy was created using bone mapping, which allowed the clinician to place the implants in predetermined positions and connect them to prefabricated provisional restorations. This resulted in a cumulative survival rate of 91% after 3 years of prosthetic load. The study confirmed the use of bone mapping as a presurgical guide prior to implant surgery. However it must be noted that the success rates are lower compared to other immediate loading studies. The study made no reference of the quantitative accuracy of the method and implied correct fitting of the prefabricated provisional restorations as being sufficient to imply accuracy.

In conclusion ridge mapping or bone sounding seems to be, at best adequate for the task of implant planning.

2.6.4 Flapless Surgery.

While the surgeon may like to raise large mucoperiosteal flaps to inspect and access the implant site, the biological consequences may favour a flapless technique where the implant site is prepared and the implant placed using a "key-hole" access in the mucosa.

The advantages of Flapless surgery are⁷²:

- Reduced surgical time. Less time required to rise and suture back flaps.
- Reduced subjective postoperative morbidity: With respect to pain and swelling⁷³.
- Less need to adjust interim prostheses. The lack of swelling, presence of sutures and disturbance to the external morphology of the mucosa mean that provisional dentures or pontics may require less adjustment.

- “Key-hole” surgery: Greater patient acceptance.
- Less bleeding in operative field.

The disadvantages are:

- Inability to inspect the implant site directly.
- Reliance on accurate pre-surgical assessment of bone volume, location and quantity.
- Extensive grafting at time of placement impossible.
- Inability to inspect the implant along its length for fenestrations or dehiscences.

Many studies have presented favourable results of longitudinal clinical trials showing success rates for flapless surgery comparable to open flap procedures.^{33,74-76}

2.7 Computer Bur Tracking

Computer bur tracking is a method of utilising the CT data during implant surgery. The CT data are registered along with a marker system placed in the patient’s bone (temporarily) or on a removable intraoral base. The implants are planned in virtual reality prior to surgery.

During surgery, a computer system using optical sensors locates the markers and the surgical headpiece and relates them to the CT data. Hence during surgery the operator can view on a computer screen the CT data with the planned implant sites and the current position of the surgical bur in real time.

Systems such as this have been used with much success in orthopaedics for spinal surgery.^{77,78} For dental implants a higher level of precision is required due to the fact that the surgical area is smaller and the bone volumes and quality reduced, however there are four factors effecting the precision of the method.

1. CT data acquisition, as discussed previously errors in the order of 0.1mm in magnitude are known to exist ⁶⁴.
2. Fiducial Marker Registration. Errors in matching the markers from the CT scan to the surgical optical system exist ⁷⁷. If the markers are on the patients skin these are greater than if they are placed in the bone or on a removable intraoral device ⁷⁹. Errors with bone based or device based markers have a mean of 0.68-0.69 mm.^{35,80}
3. Human Error. Computer bur tracking allows the surgeon a large degree of freedom as no restrictive physical devices are present to guide the drills. Hand tremors and perceptual errors on the operator's part are in the range of 0.25-0.50 mm⁸¹. However when compared to freehand drilling the navigated system reduces the human error from 6mm to 0.5 mm, independent on the surgeons experience level.
4. Accuracy of the Bur tracking System. Table 2.4 is from Widmann and Bale's meta-analysis of guided surgery studies. Only the data from bur tracking systems are given. The range of accuracy values go from a best case of 0.2 mm to a worst case of 2 mm. Angular errors range from 0.4 to 17.8 degrees.

Literature Review

	n	Accuracy	Range	Maximum	Evaluation	In vitro/ in vivo	Technique
Schneider et al ⁶¹	100	[x,y]: 0.68 ± 0.63 mm			Image fusion	In vitro	Bur tracking
Brief et al ⁶⁵	38	Base [x]: 0.5 mm [y]: 0.3 mm Tip [x]: 0.6 mm [y]: 0.3 mm [z]: 0.2 mm		1.1 mm 0.9 mm 1.1 mm 1.0 mm 0.7 mm	Image fusion	In vitro	Bur tracking
Schermeier et al ⁶⁶	24	Base [x,y]: 0.08 ± 0.41 mm 0.98 ± 1.44 degrees			Digital slide gauge	In vitro	Bur tracking
Wanschitz et al ⁶⁷	20	Base [lingual]: 0.49 ± 0.38 mm [buccal]: 0.55 ± 0.31 mm Tip [lingual]: 1.36 ± 0.70 mm [buccal]: 1.44 ± 0.79 mm	0.0–1.4 mm 0.1–1.5 mm 0.0–3.2 mm 0.2–3.5 mm		Image fusion	In vitro	Bur tracking
Wanschitz et al ⁶⁸	15	Base [lingual]: 0.57 ± 0.49 mm [buccal]: 0.58 ± 0.40 mm Tip [lingual]: 0.77 ± 0.63 mm [buccal]: 0.79 ± 0.71 mm 3.55 ± 2.07 degrees	0.0–1.8 mm 0.0–1.4 mm 0.0–2.9 mm 0.1–3.1 mm 0.9–10.4 degrees		Image fusion	In vitro	Bur tracking
Wagner et al ⁶⁹	32	Base [lingual]: 1.0 ± 0.7 mm [buccal]: 0.8 ± 0.5 mm Tip [lingual]: 1.3 ± 0.9 mm [buccal]: 1.1 ± 0.9 mm 6.4 ± 3.6 degrees	0.0–2.6 mm 0.0–2.1 mm 0.0–3.5 mm 0.0–3.4 mm 0.4–17.4 degrees		Image fusion	In vivo	Bur tracking

Table 2.4: Accuracy data for bur tracking systems.

Disadvantages of Bur Tracking Systems:

- Need for general anaesthesia. Patient movement during surgery and the lag time between bur movement and its representation on the computer screen means an unconscious patient is necessary.
- Expensive equipment is required.
- Accuracy levels are not currently sufficient for dental implant placement on a routine bases. Maxillofacial patients with complex anatomy may benefit, but for the routine case, the cost benefit ratio is not sufficient³⁵. Ewers and associates⁸² stated that “the application of this technology offers essential improvement in outcome and intraoperative safety” with a considerable technical expenditure.

- Inability to prefabricate prostheses or provisional restorations.

Advantages of bur tracking are:

- Interactive, the surgeons is free to make judgements during surgery. Bur position is constantly updated on the computer screen and allows the treatment plan to change with the prevailing surgical situation.
- Automatic and complete electronic documentation of the intervention. The position of the handpiece are recorded and can be replayed within the computer software.
- Useful teaching tool for implant surgeons.
- Makes good use of the CT scan during surgery. In cases such as post cancer resections where the usual anatomical landmarks are absent, the bur tracking system allow the surgeon to regain orientation.

In conclusion bur tracking is an emerging technology however at present its error levels are deemed inadequate for dental implant placement⁸³. Its use in all but the most complex cases is not yet justifiable. The errors are not wholly attributable to the computer system; the human error element is a major component of the inaccuracies.

2.7.1 Assessing Accuracy

Many of these studies use multiple pre and post intervention CT's to overlay the position of the implants and measure linear and angular deviations from planned to post surgical locations of the implants. The measurement of an implants position has a number of spacial dimensions. The position of the head of the implant in an X,Y and Z coordinate space along with the angular measurement of the implants trajectory. Each coordinate will affect the others in a complex manner. The method most described is the entry and exit method, where the position of the

head and apex of the implant are compared pre and post surgery. An angular measurement can be made between these two points to give a trajectory. This simplifies the measurement but does not give the opportunity to discriminate if one axis is more deviant than another.

An interesting method was put forward by Kim in 2006⁸⁴. His paper entitled “Displacement of implant components from impressions to definitive casts” was not looking at this specific problem but that of accuracy of implant impressions using a computerised coordinate measuring machine,

A coordinate measuring machine is a metrology instrument that is used to move a measuring probe to obtain the coordinates of points on an object surface. These machines use an X-Y-Z grid to determine its position on a worktable. The probe is used to touch different spots on the part being measured. The machine then uses the X,Y,Z coordinates of each of these points to determine the size and position of the object

Kim recorded the coordinates of the implant head and its angulation. This method offers advantages as each dimension of the implants position could be examined individually.

2.8 Guided Stents Derived from CT Data

Guided stents are currently the most widely used guided implant placement method. The CT data are used to create a three dimensional computer model. Implants are placed virtually and a surgical guide manufactured. There are several systems that use a variety of guide manufacturing methods. Some guides are bone borne and some soft tissue borne. Simplant^{85,86} for example generates bone borne stents for open flap procedures, mucosa borne guides and tooth borne guides for guided implant placement. Stereolithography is a common method for stent production. The most complete system to date which allows planning, stent fabrication, provisional or definitive prosthesis manufacture and controlled drilling, is the NobelGuideTM from NobelBiocare.⁶¹

2.8.1 Stereolithography.

The term "stereolithography" was coined in 1986 by Charles W. Hull. Stereolithography was defined as a method and apparatus for making solid objects by successively "printing" thin layers of an ultraviolet curable material one on top of the other. Hull described a concentrated beam of ultraviolet light focused onto the surface of a vat filled with liquid photopolymer. The light beam draws the object onto the surface of the liquid layer by layer, causing polymerization or cross linking to give a solid object. Because of the complexity of the process, it must be computer-controlled. Figure 2.17 gives a representation of the stereolithographic apparatus (SLA).

After a pattern has been traced, the SLA's elevator platform descends by a single layer thickness, typically 0.05 mm to 0.15 mm (0.002" to 0.006"). Then, a resin-filled blade sweeps across the part cross section, re-coating it with fresh material. On this new liquid surface the subsequent layer pattern is traced, adhering to the previous layer. A complete 3-D part is formed by this process. After building, parts are cleaned of excess resin by immersion in a chemical bath and then cured in a UV oven.⁸⁷

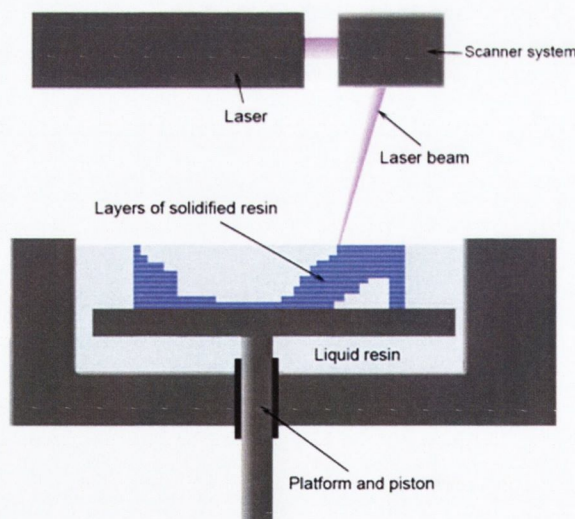


Figure 2.17. Stereolithographic apparatus.

2.8.2 CT Based NobelGuide™

This system uses CT computer planning data to create a stereolithographic guide. The novel concept here is the drilling guides placed in the stent. Stainless steel cylinders are positioned in the stent. These cylinders in conjunction with a number of drilling wrenches are used to precisely drill the osteotomy sites and place the implants. While other systems have holes placed in the stent this system purports to precisely control the position of the implants to a precision level where the fabrication of the prosthesis prior to surgery is possible. (Fig 2.18.1-2.18.2).⁸³

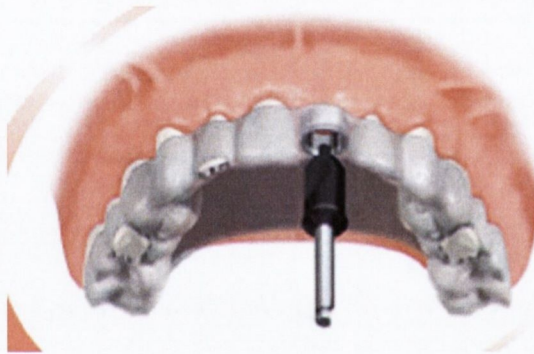


Figure 2.18.1 Stent Incorporates metal drilling sleeve to guide the matched drills into position.

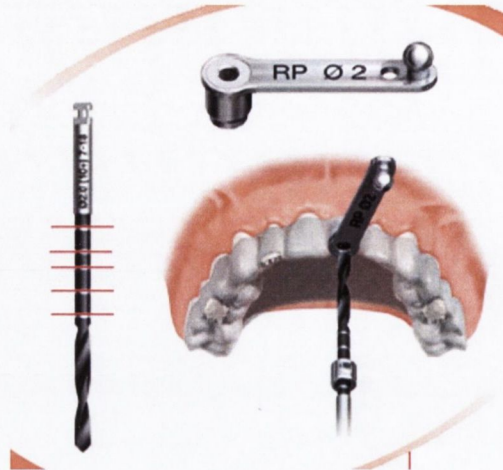


Figure 2.18.2 Matched keys are used to constrain the angulations and position of each successive drill until final implant placement. The precise fit of the drills to the sleeve give greater accuracy than other systems.

This system was developed by van Steenberghe and co-workers. Several studies have measured the accuracy of the method and found it satisfactory for implant placement in conjunction with flapless surgery and immediate or definitive restoration.

Besimo in 2000⁸⁸ evaluated *in vitro* the magnitude of error in transferring the planned position of implants from reformatted CT scans to that of a standard surgical template. The deviation between the position of the apex of the proposed implant in paraxial CT reformats and on the corresponding study cast was measured in 77 prospective sites in five maxillas and nine mandibles. The transfer error was 0.6 mm in the maxilla and 0.3 mm in the mandible. This study showed that transfer of the position from planning to the stent was within acceptable limits. However the surgical placement of the implants using the experimental stent was not carried *in vivo* out and the authors noted this may be of more relevance.

Naitoh in 2000⁸⁹, carried out a study to evaluate the placement accuracy using a surgical template using drilling guides similar to the NobelGuideTM system. Twenty-one implants were evaluated in 6 patients. All implants were implanted using a two step surgery in the posterior mandible. A surgical template based on the CT images and the abutment replica on the working models was used for the evaluation of the accuracy of implant placement. The difference between the proposed and actual directions was measured by a milling machine. The

differences in the angles between the proposed direction and actual direction were from 0.5 degrees to 14.5 degrees. The average was 5.0 degrees, and there were 12 implants within 5.0 degrees. This study showed that a drilling guide can increase accuracy over freehand drilling.

Sarment in 2003⁹⁰ compared the accuracy of a conventional surgical guide to that of an experimental stereolithographic surgical guide. CT scanning of epoxy edentulous mandibles was performed using a cone beam CT scanner, while planning for 5 implants on each side of the jaw was performed using the SimplantTM software package. Five surgeons performed osteotomies on a jaw identical to the initial model; on the right side a conventional surgical guide (with guide holes) (control side) was used, and on the left side a stereolithographic guide was used (several guides with incrementally larger guide holes for each drill) (test side). Each jaw was then CT scanned, and a registration method was applied to match it to the initial planning. Measurements included distances between planned implants and actual osteotomies. The average distance between the planned implant and the actual osteotomy was 1.5 mm at the entrance and 2.1 mm at the apex when the control guide was used. The same measurements were significantly reduced to 0.9 mm and 1.0 mm when the test guide was used. Variations were also reduced with the test guide for both intra and inter- surgeon results.

A preliminary study was carried out using the NobelGuideTM system in 2002 by van Steenberghe⁸³ using zygomatic implants in a human cadaver model. Six 45 mm long implants were placed in three cadavers using a preproduction NobelGuideTM. CT scans before and after surgery were used to assess accuracy. The long implants used were to magnify any errors that arise. Measurements of the entry in the maxilla and exit from the zygoma (angular and linear deviations) were made using image fusion software.

The results of van Steenberghe's study were promising (Table 2. 5.) with angular deviations of less than 3 degrees, which compared favourably with the other available literature outlined above.

Literature Review

In a follow-up clinical study with the NobelGuide™ system, using conventional implants (not zygomatic)⁶¹, both cadaver specimens (n=2) and *in vivo* test (n=8) were carried out. The cadaver tests were rescanned after placement of the implants and image fusion software used to obtain

Table 2.5 Deviation in the caudocranial, frontal and sagittal directions between actual and planned implant positions determined at the entry point of the implants to the maxilla and the exit point from the zygoma.

	Deviation (mm)											
	Cadaver 1				Cadaver 2				Cadaver 3			
	At entry to maxilla		At exit from zygoma		At entry to maxilla		At exit from zygoma		At entry to maxilla		At exit from zygoma	
	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
Caudocranial	-3.86	0.28	-6.74	0.21	0.26	1.80	-0.72	1.80	1.67	1.06	1.05	0.95
Frontal plane	-4.62	1.33	-1.65	0.94	-0.46	-0.83	0.24	-0.83	0.33	0.29	0.93	0.12
Sagittal plane	-0.22	-0.10	-3.76	-2.16	0.48	0.74	-0.15	0.74	-0.11	-0.08	-0.77	-2.51

Positive values indicate a deviation of the planned implant position in the indicated directions (caudocranial, frontal or sagittal). Negative values indicate a movement in the reverse direction.

accuracy data. The trial in the 2 cadaver specimens indicated that the drilling template achieved an accurate fit to the underlying bone. The drills and especially the slow turning taps and implants were most accurately guided as a result of their intimate fit with the inserted sleeves. At the level of implant entry in the maxilla, the match was on average within 0.8 mm (SD 0.3), and at the target level the match was on average within 0.9 mm (SD 0.3). The differences in distance between planned and achieved entry and target locations were most prominent in the longitudinal direction of the implants (maximum 1.1 mm). Finally, the match between planned and actual implant axis was on average within 1.8 degrees (SD 1.0). The *in vivo* trials all showed successful prosthesis connection at the time of each surgery.

Due to this longitudinal error the system evolved to contain an expandable abutment to allow extension or compression of the abutment to make up the difference in depth during prosthesis connection. Indeed it is intuitive that depth is the most variable as the guide contains the trajectory of the drills and implants in all but this dimension.

Widmann and Bale³⁵ give a table of accuracy studies on CT generated stents (not all NobelGuideTM) shown in table 2.6. **By combining the data on acceptable accuracy level for guided surgery from these studies can be seen a, linear deviations of less than 0.8mm, and angular deviations less than 3.8 degrees.** (Degrees of freedom are unknown. As such the cumulative standard error is not calculable).

	n	Accuracy	Range	Maximum	Evaluation	In vitro/ in vivo	Technique
Besimo et al ¹⁹	26	Tip [maxilla]: 0.6 ± 0.4 mm	0.0–1.5 mm		Postoperative CT	In vitro	IGTP
	51	Tip [mandible]: 0.3 ± 0.4 mm	0.0–1.4 mm				
Naitoh et al ⁷⁰	21	Base: 0.3 ± 0.6 mm 5.0 ± 3.5 degrees	0.0–2.0 mm		Milling machine	In vivo	IGTP
van Steenberghe et al ³⁷		Base: 0.8 ± 0.3 mm Tip: 1.0 ± 0.6 mm 1.8 ± 1.0 degrees		1.1 mm	Image fusion	In vitro/ in vivo	IGTP CAD/ CAM
Sarment et al ³⁹	25	Base: 0.9 ± 0.5 mm Tip: 1.0 ± 0.6 mm 4.5 ± 2.0 degrees	0.7–1.2 mm 0.7–1.6 mm		Image fusion	In vitro	IGTP CAD/ CAM
Chen et al ⁷¹	30	Base: 0.75 ± 0.15 mm Tip: 1.36 ± 0.28 mm			Image fusion	In vivo	IGTP CAD/ CAM

IGTP = image-guided template production.

IGTP CAD/CAM denotes sterolithographic surgical templates.

Table 2.6 Accuracy of image guided template production (IGTP)

With its *in vitro* accuracy proven, clinical studies on the success of the NobelGuideTM system have been published which reinforce the accuracy and predictability of the system^{35,61,91-93}. The levels of accuracy, relative simplicity of the system and its prosthetic flexibility have seen this modality being used more than other complex bur tracking methods or less precise types of CT-based stents. At present however the NobelGuideTM system limits the surgeons choice of implants to the range from Nobel BiocareTM.

2.9 Model Based NobelGuideTM (MBNG)

The Model Based NobelGuideTM (MBNG) is in many way very similar to the CT based NobelGuideTM differing only in the manufacture of the surgical stent without the use of CT data.

The idea was to bring the components, accuracy, and advantages of the CTBNG to less complex cases with fewer implants placed, where the expense and radiation dose of a CT would not be justifiable. Without the CT data, the MBNG used bone mapping to plan the preoperative placement. A stone cast of the edentulous area is prepared to conform to the bone mapping data. An implant analogue is placed in the area required and a cold cured acrylic stent with integrated NobelGuide™ sleeves constructed. Figs 2.19.1-2.19.23 show pictorial representations of the steps in producing this stent. From here the system acts in the same way as the CTBNG. The drilling protocol and placement technique are identical.

The system is not designed for direct connection of the final restoration. However provisional restorations can be made prior to surgery on the planning model.

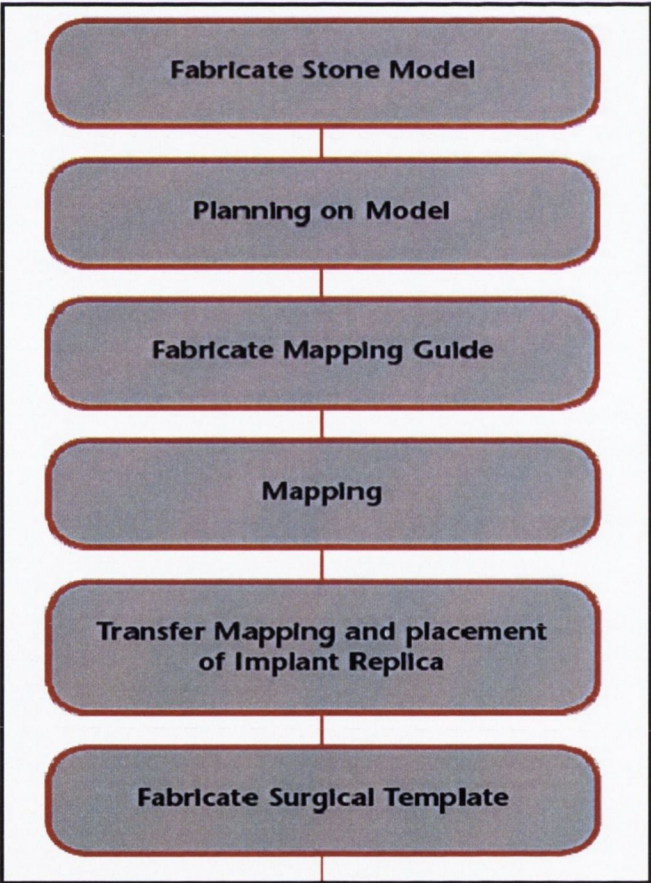


Fig 2.19.1
Manufacturer’s algorithm for stent production via the Model Based NobelGuide

Literature Review



Figure 2.19.2. Edentulous ridge clinical examination,

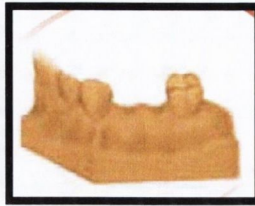


Figure 2.19.3. Stone Cast generated,

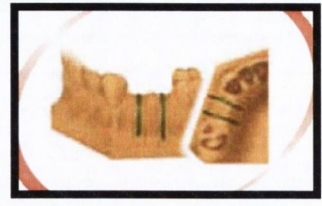


Figure 2.19.4. Proposed implant position marked,

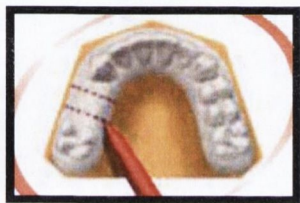


Figure 2.19.5. Vacuum pulldown made and implant position marked,



Figure 2.19.6 Bone mapping holes placed in mapping stent

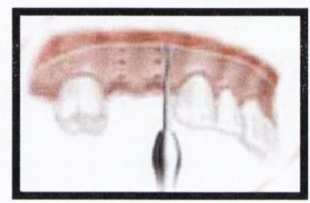


Figure 2.19.7. Mapping stent placed orally. Haemorrhage induced at mapping points with probe



Figure 2.19.8. Mapping points without stent in place

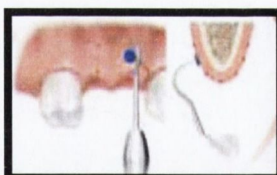


Figure 2.19.9. Bone sounding with a sharp explorer until bone is felt.

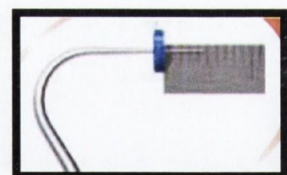


Figure 2.19.10. Depth of soft tissue measured in millimetres

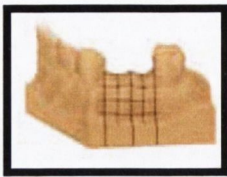


Figure 2.19.11. Cast made into removable sections to correspond to implant.

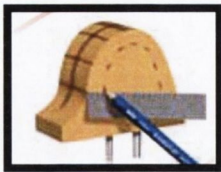


Figure 2.19.12. Mapping points transferred to each implant section.



Figure 2.19.13. Stone removed with bur to conform to bone morphology.



Figure 2.19.14. Implant analogue glued into proposed position

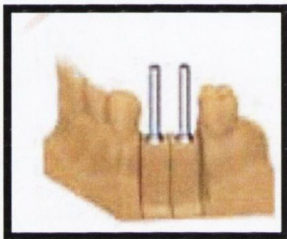


Figure 2.19.15. Removable sections replaced in solid cast.



Figure 2.19.16. Solid cast with planned implant position



Figure 2.19.17. Gingival Silicone placed in mapping guide and seated on planning cast.

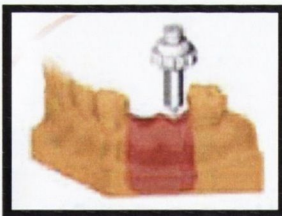


Figure 2.19.18. Soft tissue punch used to expose implant analogues.

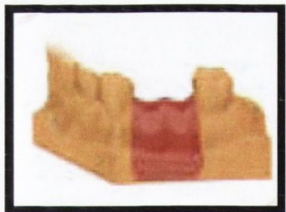


Figure 2.19.19. Finished planning cast.

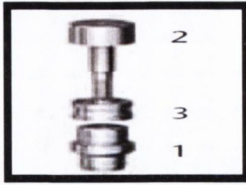


Figure 2.19.20. Guided surgical sleeve assembly.

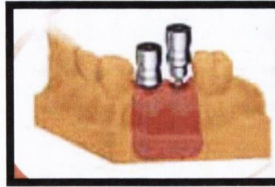


Figure 2.19.21. Guided sleeves placed on planning cast.

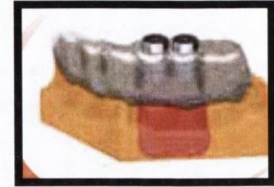


Figure 2.19.22. Clear selfcure resin cured against model



Figure 2.19.23. Finished stent.
Cusp tip of teeth cut out.

The proposed advantages of the system are according to the manufacturers literature:

- High level of accuracy and predictability in implant position.
- Allows restorative based approach to be strictly applied. Maximum control for the restorative dentist.
- May be used flaplessly.
- No requirement for a CT scan.
- Allows fabrication of a provisional prosthesis prior to surgery.

- Applicable to single tooth or short edentulous span cases.

Some disadvantages may be:

- Unknown levels of accuracy, the stent is constructed differently from the CT based NobelGuide TM and the planning data used at the systems core is of questionable accuracy. Only one published paper at the time of writing used this system in a clinical situation. To imply that this system shares the same accuracy as the CT based system would be without basis.
- Limits the implant type to those from Nobel Biocare[®].
- In free end saddle situations where the stent is not supported by teeth at either end of the edentulous span, the stent may move during surgery. No mention is given in the manufacturer's instructions or in the data regarding the systems suitability for free-end saddle cases. It may be concluded that the system is restricted to bounded saddles.
- More laboratory steps are required than for a conventional unguided stent.
- Patient requires local anaesthetic for the bone mapping procedure.

The possible error points in this system are:

- The bone mapping
- Stone removal from the cast to replicate the bone mapping.
- Shrinkage of the acrylic and impression material. Expansion of the gypsum products.

- Surgical Error – according to the manufacturer the sleeves are restrictive enough that only apico-coronal errors of any consequence are permitted.

It may be argued that this system is excessively complex for the cases it is intended to be used with. However it must be appreciated that in cases where ample bone exists and teeth on either side of the proposed site are present, the number of differing positions the implant may be placed in is great. However only a small number of these positions are prosthetically ideal. While an experienced surgeon will place the implant with knowledge of the restorative procedures to come, it must be remembered that not all implant surgeons are experienced or have knowledge of the restorative complications.

A Google search for the term model based NobelGuide™ reveals 716 hits; sites include continuing dental education site with downloadable videos of live demonstrations of the technique, along with a number of laboratories who will produce these stents for clinicians. However there is a paucity of data regarding the accuracy of this method or its clinical results.

Rocci's⁷¹ study mentioned previously is the only one available which used this system. This paper had 46 patients with 96 implants placed flaplessly using the model based NobelGuide™ protocol. Both single units and 3 unit fixed partial dentures were placed, with immediate provisionalisation and loading. The success rates at 3 years were 91% which, while relatively high, does not compare favourably with other studies using more conventional techniques (98%)

33 20

The only mention of accuracy is that all the provisional restorations made on the planning model were placed successfully in the patients mouths after implant placement. This is taken to imply accuracy of the transfer of the implant position from the planning to the surgical stage (or the accuracy of the stent). While this study was retrospective and without a control group, it is the only data regarding this MBNG system. However many questions still remain.

2.10 Outstanding Questions with the Model Based NobelGuide.

CT guided surgery has many advantages. However the radiation dose, cost, time required and equipment needed, do limit its applications in the smaller partially dentate cases. These smaller cases however are often the most aesthetically challenging and disappointing when implant placement is less than ideal despite adequate bone volume. The model based NobelGuide[™] aims to bring the surgical advancements and accuracy of the CT based system to these less complex cases.

As discussed above the cornerstone of any guided system is its planning data set. If this is accurate the accuracy of the stent itself becomes a limiting factor in the overall precision of the procedure. The stent for the MBNB differs from the CTNG in construction materials and techniques. As with many new products the model base NobelGuide[™] was brought to market without much peer reviewed published data regarding its efficacy or accuracy.

2.11 Current Study.

2.11.1 Aims of Study.

The aims of this study are to:

1. Asses the accuracy of the Model Based NobelGuide[™] stent in transferring preoperative planning to the surgical procedure.
2. Asses the adequacy of the preoperative bone mapping as a presurgical representation of the underlying implant site.

2.11.2 Objectives of the Study.

The objectives of the study are to:

1. Place implants in a human cadaver model strictly using the MBNG published protocol.
2. Measure the preplanning positions of the implants and compare them to the post surgical positions of those implants.
3. Examine the implant site using an open flap procedure to discover if the preplanning data was sufficient for successful implant placement where each implant is encased in bone.
4. Judge the accuracy of the system with regard to the published literature for guided implant placement.

2.11.3 Null Hypotheses.

1. There is no difference between the position of the pre planned (control) implant and the final (Test) implant location.
2. Complete stone encasement of the implant on the preoperative stone cast will give complete bone encasement of the implant in each specimen.

3. Materials & Methods

3.1 Introduction

The materials and Methods of the current study will be dealt with in under the following headings.

1. Pre Experimental Training and Calibration.
2. Study Design.
3. Specimen Acquisition and Preparation.
4. Presurgical bone mapping and Planning cast.
5. Surgical Protocol.
6. Measurement.
7. Statistics and Analysis.

3.2 – Pre Experimental Training and Calibration.

Once the aims and objectives of the study were decided upon, pre-experimental training commenced to familiarise the investigator with the workings of the system.

Firstly the laboratory aspect of the technique was demonstrated on mannequin models in the undergraduate teaching laboratory of the Dublin Dental School and Hospital. Mr. Kjell Carlsson

Materials & Methods

(SML Dentallaboratorium AB, Gothenburg, Sweden,) dental technician attended, giving a presentation of the technique followed by a hands on demonstration. Consequently several test stents were made by the principle investigator and approved by Mr. Carlsson.

Surgical training was given by Dr. David Harris (Blackrock Clinic, Blackrock Co. Dublin). A two day course on the CT based NobelGuide™ was completed by the principle investigator. Aspects of the computer planning and the surgical procedure were given. Surgical training took place in the Blackrock Clinic on demonstration plastic casts. (Fig 3.1)

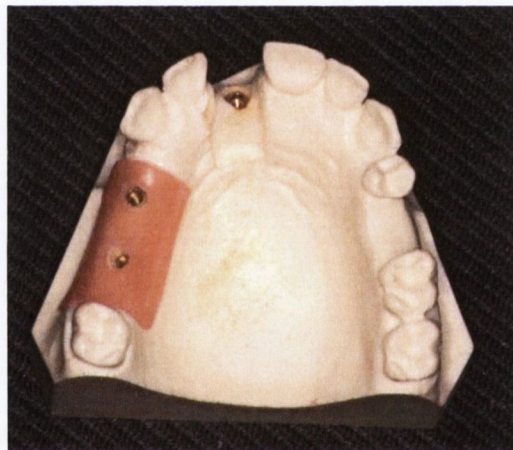


Fig 3.1. Surgical Training Model

The manufacturer's literature was reviewed (Appendix 1). Online videos were reviewed from the manufacturers website (www.nobelbiocare.com). The literature in this area was reviewed and methods of assessing accuracy investigated. This information was used to draw up a study protocol.

3.3 – Study Design.

The following algorithm was developed to apply to each specimen. A human cadaver model was chosen similar to the van Steenberghe⁸³ studies on accuracy of the CTBNG. This model had the advantages of an *in vitro* system while maintaining most of the clinical significance.

Advantage of the Cadaver Model:

- *In Vitro*. Pilot and experimental stages could be carried out without time constraints.
- More clinically significant than a study on stone or plastic casts. Anatomy and surgical procedure can closely mimic the clinical situation.
- No requirement for ethical. The Anatomy Department Trinity College Dublin and Royal College of Surgeons in Ireland do not require ethical approval for experimentation on the cadavers provided each specimen remains intact and no specimen or part thereof is removed from the anatomy room.
- Bone volume and implant position will vary from specimen to specimen.
- Mucosal thickness will differ between specimens.
- A mucoperiosteal flap can be raised after implant placement simulation in order to inspect the surgical site.

Disadvantages of the Cadaver Model:

- The embalming process dehydrates the mucosa and may possibly make bone sounding more difficult.
- Surgical access is restricted due to rigor mortis.
- The osseous bone is more compliant and offers less resistance due to embalming.
- Inability to take radiographs.

Materials & Methods

- Embalming fluids retard the setting reaction of Polyvinylsiloxane materials (PVS).
- Cadaver specimens were mostly edentulous in one or both arches (chronological age related). Bounded edentulous areas were less common, limiting the number of specimens available.

The following outline protocol was proposed.

1. Identify human cadavers with bounded edentulous saddles in either jaw.
2. Classify the implant site as having sufficient width and height of bone or having insufficient width and height.
3. Make PVS impressions of the proposed implant sites.
4. Cast the impressions to generate planning casts.
5. Plan the placement of one or more implants in the edentulous site.
6. Create a mapping guide for the site.
7. Carry out bone mapping procedure on each specimen.
8. Follow manufacturer's instructions to generate a MBNG.
9. Place implant replicas according the manufacturers instructions using the MBNG.

10. Make an open tray impression of the implant position and adjacent teeth using PVS impression material.
11. Raise a full thickness mucoperiosteal flap and examine the implant site for fenestrations, dehiscences and exposed threads of the implant replica.
12. Pour the impressions of the implant position to generate a post surgery cast.
13. Using a coordinate measuring machine (Renscan5™ Renishaw plc, New Mills, Wotton-under-Edge, Gloucestershire, GL12 8JR, United Kingdom) and with reference to the adjacent teeth, obtain data of the X,Y,Z and angular deviation of the implants in the planning and post surgery casts.
14. Statistically and graphically compare the data to test the null hypothesis.

3.4 – Specimen Acquisition and preparation.

In order to obtain the maximum number of specimens possible two anatomy department were approached: the Anatomy Department of Trinity College Dublin (Dublin 2, Ireland) and the Anatomy Department of the Royal College of Surgeons in Ireland (Dublin 2, Ireland).

Once approval from the respective professors of anatomy was obtained, the human cadavers currently available in the department were examined for suitability. The inclusion criteria were:

- Intact maxilla or mandible with continuous mucosa covering the bone.
- Bounded edentulous space in any quadrant with natural teeth, or tooth borne fixed dental prostheses.

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- No visible retained roots in the edentulous spaces.
- Access sufficient or could be made sufficient by dissection of the facial muscles and fascia.
- Sufficient available ridge width and height for implant placement. If width was less than 5 mm then the specimen was classed as having a small bone volume. If the width was greater than 5 mm the specimen was classed as having a large bone volume.

Of the 41 specimens examined only 10 fulfilled the inclusion criteria, 6 cadavers in the Royal College of Surgeons Ireland and 4 in Trinity College Dublin. Saggital sections if not already prepared, were made of the specimens by the anatomy technical staff of the respective department. One specimen in Trinity College anatomy department had to be later excluded due to a previously undiagnosed retained root discovered at the bone sounding stage of the study.

The specimens had been previously embalmed in the same manner in both departments. The bodily fluids were drained and replaced with the embalming fluid. This fluid consisted of:

- 12 Parts – Methylated Spirits (fixation and diffuser into the tissues)
- 3 Parts – Glycerine (maintain moisture content)
- 1 Part – Liquid Phenol (antiseptic)
- 1 Part- Formaldehyde (fixation agent)

A research log book was kept recording the identification number and location of each specimen, the proposed implant site and measurements of the bone volume.

3.5 –Presurgical planning cast and bone mapping.

Each specimen was now saggitally sectioned and surgical access attained. A polyvinylsiloxane addition cured impression material (President putty and low viscosity wash, Coltene Whaledent) in an adhered (Adhesive, Coltène/Whaledent Ltd. ,The President Suite-A , Kendal House, Burgess, Hill , Victoria Way West Sussex, RH15 9NF/U.K) metal sectional tray was made of each edentulous site. A one stage impression was used (Fig 3.2). Once setting of the material was complete, the impression was removed, disinfected with CIDEX OPA (Advanced Sterilization Products, 33 Technology Drive, Irvine, CA 92618 USA) an 0.55% ortho-phthalaldehyde solution, for 30 seconds and surfactant sprayed lightly on the surface (Debubbler, KerrHawe). The impressions were cast in vacuum mixed resin reinforced die stone (Fig 3.3). (C&J “R” Die stone, Chamberlin and Jacobs Ltd, Surrey, England). The die stone used had a compressive strength of 16,500 psi giving it superior abrasion properties compared to most standard type IV or V dental stones. The expansion was 0.1% which is well within the ADA specification 25 for die stone. Each mix of stone was precisely measured using a scales and graduated cylinder to give a 19 g to 100 ml powder to liquid ratio. The casts were retrieved from the impressions and allowed to stand at room temperature for 24 hours.



Fig 3.2 PVS Impression of the edentulous area



Figure 3.3 Impressions cast in Dental Stone

The proposed implant site was located on the edentulous portion of the casts. Implants were planned 1.5 mm from adjacent teeth with 3 mm between implants. If space permitted two implants were planned in the edentulous space. A line was marked using an indelible marker

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from buccal to lingual for each implant. Along this line, 3 buccal marks, 3 lingual marks and one mark at the crest of the ridge were made.

A 3 mm thick polypropylene sheet (Raintree Essix, Metairie, LA 70002) was heated and a vacuum pull-down made on each cast (Vacuum former, T & S Dental & Plastic Co Inc, Myerstown, PA). This was trimmed to cover the edentulous ridge and the adjacent teeth. This pull-down was marked at the mapping points described previously and a straight headpiece carbide bur (556 bur, DENTSPLY International, Susquehanna Commerce Center, 221 W. Philadelphia Street, P.O. Box 872, York, PA 17405-0872) was used to perforate the pull-down at the 7 points. This was then the completed mapping guide (Fig 3.4).



Fig 3.4. Bone mapping stent on cast.

The mapping guide was brought to its matching specimen and verified for good adaptation to the surgical site (Fig 3.5). A sharp probe tip (DG16, Stardental) was inked with an indelible marker (BIC international) and pushed through the holes in the stent, leaving a mark on the mucosa (Fig 3.6). The guide was removed and a probe (DG16, Stardental) with an endodontic stop was pushed through the mucosa at each mark until the bone level was felt as resistance. The depth was measured to an accuracy of 0.5 mm using a stainless steel ruler. A mapping diagram was developed in this way for each implant site (Fig 3.7).

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Fig 3.5. Mapping Stent on the Cadaver specimen.



Fig 3.6. Ink transfer of the mapping points

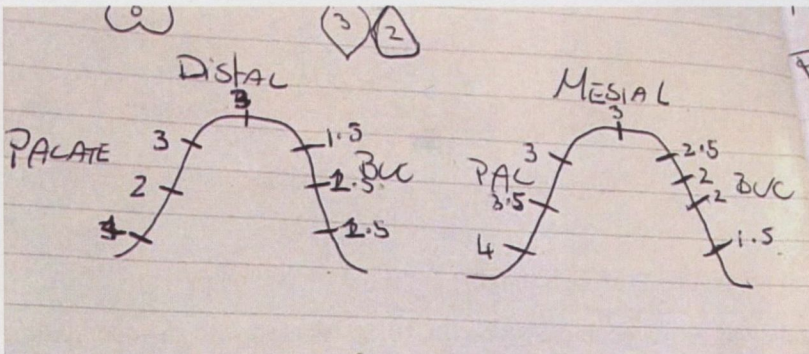


Fig 3.7. Bone map of the proposed implant site.

In the laboratory the planning cast was made into removable sections. The Pindex system (PINDEX Pin Long (20 mm) with Synthetic Core, Coltène/Whaledent) was used. If one implant was planned then two sections were required, if two implants were planned the three sections were needed. Using the Pindex laser guided drill (Fig 3.8) (Pindex laser, Coltene/Whaledent) at least two pins were glued into place in each section to be made removable (Fig 3.9). The plastic

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sleeves were placed and soft wax placed over the pin tip to aid in later retrieval. A film of separator (Super-Sep, KerrHawe) was sprayed around the pins to ease removal of the individual sections. The casts were now based using sectional base formers with the same stone as used to cast the impressions. The based cast were retrieved once the stone was set. A fret saw (Vitrex, TH159 Tilesaw - Hacksaw 250360, Lancashire FY8 3AZ England) was used to cut through the line marking the implant location (Fig 3.10). Each planning model now had removable sections which could be accurately repositioned in the base to reassemble the cast (Fig 3.11).



Fig 3.8. Pindex Laser Drill. The laser marker pinpoints the location of the drill hole on the cast.



Fig 3.9. Each implant section is made removable, with brass pins fitting into plastic sleeves in the cast base

The bone mapping data were now used to remove stone from the cast to create an analogue of the clinical bone morphology. The mapping data were transferred at each mapping point, using a ruler and an ink pen.

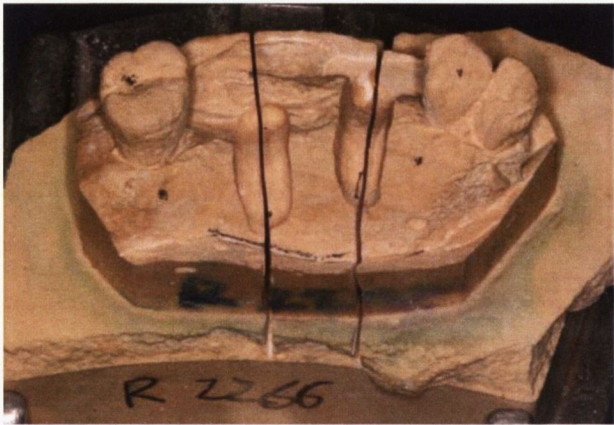


Fig 3.10. Fret Saw used to cut each implant site into a removable section.

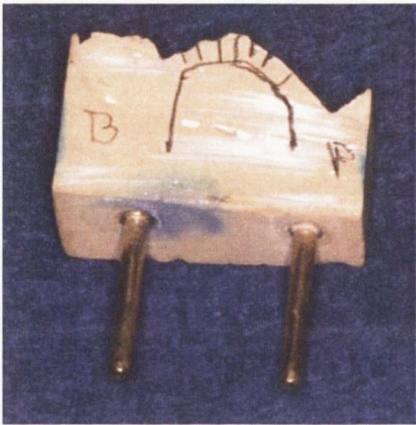


Fig 3.11. Mapping transferred to each implant section

Using a large round tungsten carbide bur (1558 bur, DENTSPLY International, Susquehanna Commerce Center, 221 W. Philadelphia Street, P.O. Box 872, York, PA 17405-0872), a hole 0.2mm wider than a 3.75mm regular platform implant was made at an appropriate location at each proposed implant site. An implant analogue (R/P Brånemark Mark III) was placed in the hole and luted using cyanoacrylate glue (Superglue, Loctite Plc.). The glue was set instantaneously by the application of PMMA monomer to the wet glue surface (SNAP monomer, Parkell, Inc. Edgewood, NY) (Fig 3.12-3.13).

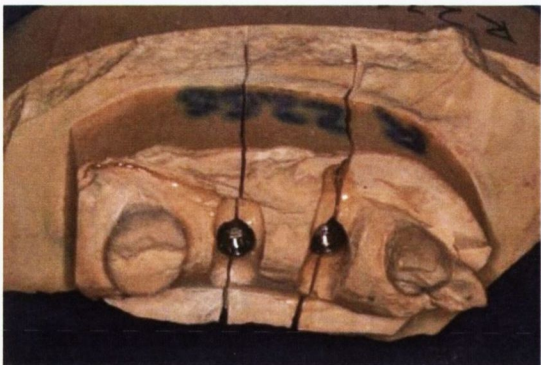


Fig 3.12. Analogues glued in place in the reassembled planning cast

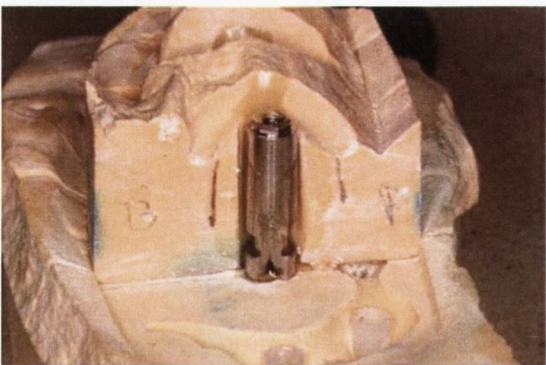


Fig 3.13. Removable section showing the implant analogue and the stone removed to reproduce the bone profile.

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The fret saw cut was blocked out with beading wax. Using the mapping guide as a record of the soft tissue, gingival coloured silicone (Gingifast Rigid, Zhermack SpA, Italy) was placed in the guide and replaced on the planning cast. Once the setting reaction was complete (15 minutes), the mapping guide was removed and the gingival silicone adhered to the cast through surface roughness. A soft tissue punch (Nobel Biocare, Sweden) was used to remove the portion of gingival silicone covering the implant analogue head. This was now a completed planning cast, showing the proposed position of each implant to be placed (Fig 3.14).

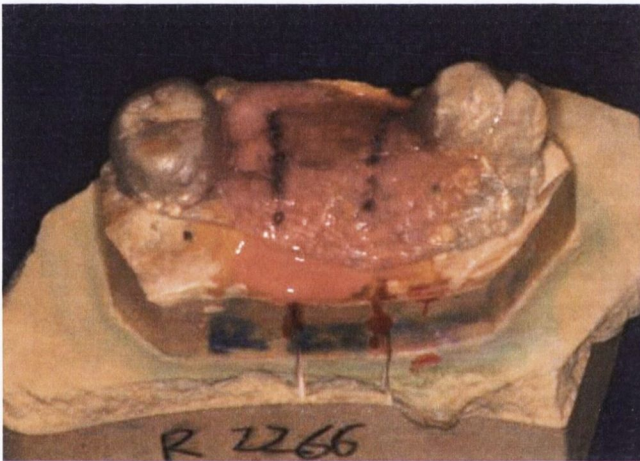


Fig 3.14. Soft tissue mask placed to reproduce the soft tissue profile of the edentulous ridge

The surgical guide was then constructed. A three part NobelGuide™ sleeve was screwed to each implant analogue (Fig 3.15). The screw held the components together whilst the sleeve was to remain in the stent and guide the surgical burs and the cylinder spaced the sleeve 10 mm from the implant head. (Fig 3.16)



Fig 3.15. NobelGuide Sleeve assembly.



Fig 3.16. Guided Sleeves on the planning cast without soft tissue mask to verify complete seating.

Each cast with the guided sleeve attached was surveyed using a dental surveyor. (Ney surveyor, Neytech™ Equipment Ltd.) The height of contour (most bulbous portion of the teeth at that given survey table angle) of the stone teeth were marked using a graphite surveyor (Fig 3.17). Every part of the cast below the height of contour was blocked out using PVS putty, (Fig 3.18) (Verone lab putty (Schottlander, Letchworth, UK.). This ensured the stent would have a path of removal from the cast unencumbered by undercuts.



Fig 3.17. Height of contour marked with dental surveyor.

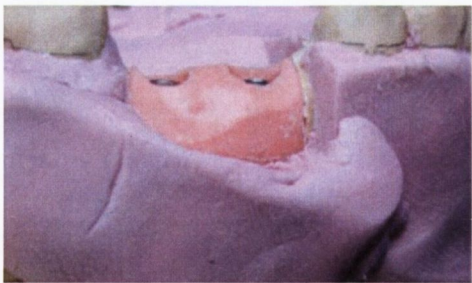


Fig 3.18. Lab putty used to block out under the Height of contour.

Acrylic separator was applied in three layers to each blocked out cast, avoiding coating the guided sleeve with separator (Fig 3.19) (Ivocron Separator, SR Separating Fluid, C&B Resins, Ivoclar Vivadent Liechtenstein). Self curing clear acrylic (Vertex™ Self Curing, Vertex Dental, Netherlands) was mixed as per the manufacturer's instructions. Once the doughy stage was reached it was pressed onto the cast and cured in a thermostatically controlled pressure pot at 55 degrees Celsius and under pressure of 2.5 bar (Palamat Practic EL, Heraeus Kulzer Dental) (Fig 3.20-3.21).



Fig 3.19. Acrylic Separator

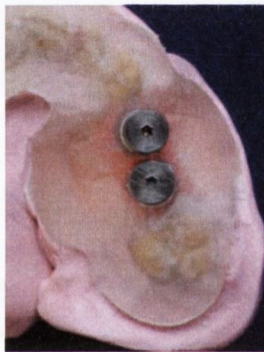


Fig 3.20. Acrylic at dough stage placed on blocked out cast.



Fig 3.21. Acrylic packed to form stent and cured under heat and pressure.

Once curing was complete, the guided sleeve was unscrewed from the cast and the stent removed. Finishing of the stent involved trimming the stent with an acrylic bur (1558 bur, DENTSPLY International, Susquehanna Commerce Centre, 221 W. Philadelphia Street, P.O. Box 872, York, PA 17405-0872), and polishing with pumice on a lathe. The cusp tips of the teeth either side of the edentulous space were exposed through the stent to allow verification of seating during surgery. The stents were now ready for the surgical stage of the experiment. (Fig 3.22)

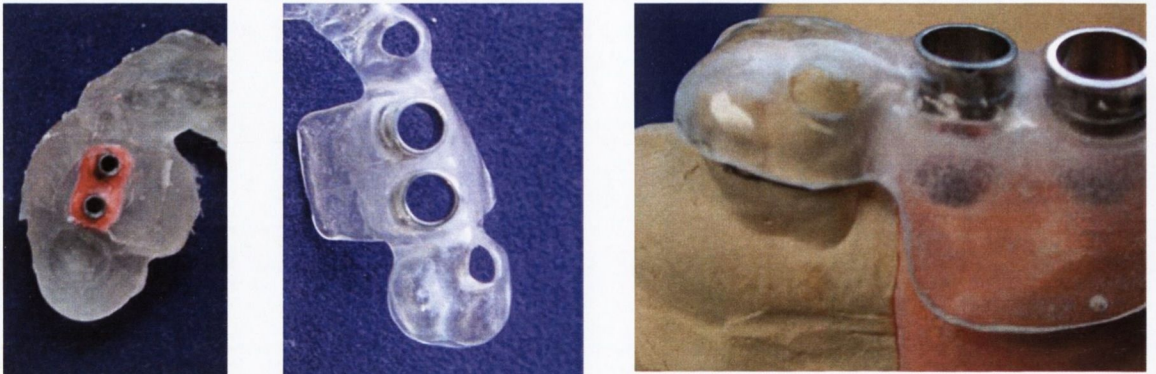


Fig 3.22. Stent retrieved from cast. Trimmed and cusp tips exposed to be visible through the stent to verify seating during the surgical phase.

3.6 – Surgical Protocol.

A Brånemark system surgical kit was obtained from NobelBiocare. This kit contained all the required drills and guides necessary for the surgical procedure (Fig 3.23). A torque control hand piece and electric motor (OSSEOCISION® Biomet 3i) were used for all osteotomy and implant placement procedures.

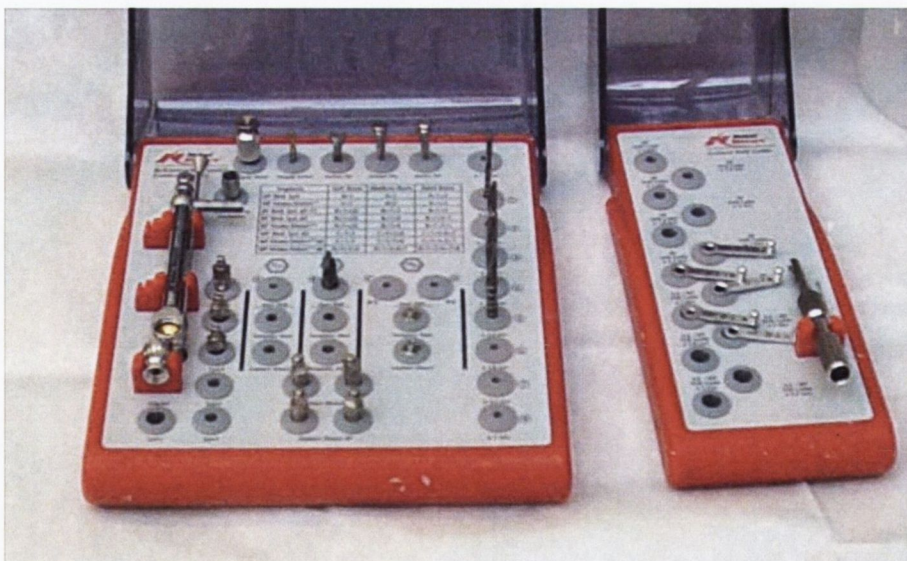


Fig 3.23. Guided Surgical Kit for the Brånemark mark III implant system.

In place of implants, brass training replicas were used from NobelBiocare. These replicas corresponded in every way to the Brånemark Mark III regular platform implant except for its alloy content.

Each stent was positioned on its respective specimen. The viewing holes of the cusp tips of adjacent teeth were examined for verification of seating. Once the stent was satisfactorily placed with the cusp tips of the adjacent teeth protruding through the stent, the drilling protocol commenced. At each stage the matched guided key was placed in the guided sleeve to direct the bur. All implants were placed at a depth of 13 mm corresponding to the replica length (Fig 3.24).



Fig 3.24. Drilling sequence for the guided surgery. Red shading indicated use of a guided drill sleeve.

Drilling Protocol

1. Site Preparation – (Fig 3.25) the guided start drill/counterbore Brånemark system® (RP) is placed directly in the template sleeve and drilled to the stop depth of 13 mm marked on the shank of the bur. This removes the mucosa covering the site as well as starting and countersinking the osteotomy site (2000 RPM) .



Fig 3.25. Diagram and actual experimental site preparation using start drill. Stent verified for seating.

2. The guided drill guide (RP) $\varnothing$ 2 mm was placed in the template sleeve. Thereafter, the guided twist drill was used to the desired depth under profuse irrigation (Normal Saline, Baxter Healthcare, Norfolk, United Kingdom). The drills are designed so that the marking at each depth corresponds to that depth plus the 10 mm spacing between the guided sleeve and the bone (Fig 3.26) (2000 RPM).

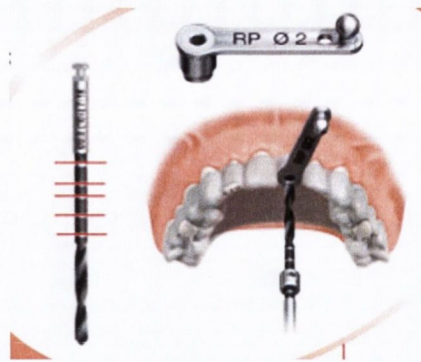


Fig 3.26. Guided pilot Drill in the guided drill sleeve.

3. Next the guided drill guide (RP) $\varnothing$ 3.2 mm was placed in the sleeve and Guided Twist Drill 3.2 used to drill to the desired 13mm depth under profuse irrigation (Normal Saline) (2000 RPM) (Fig3.27)

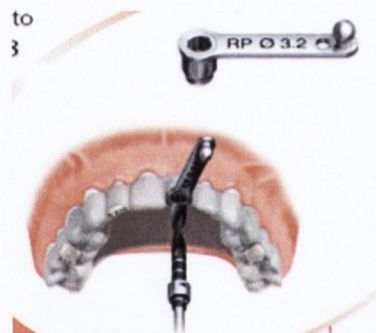


Fig 3.27. 3.2mm guided drill in the guided drill sleeve.

4. Guided screw tap (RP) $\varnothing$ 4.0 mm was used in situations where the bone was judged dense or locally dense bone. Tapping was carried out to the desired depth then the handpiece was switched to reverse mode and the screw tap backed out (100 RPM) (Fig 3.28).

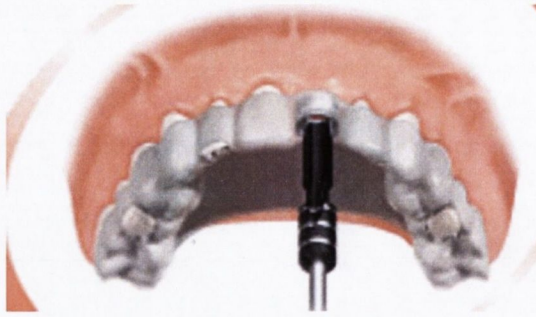


Fig 3.28. Tapping of the osteotomy.

5. **Implant Placement.** The implant replica was mounted using the implant mount and this mounted implant inserted using the connection to handpiece until the flange of the Implant mount touched the top of the sleeve in the surgical template. If two implants were to be placed using the same stent, each was carried out separately with the implant mount left in situ to stabilise the stent. No irrigation was used at the step. If a primary stability of 45 N Cm was not achieved, the implant was reversed out, some cyanoacrylate glue (Superglue, Loctite Plc.) applied to the osteotomy and the implant reinserted. Primary stability was tested using a hand torque wrench set to 45 Ncm (Fig 3.29).

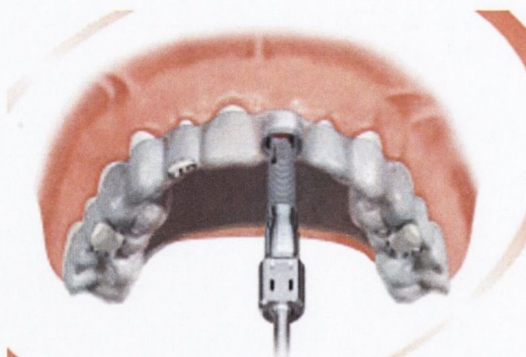


Fig 3.29. Implant placement using the guided fixture mount.

6. The implant mount was released using the unigrip screwdriver included within the surgical kit.
7. Removal of soft tissue using the guided soft tissue punch (RP) directly in the template sleeve to completely remove all soft tissue. (Fig 49).

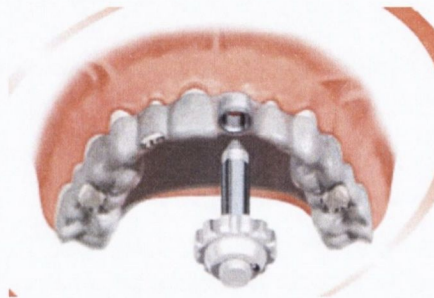


Fig 3.30. Soft tissue punch.

8. Removal of the Surgical Template.

Once the implant replica was installed and the stent removed, a mucoperiosteal flap was raised over the implant site. Exposed threads, fenestrations and dehiscences were noted (Fig 3.31-3.32).

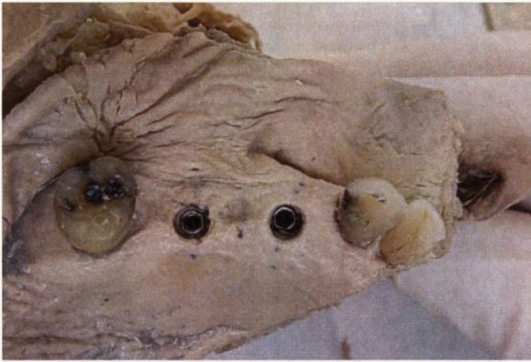


Fig 3.31. Situation after implant placement.



Fig 3.32. Flap reflection and implant site examination.

An open tray impression coping was attached to the replica, and a stock tray adjusted (Henry Schein Ireland) so the screw of the impression coping would extend through the tray. A PVS impression (President putty and low viscosity wash, Coltene Whaledent) was made recording the implant position and the adjacent teeth. An analogue was attached to the impression coping in the impression and the cast poured as previously described in Section 3.5.

Now two casts existed for each specimen, one the planning cast with the proposed implant position and the other the actual post surgical position of the implant. (Fig 3.33).



Fig 3.33. The planning cast and the post surgical situation.

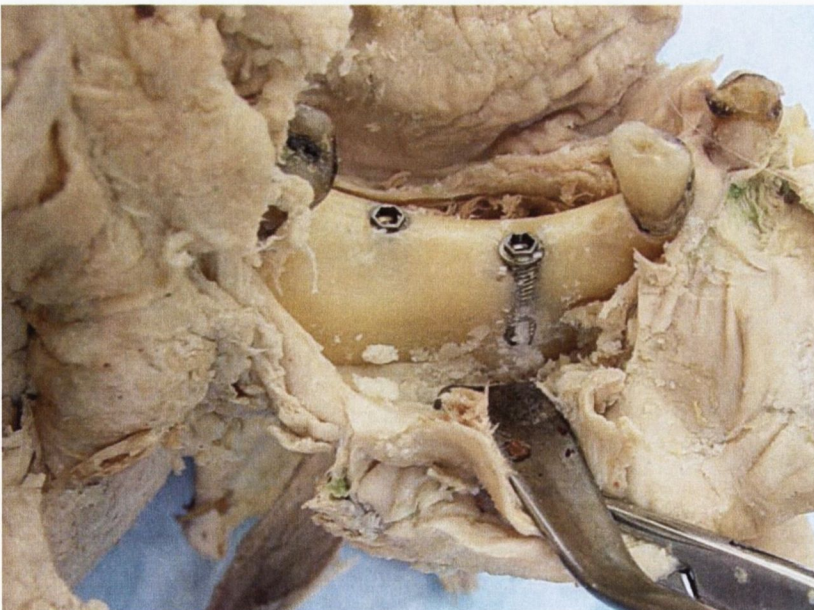


Fig 3.34. After dissection exposed threads were present.

3.7 – Measurements.

Following the work of Kim⁸⁴ and associates, a coordinate measuring machine (CMM) was judged to be the most reliable method of measuring the implant position. CT scans were not available and as such image fusion was not an option. The CMM (Reniscan5™ Renishaw plc, New Mills, Wotton-under-Edge, Gloucestershire, GL12 8JR, United Kingdom) consisted of a vibration dampening table, a measuring probe mounted on a mechanised gantry and a personal computer to analyse the data (Fig 3.35). The planning cast and the post surgery cast were of differing dimensions due to the way in which the bases of the casts were trimmed. A method of solid body transformation was used to measure the position of the implants. This method basically involved using the implant as an object of known dimension on both casts. Reference points on the adjacent teeth were measured and the data transformed so the reference markers were transposed to coincide with each other and the position of the implant changed. It was this change in implant location that delineated the difference in position of the implants.

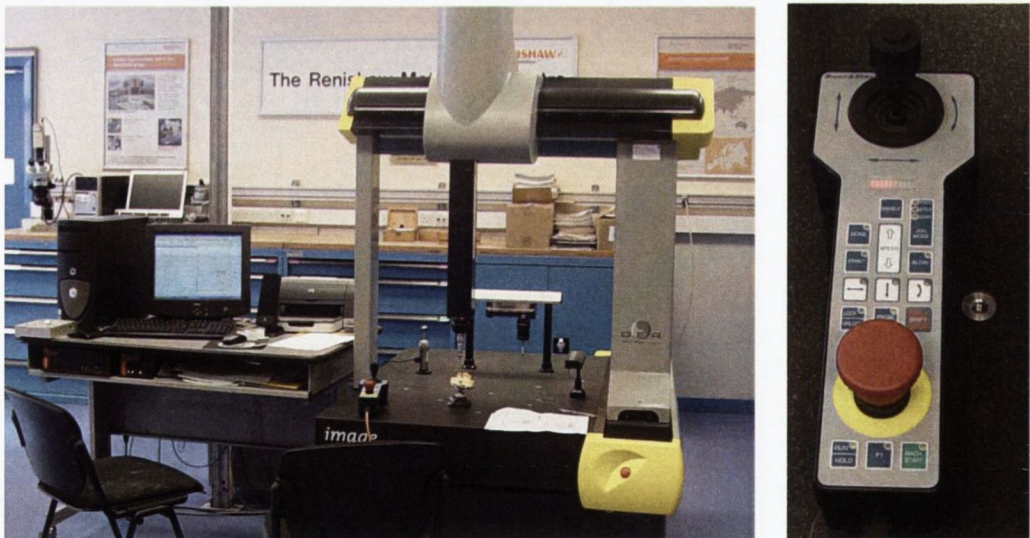


Fig 3.35. Coordinate measuring machine on the left. Right shows the control unit for the mechanised gantry.

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Firstly reference points on the casts were made. The mapping guide on the planning model was used and points on the cusp tips or some other obvious landmark on the adjacent teeth marked. Holes were drilled in the mapping guide and placed on the matching post surgical cast. A sharp pencil was used the mark through the guide onto this cast. Points were chosen as far distant from the implant as feasible in order to reduce the impact of transfer errors of the points. Three points were needed which would create a triangle with the implant inside its boundaries. These points were labelled A,B and C.

The measurements were not made directly of the implant. Instead to overcome the problems of the differing cast dimensions, the implant was mathematically aligned to be perpendicular to a plane made of the reference points. This transformation was then repeated for one of the reference points. It is the change in this point which then reflected the change in position of the implants between the planning cast and the post surgery cast.

The first measurement was made of the implant head, each model had a 15mm long waxing screw placed into in the implant. If more than one implant existed per cast, each was treated as a separate measurement. The cast was placed on a dental surveyor and the waxing screw made perpendicular with the CMM measuring table. The cast was positioned so the X axis corresponded to the bucco-lingual position, Y axis to the mesio-distal position and the Z axis to the implant apico-coronal (depth) position (Fig 3.36).

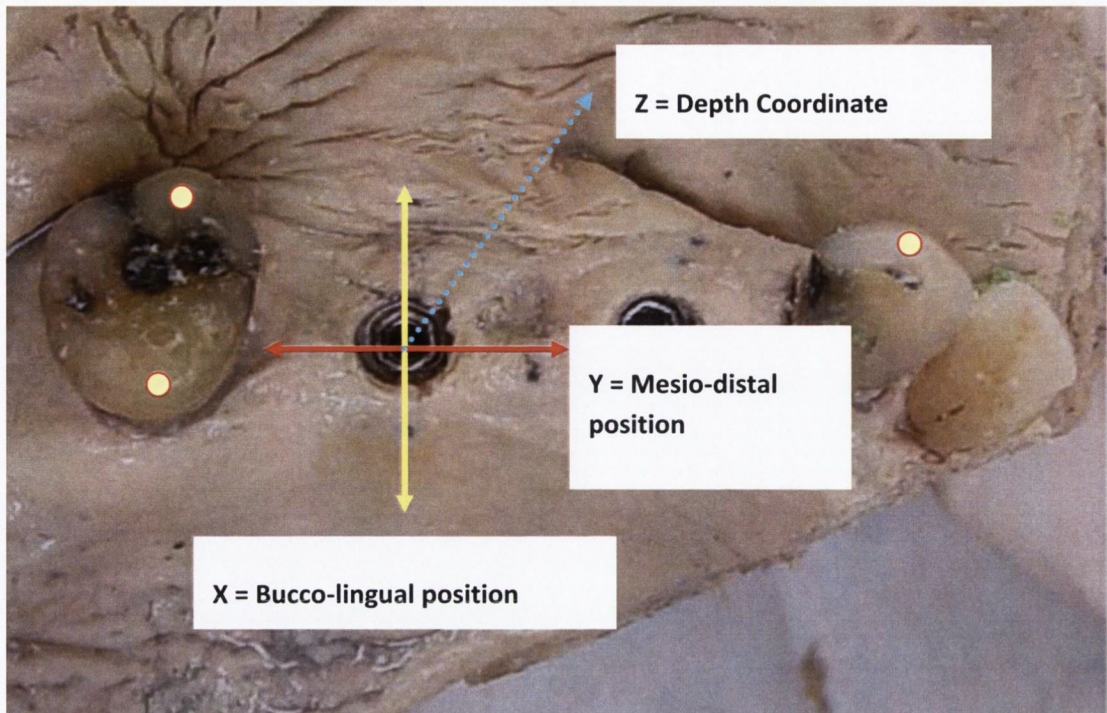


Fig 3.36. Coordinate space and its relationship to the surgical site.

The waxing screw was removed and the measuring probe (1 mm diameter) placed into the implant screw channel. This coordinate was measured and was described as point 1 (PNT 1). The waxing screw was replaced and the tip measured, this was point 2 (PNT 2). At this point the three dimensional axis of the machine was the default axis corresponding to the measuring table. Using the computer software (Renishaw plc, New Mills, Wotton-under-Edge, Gloucestershire, GL 12 8JR, United Kingdom) the origin (datum $X=0$, $y=0$, $z=0$) was transformed to PNT 2 (tip of the 15mm tall waxing screw). A line joining PNT 1 and PNT 2 named LIN1 was created in the computer. The Z axis was aligned to this line. This step calibrated the software to regard the implant as perfectly perpendicular to the X and Y planes.

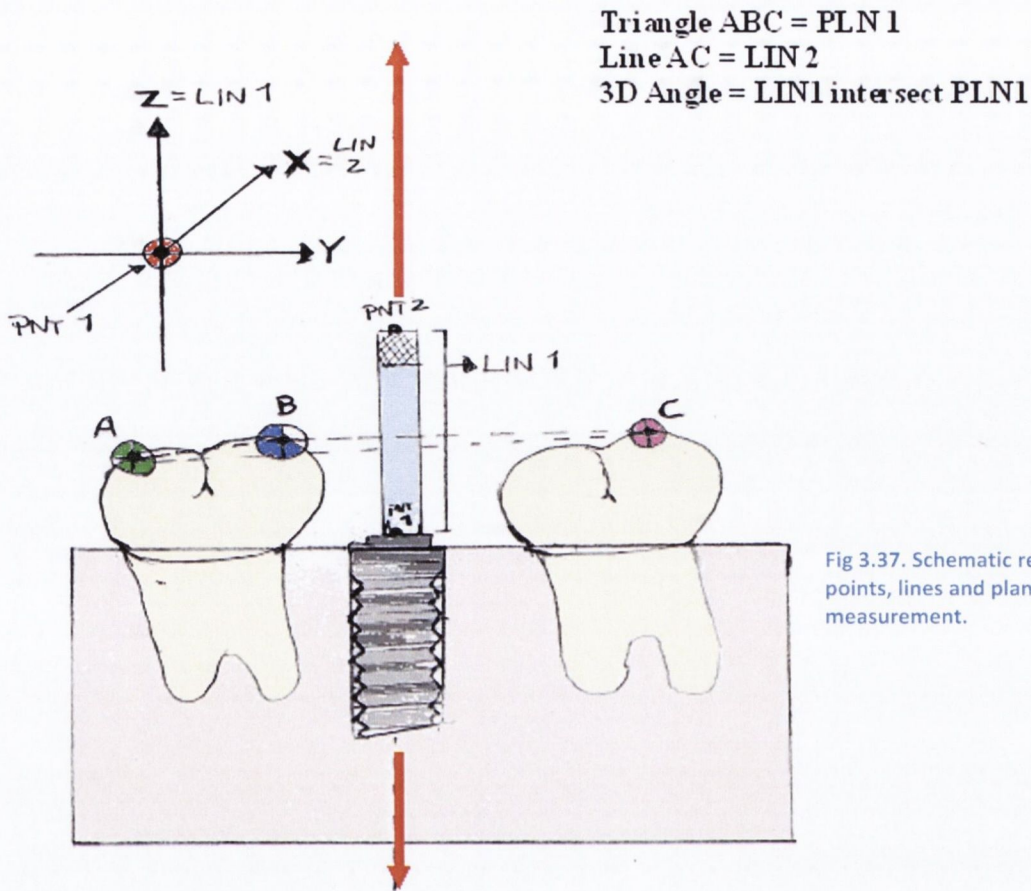


Fig 3.37. Schematic representation of the points, lines and planes used for measurement.

The three reference points were measured and X,Y and Z coordinates made for each point A, B and C. The order in which the points were measured was noted. These points were used to create a plane named PLN1. Two of the points (always points A and C) were used to create a new line from A to C. This was named LIN2. The X axis was now aligned to the line LIN2. The second and most reproducible point B (this point was always allocated to the most easily discernable landmark on the cast) was now translated to the new axis alignments. The X,Y and Z coordinates of this point were noted. (Fig 3.37)

For angular measurement the angle between LN1 (implant line) and PLN1 was calculated. Complete computer output for each specimen is given in Appendix 2. In this way a direct measurement was made of the implant angulation with regard the plane between the three

reference points and the coordinated of a chosen reference position (B) with regard to an implant aligned to the Z axis and reference line (LIN2) aligned to the X axis.

3.8 – Statistics and Analysis.

Measurements were carried out for both the planning cast and the post surgery cast. The difference in the coordinates of point B and angular measurement between these two casts represented the change in implant position from the planning (control) to the surgery.

In order to ascertain the error incurred in repeatable location of the reference points on the reference teeth, multiple coordinates were made in a single cast. These coordinates were used to generate a mean and standard deviation for the ability to find and reproduce the same points across test and control casts.

The data were collected and stored in a Microsoft Excel spreadsheet (Microsoft Corporation, California). Statistical analysis was carried out to determine if the difference between the planning positions of the implant was statistically significantly different from the final surgical position at a P value of < 0.05 . The data were analysed for normality and parametric or non parametric tests chosen for correlation of the data using the R software program (Freeware version 2.7.0, <http://www.r-project.org>) and SPSS for Windows (version 12, SPSS Inc. Chicago, IL 60606).

Descriptive statistics were generated regarding the presence or absence of exposed threads, fenestrations and dehiscences.

4. Results

4.1 Sample information.

In total 13 Implant replicas were placed in 9 specimens. The subjective bone volume was large in 9 specimens and small in 4 specimens.

Ten implants replicas were placed in the maxillary arch and 3 in the mandibular arch. Ten edentulous areas received the 13 implants, as such 3 stents had two implants and 10 stents had only one implant.

During surgery there were only two replicas which showed initial stability problems, not reaching the 45 NCm torque cut off of the implant motor. In these cases cyanoacrylate was used to stabilise the replica.

Four dehiscences and or fenestrations were revealed after flap reflection. It is of note that with the two implants which failed the initial stability test both had a large dehiscence's causing poor engagement of the threads of the implant replica by the bone. All the teeth with small bone volume preoperative showed a dehiscence or fenestration post operatively.

4.2 Accuracy of the technique.

The coordinate measurements and angular measurements for all 13 of the samples are given in Table 4.1. The sign of the value refers to its position either side of the datum and are given in millimetres.

By subtracting the control coordinate (planning cast) from the test (post surgical cast) the difference in millimetres for each coordinate X,Y and Z was obtained. The angular differences were also subtracted (given in degrees rather than radians). Table 4.2 shows the difference in millimetres and degrees for each sample.

Specimen Number	Implant #	Test/Control		x	y	z	Angle
R 16	1/1	Control		-3.233	5.925	6.123	-60.621
R 16	1/1	Test		-3.012	6.782	6.511	-61.329
R 7 Man	1/1	Control		8.689	4.57	12.437	-84.271
R 7 Man	1/1	Test		8.541	4.879	12.164	-79.672
R 9 Max	1/1	Control		-4.98	-0.033	8.588	-82.671
R 9 Max	1/1	Test		-3.2	-0.389	10.085	-75.79
T10 Max	1/2	Control		-6.033	3.158	9.138	72.573
T10 Max	1/2	Test		-6.17	3.41	9.372	74.556
T10 Max	2/2	Control		-12.845	6.144	10.143	70.506
T10 Max	2/2	Test		-12.83	5.225	9.482	72.289
R 5 Max	1/1	Control		5.787	-3.927	9.809	64.431
R 5 Max	1/1	Test		5.417	-3.151	9.378	57.652
R 223	1/2	Control		-9.316	-1.688	10.842	86.206
R 223	1/2	Test		-7.96	-2.373	10.394	81.414
R 223	2/2	Control		-19.802	-3.117	11.864	86.605
R 223	2/2	Test		-19.224	-4.526	10.062	83.734
R 7 Max	1/1	Control		-6.501	2.526	11.099	-29.264
R 7 Max	1/1	Test		-6.26	0.793	10.02	-23.121
R 3 Man	1/2	Control		-5.531	-6.435	12.35	-81.232
R 3 Man	1/2	Test		-6.294	-6.294	11.036	-80.184
R 3 Man	2/2	Control		-17.373	-6.206	12.752	-82.336
R 3 Man	2/2	Test		-17.891	-5.135	10.934	-88.585
T12 Max	1/2	Control		11.371	2.727	9.477	84.606
T12 Max	1/2	Test		11.196	2.207	9.305	84.417
T12Max	2/2	Control		-5.91	-2.165	7.292	80.339
T12Max	2/2	Test		-6.217	-1.978	7.359	81.46

Results

Table. 4.1 All coordinate data

Specimen Number	Difference Between planning and postsurgical implant position			Degrees
	x	y	z	Angle
R16	0.221	0.857	0.388	0.708
R7 Man	0.148	0.308	0.273	4.559
R9 Max	1.78	0.356	1.497	6.881
T10 Max	0.137	0.252	0.234	1.983
T10 Max	0.015	0.919	0.661	1.783
R5 Max	0.37	0.776	0.431	6.779
R2266	1.356	0.685	0.448	4.792
R2266	0.578	1.409	1.802	2.871
R7 Max	0.241	1.733	1.079	6.143
R3 Man	0.763	0.141	1.314	1.048
R3 Man	0.518	1.071	1.818	6.249
T12 Max	0.175	0.52	0.172	0.189
T12Max	0.307	0.187	0.067	1.119

Table 4.2. Difference between planning (test) and postsurgical (control) implant position in mm. Angles given in degrees.

The sample statistics (quartile ranges, mean, median and standard deviations) for these errors are given in Table 4.3. The mean error (degrees of freedom controlled) across the combined X, Y, Z coordinates is 0.156 mm (SD +/- 0.84 mm) with an angular mean deviation of 0.15 degrees(SD +/- 4.4 degrees).

The mean of the standard deviations is given by:

$$\text{Mean SD} = \sqrt{\frac{(SDX^2 + SDY^2 + SDZ^2)(n-1)}{3(n-1)}}$$

{n=13}

Quartile Analysis of (Test – Control) for the Co-ordinates and the Composite Angle							
Co-ordinate	minimum	1 st quartile	median	mean	3 rd quartile	maximum	sd
X (mm)	-0.763	-0.307	-0.137	+0.136	+0.241	1.780	0.73
Y (mm)	-1.733	-0.685	+0.141	-0.156	+0.309	1.071	0.87
Z (mm)	-1.818	-1.079	-0.431	-0.447	+0.067	1.497	0.92
Angle (Degrees)	-6.779	-2.871	+1.048	+0.152	+1.983	6.881	4.40

Table 4.3. Quartile analysis for the test minus control errors. This is using the signed data.

The data can be view in two ways: firstly keeping the sign of each measurement (as above) or secondly using the absolute values of the data where the side of the measuring apparatus the error occurred on was made irrelevant (This is done by squaring and getting the root of each value.).

The quartile analysis for the absolute data is given in table 4.4. The mean error across the X, Y, Z coordinates is 0.667 mm (SD +/- 0.55mm) with an angular mean deviation of 3.473 degrees (SD +/- 2.51 degrees).

Quartile Analysis of <u>Absolute</u> (Test – Control) for the Co-ordinates and the Composite Angle							
Co-ordinate	minimum	1 st quartile	median	mean	3 rd quartile	maximum	sd
X (mm)	0.0150	0.1750	0.3070	0.5084	0.5780	1.7800	0.52
Y (mm)	0.1410	0.3090	0.6850	0.7088	0.9190	1.7330	0.49
Z (mm)	0.0670	0.2730	0.4480	0.7834	1.3140	1.8180	0.64
Angle (Degrees)	0.189	1.121	2.871	3.473	6.143	6.881	2.51

Table 4.4. Quartile analysis for the absolute value of the test minus control errors.

4.3 Statistical Analysis.

Two methods were used to judge if the errors shown were of significance levels sufficient to satisfy the null hypothesis. Firstly graphical plotting of the data was carried out using the R

Results

software {version 2.7.0 (2008-04-22)}. If the data showed no errors then plotting each test coordinate (planning cast) against the control coordinate (post surgery cast) would produce a straight line. Each coordinate was given the designation C or T (control or test) along with its axis i.e. CX is the control x coordinate. The points were plotted and a line of best fit was placed using the software. Figures 4.1 – 4.4 show the plot for the X,Y,Z and angular measurements.

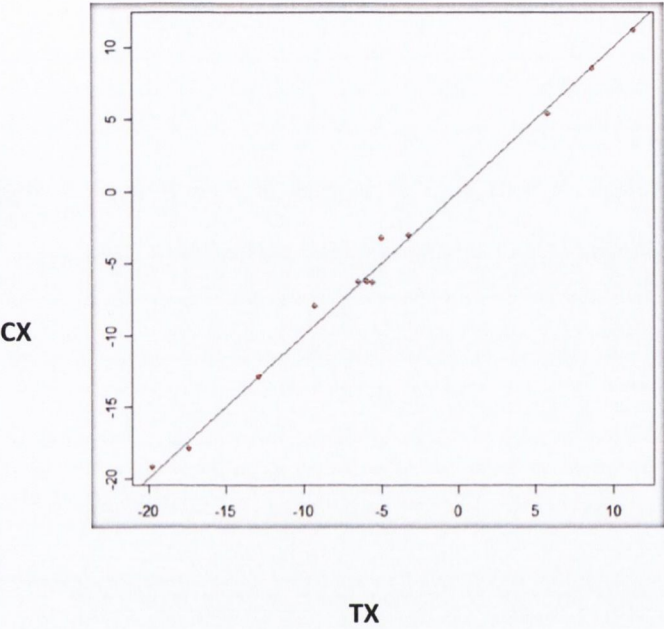


Fig 4.1 X coordinate plot (mm).

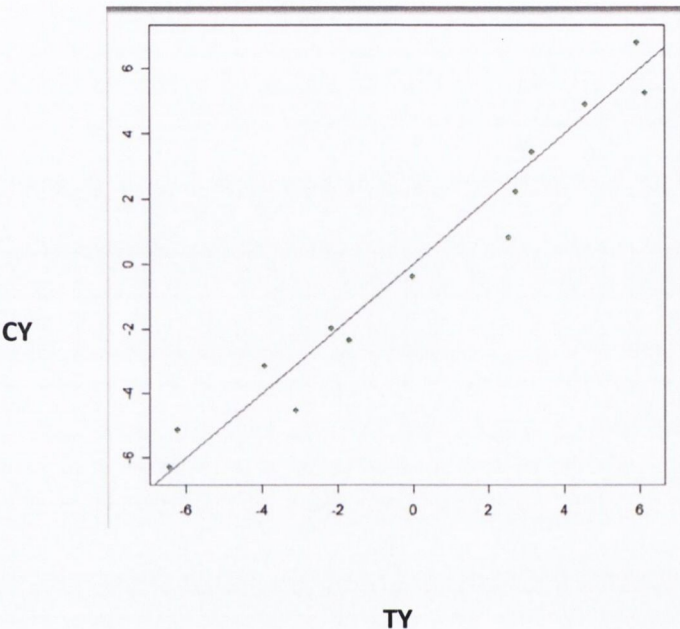


Fig 4.2 Y coordinate Plot (mm)

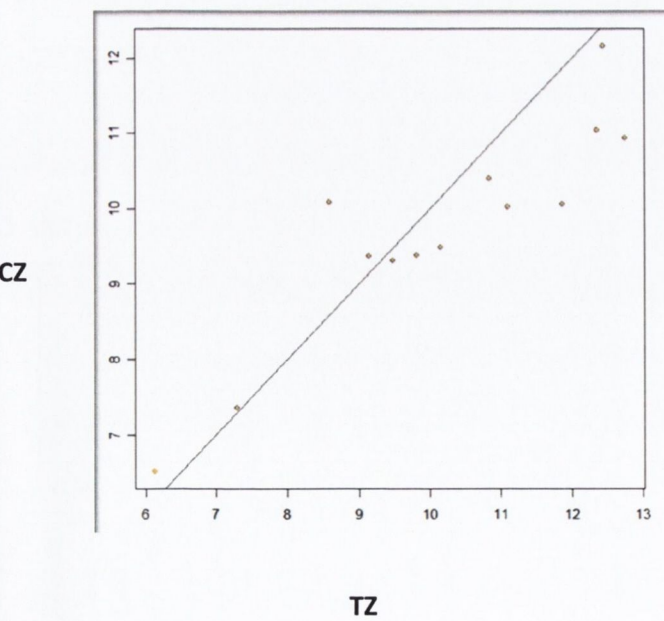


Fig 4.3 Z Coordinate Plot (mm)

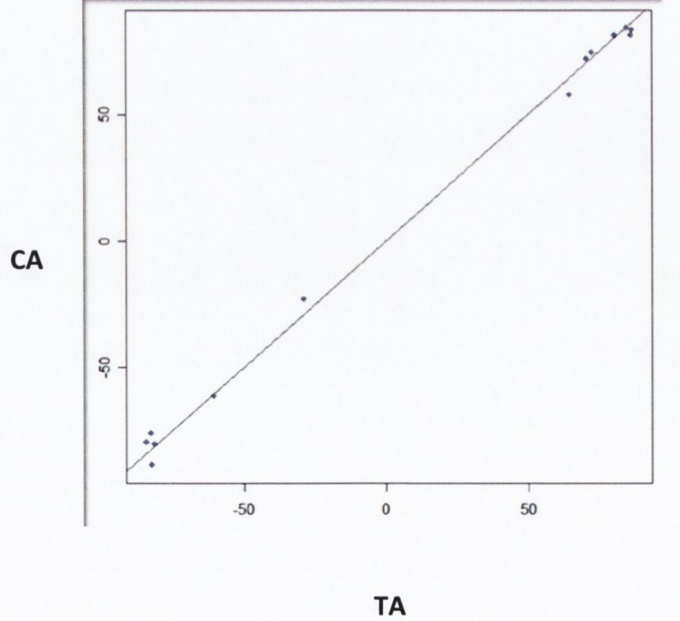


Fig 4.4 Angular Measurement Plot (degrees)

4.3.1 – Parametric Test

It can be seen from these plots that the data does indeed follow a basically linear trend inferring correlation of test and control coordinates. The Z coordinates visually showed the most variance from the linear.

The second analysis of the data was in order to see if the correlation was the result of a random effect. In order to apply a formal statistical correlation test to the data, the normality must be known. However with small sample sizes, normality testing did not show reliable results (Kolmogorov-Smirnov Goodness of Fit Test⁹⁴). Graphical representation of the data of each measurement set is shown in Table 4.5 along with a normal curve. While the data followed a normal distribution, the sample size (n=13) does not allow a definite interpretation. It was decided to apply both parametric and non parametric correlation tests to the data.

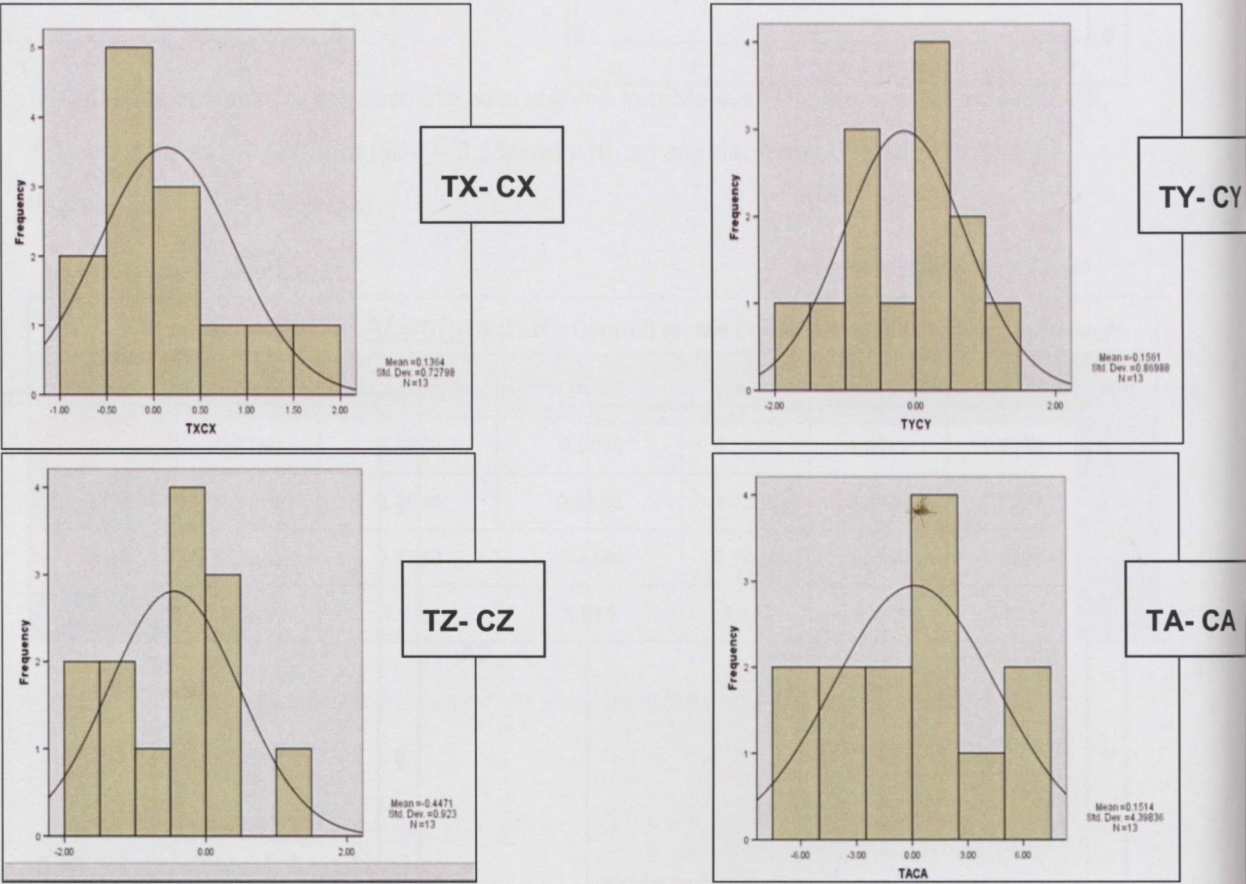


Table 4.5. Frequency data with normal curve for each data set X, Y, Z and angle.

Results

The correlation between two variables reflects the degree to which the variables are related. The most common measure of correlation is the Pearson Product Moment. When measured in a population the Pearson Product Moment correlation is designated by rho (ρ). When computed in a sample, it is designated by the letter "r" and is sometimes called "Pearson's r." Pearson's correlation reflects the degree of linear relationship between two variables. It ranges from +1 to -1. A correlation of +1 means that there is a perfect positive linear relationship between variables. Table 4.6 give the Pearson correlation for all the data sets to each other. The test and control for the X, Y, Z and angle showed strong correlation (ρ approaching +1). The Z coordinate (depth of implant placement) showed the weakest correlation but is still acceptable at 0.909.

Correlations									
		CZ	CA	TX	TY	TZ	TA	CX	CY
CZ	Pearson Correlation	1	-.217	-.240	-.475	.909**	-.230	-.221	-.424
	Sig. (2-tailed)		.477	.430	.101	★.000	.450	.468	.148
	N	13	13	13	13	13	13	13	13
CA	Pearson Correlation	-.217	1	-.046	-.007	-.328	.999**	-.049	.062
	Sig. (2-tailed)	.477		.881	.981	.274	★.000	.874	.841
	N	13	13	13	13	13	13	13	13
TX	Pearson Correlation	-.240	-.046	1	.391	-.014	-.034	.997**	.337
	Sig. (2-tailed)	.430	.881		.186	.963	.911	.000	.260
	N	13	13	13	13	13	13	★13	13
TY	Pearson Correlation	-.475	-.007	.391	1	-.329	.019	.380	.980**
	Sig. (2-tailed)	.101	.981	.186		.273	.951	.200	.000
	N	13	13	13	13	13	13	13	★13
TZ	Pearson Correlation	.909**	-.328	-.014	-.329	1	-.329	-.015	-.289
	Sig. (2-tailed)	★.000	.274	.963	.273		.272	.961	.337
	N	13	13	13	13	13	13	13	13
TA	Pearson Correlation	-.230	.999**	-.034	.019	-.329	1	-.038	.093
	Sig. (2-tailed)	.450	.000	.911	.951	.272		.902	.762
	N	13	★13	13	13	13	13	13	13
CX	Pearson Correlation	-.221	-.049	.997**	.380	-.015	-.038	1	.320
	Sig. (2-tailed)	.468	.874	.000	.200	.961	.902		.287
	N	13	13	★13	13	13	13	13	13
CY	Pearson Correlation	-.424	.062	.337	.980**	-.289	.093	.320	1
	Sig. (2-tailed)	.148	.841	.260	.000	.337	.762	.287	
	N	13	13	13	★13	13	13	13	13

** . Correlation is significant at the 0.01 level (2-tailed).

Table 4.6. Pearson Correlation. Values approaching 1 have a correlation. Those cells with stars show correlation, as expected the test and control for each coordinate and angle show strong correlation.

The Pearson correlation is a parametric test and as such makes presumptions about the normality of the data. To test the correlation assuming non-normality the Wilcoxon Signed Rank Test was preformed.

4.3.2 – Non Parametric Test

The Wilcoxon signed-rank test is a non-parametric alternative to the paired Student's t-test for the case of two related samples or repeated measurements on a single sample. It does not require assumptions about the form of the distribution of the measurements. It should therefore be used whenever the distributional assumptions that underlie the t-test cannot be satisfied (such as the small sample size). Table 4.7 shows the SPSS output for this test.

Ranks		N	Mean Rank	Sum of Ranks
TESTX - CONTROLX	Negative Ranks	7 ^a	6.29	44.00
	Positive Ranks	6 ^b	7.83	47.00
	Ties	0 ^c		
	Total	13		
TESTY - CONTROLY	Negative Ranks	6 ^a	8.83	53.00
	Positive Ranks	7 ^b	5.43	38.00
	Ties	0 ^c		
	Total	13		
TESTZ - CONTROLZ	Negative Ranks	9 ^a	7.89	71.00
	Positive Ranks	4 ^b	5.00	20.00
	Ties	0 ^c		
	Total	13		
TESTANGLE - CONTROLANGLE	Negative Ranks	6 ^a	7.00	42.00
	Positive Ranks	7 ^b	7.00	49.00
	Ties	0 ^c		
	Total	13		

Test Statistics^c

	TESTX - CONTROLX	TESTY - CONTROLY	TESTZ - CONTROLZ	TESTANGLE - CONTROLAN GLE
Z	-.105 ^a	-.524 ^b	-1.782 ^b	-.245 ^a
Asymp. Sig. (2-tailed)	.917	.600	.075	.807

a. Based on negative ranks.

b. Based on positive ranks.

c. Wilcoxon Signed Ranks Test

Table 4.7. Wilcoxon signed-rank test.

The corrected assumed significance figures shown are all much greater than $p < 0.05$ and as such no significant difference is seen between the test and control data for each coordinate or angle (at the $p < 0.05$ level). It must be noted that the Z coordinate (depth of implant) show a value more closely indicating a difference than the others.

4.4 – Measurement Repeatability.

The data collected by repeatedly locating and recording the same 3 reference points is given in Table 4.8. The average difference from the mean of X, Y, Z and angle was respectively 0.37 mm (SD +/- 0.44 mm), 0.23 mm (SD +/- 0.32 mm), 0.38 mm (SD +/- 0.48 mm) and 1.6 degrees (SD +/- 2.2 degrees).

	x	y	z	Angle
Control	6.306	-1.81	13.492	-86.276
Control	7.164	-1.461	14.488	-82.279
Control	7.258	-1.397	14.751	-85.956
Control	6.497	-1.021	14.971	-85.528
Control	5.984	-1.569	13.945	-82.456
Control	6.542	-1.543	14.521	-89.564
Control	6.352	-2.014	14.236	-85.674
Control	6.452	-1.125	14.421	-83.481
Control	6.852	-1.956	13.645	-87.564
Control	7.245	-1.564	13.948	-85.231

Operator Reliability

SD **X** coordinate = 0.44 mm

SD **Y** coordinate = 0.32 mm

SD **Z** coordinate = 0.48 mm

SD **Angular** Measurement = 2.2 Degrees

Table 4.8. Measurement error data.

4.5. Seperating Transfer Accuracy from Mapping accuracy.

When the bone volume was classed as small (< 5 mm ridge width) preoperatively the chance of a dehiscence, fenestration of exposed threads was 100%. Analysing the accuracy data for only these cases is shown in Table 4.9. When Compared to the total accuracy data in Table 4.4, no significant difference existed between these two groups and the confidence intervals had a large degree of overlap. The inaccuracy hence was independent from the transfer of the implant position from planning to the surgery.

	X (mm)	Y (mm)	Z (mm)	Angle (Degrees)
Mean	0.37	0.87	0.77	5.13
SD	0.12	0.14	0.70	2.96

Table 4.9. Accuracy when a fenestration etc. was present. N=4

5. Discussion

5.1 Guided Surgery

The literature and clinical experience with dental implants certainly supports their use for replacing missing teeth in any configuration^{34,95-99}. However the problems of sub optimal placement are numerous and well documented^{18,36,38,39,50-52,56,59,89,100,101}. While many prosthodontic techniques exist for correction of malpositioned fixtures it is preferable to avoid these complications in the planning stage.

The restorative driven approach has many advantages and can elucidate potential problems before they occur³⁶. The use of a conventional stent for even the "simplest" implant placement must be recommended.

In more complicated cases with more aesthetically demanding situations the use of guided surgical techniques has advantages over conventional stents. Computer navigation is an interesting technology, and in the most complicated cases such as maxillio-facial defects, zygomatic implant placement or cases which require general anaesthetic it may have a place. However as discussed by Widmann³⁵ and others the complexity of these systems, expense, radiation dose and capital costs do not currently promote their widespread use. The accuracy of this technique raises some concerns with some authors giving accuracy values in the region of 1.1 mm at the implant tip¹⁰² with a range deviation of up to 3.4 mm. Angular errors are reported in the range of 6.4 degrees with a upper range of 17.4 degrees.

With any accuracy data the upper limits or worst case scenario is probably more important than the mean values. Consideration not of the average accuracy but how badly any system may perform is of paramount importance. As such computer bur tracking navigation cannot currently be recommended.³⁵

The CT based CAD/CAM guides show more promise^{16,61,74,75,83,101,103-108}. They require less capital outlay, are cheaper the use, simpler and maximise the use from a radiation dose. The current market leader is the NobelGuideTM and the data regarding its accuracy favours its use over bur tracking technologies. The errors are more predictable with less disparate

ranges. van Steenberghe ⁶¹ has shown an accuracy of 1 mm with upper limits of 1.6 mm at the implant tip, angular errors of 1.8 degrees with a range of 1 degree. While still not perfectly accurate the level of error is more manageable as is shown by the fact that the final prosthesis can be pre-manufactured albeit with the use of an expandable abutment to take up the errors in depth of implant placement. This depth error is most likely due to the final hand torque of the implant which can distort the stent and leave the implant placed deeper than planned. In its current version, the surgical technique has been altered to minimise this effect, implants are placed sequentially contra lateral to each other in order to secure the stent, maintain the position of the stent, and minimise tipping on the side where implants are being placed.

The clinical data on the success of the “teeth-in-an-hour TM” technique is extremely promising. van Steenberghe in 2005 ⁶¹ stated that “The present prospective multicenter study indicates that the prefabrication, on the basis of models derived from three-dimensional oral implant planning software, of both surgical templates for flapless surgery and dental prostheses for immediate loading is a very reliable treatment option”. This study showed no implant failures and all prostheses (n=24) were connected at the time of implant placement.

5.2 Model Based NobelGuide. - Discussion

From the concept of the CT based NobelGuide TM came the idea of the Model based version. This product is intended for single implant and short span multiple implant placements. The use of the surgical guide remains basically the same as only the method of planning data acquisition changes from CT data to bone mapping data. It is the use of this type of planning information which shows the most concern. Little data exists regarding its clinical efficacy and no data exists regarding its accuracy level. Rocci et al ⁶² published a 3 year clinical study which confirmed the accuracy of the technique but only through the surrogate measure of provisional prosthesis fit. The implant success rates were low however at 91%.

The current study aimed to fill this gap in the literature regarding the accuracy of the Model Based stent and to look at the use of bone mapping as a means of generating a planning model.

The method used to measure accuracy in the current study showed an interesting statistical anomaly which appears in much of the previously published data⁸³. When a coordinate system is used the datum point (0,0,0) is the measurement centre. When coordinated are either side of this point they are designated as positive or negative. However statistical manipulation of this data can be misleading. Negative values cancel out positive values and lead to a smaller mean (but larger standard deviation). A more correct use of the data is the use the absolute values (square and then square root) of the data. As all values are now positive (the position with relation to the datum is of no significance) the mean error becomes greater but the standard errors are reduced.

Analysing the data in this way, the current study revealed a cumulative accuracy level for the X, Y and Z coordinates of 0.667 mm (SD +/- 0.55 mm) with an angular mean deviation of 3.47 degrees (SD +/- 2.51 degrees). This compares favourably with the data from the CT based NobelGuideTM, and falls within the limits given in the literature review (0.8 mm positional error and 3.8 degrees angular error). The greatest disparity between planning and surgery was in the Z coordinate or depth of the implant. This result is also in line with the previous literature⁸³ using the CT based NobelGuideTM.

The differences between the planning cast implant position and the post surgery cast have been shown to be statistically insignificant. Correlation tests show the corollary where the coordinate data from the planning cast implant position and the post surgery cast show a strong correlation at $p < 0.01$ (or 99 percentile). The maximum error seen was in the Z (depth) coordinate at 1.8 mm and the maximum angular error was 6.8 degrees. It is this maximum possible error which must temper the use of this technique for some situations such as placement of a definitive prosthesis at the time of surgery. Only provisional prosthesis are recommended as it is easy to adjust both interproximal contacts and occlusal contacts.

With any statistical analysis using conventional parametric or non parametric test, it is wise to remember that all these tests, while useful for putting a quantity on significance levels, all make assumptions about the data that may not be true. The most useful method for analysing the data is graphically. Table 4.1 -4.4 are the most revealing, and give a good representation of the correlation of the test and control data.

5.3 Materials and Methods -Discussion

Some criticism of the methods use must be made. Firstly the number of samples is limited (N=13) where N is each individual implant placement. This was due to the difficulty in obtaining specimens which fulfilled the inclusion criteria. However the numbers compared favourably both in number and specimen type to the published literature for similar studies. Chiu et al¹⁰⁹, in their study entitled "Three-dimensional accuracy of implant placement in a computer-assisted navigation system", used 8 acrylic resin models and 8 simulated implants. Sarment et al⁹⁰ in the study "Accuracy of implant placement with a stereolithographic surgical guide", used 5 acrylic jaws with 5 implants per jaw. Wagner et al¹⁰² in "Computer-aided placement of endosseous oral implants in patients after ablative tumour surgery: assessment of accuracy", placed 32 implants in 6 clinical subjects. van Steenberghe et al⁸³ in "Accuracy of drilling guides for transfer from three-dimensional CT-based planning to placement of zygoma implants in human cadavers" placed 6 zygomatic fixtures in 3 cadaver specimens.

The cadaver model is also an imperfect model from which to draw clinical conclusions. Although it is the most anatomically accurate *in vitro* model available for implant placement⁸³. Some concerns here are the tissue elasticity and hydration which is less than in the clinical situations. This is a function of the embalming process and as such the tissues were thinner than would be seen on a living sample. The bone density and resilience was not seen as a factor in the current study, the cadaver bone giving good resistance to a probe during the sound procedure and giving sufficient implant stability during surgery. The cases in which implant primary stability had to be augmented with cyanoacrylate glue, were seen after dissection, not as a function of poor bone quality, but of thread exposure.

The greatest variable in the current study was the bone sounding. Measurement using a ruler was somewhat inexact and certainly the removal of stone from the cast to reproduce the mapping data involved much approximation. When the available bone volume was small (< 5 mm in width) preoperatively, the bone sounding was more difficult and the amount of ridge width left after the stone was removed from the planning cast was likewise small. Placement of an analogue into this stone often resulted in the analogue not being encased in a thick body of stone. On transfer of this implant position to the surgical site, exposed threads, dehiscences or fenestrations were always present. When these cases were analysed

for accuracy, it was seen that the stent transferred the planning position as well for these cases as those with large bone volumes. As such the error lies not with the surgical stent but with the planning data. Either the site was not suitable for implant placement in the first instance or the resolution of the mapping data and its transfer to the stone case was insufficient to avoid these complications. A standard DG16 probe was recommended by the manufacturers for the mapping procedure, it was possible that the resolution of the instrument was insufficient for this purpose.

It could be seen that when such a clinical instance arises, the planning data highlights the need for an augmentation procedure after placement of the implant. In this instance, the implant can be placed in its prosthetically ideal position using the stent, and afterwards the exposed threads can be grafted using bone, bone substitute or a mixture of both. Membrane coverage and a period of unloaded healing would be indicated ³¹.

During implant placement some difficulties were encountered during insertion of the implant replica. If the implant was not positioned exactly in line with the osteotomy, the implant tended to bind on the guided sleeve. This problem was overcome by routinely tapping the osteotomy to half the implant length, inserting the replica as far as possible into the osteotomy and only then starting the torque motor. The final 1-2 mm of depth needed to be achieved with a manual torque wrench. Complete seating of the fixture mount against the guided sleeve was confirmed with an explorer. The loss of accuracy in the Z coordinate or depth of the implant may be due to this hand torque, although the results obtained were in line with the previously published literature ^{61,107,108}.

At the outset of this study, consideration was given to the possible errors, of the setting expansion of the stone, impression material and shrinkage of the acrylic guide. In practice these errors, although certainly present, were not of significance at the accuracy levels required. The literature has shown these materials and method of their use sufficient for fixed prosthodontics which require far finer tolerances than with implant placement ¹¹⁰. Construction of the stent, retrieval from the model and accurate placement of the stent on the reference teeth was less problematic than expected.

No consideration was given in this study to the length of implant being placed. In the clinical situation conventional radiography and surgical experience would be needed to plan the length of implant prior to stent fabrication. An OPG used in conjunction with transparent overlay templates modified for magnification is advocated. Periapicals with markers of known dimension (such as ball bearings) could be utilised ⁶⁴.

In the clinical situation a diagnostic waxup of the desired final restoration would be use to judge implant placement, in the currency study the implants were placed irrespective of the prosthetic suitability, as only the accuracy of the method was being investigated.

5.4 Measurement – Limitations

The method used in the current study was a modified version of that used by Kim et al ⁸⁴. The inability to use the image fusion techniques used in CT based studies prevent direct comparison with these studies. The method used in these CT based studies often used a measurement of the tip and base of the implant. While this produces a measurement of the accuracy, the axis of the errors is uncertain. Using a coordinate system allows the separation of each axis along with an angular measurement. The angular measurement used was a three dimensional compound angle. This gave one angular measurement for simplicity but does not allow the breakdown of the angular measurement into its individual axis components.

Inherent in the measurements in the current study was the ability to locate the chosen reference points on the adjacent teeth. Features such as cusp tips, restorations margins and wear facets were chosen. Repeat coordinate acquisition of these points was carried out to determine the reproducibility of measuring these points. The errors in recording these were a maximum of 0.38 mm (SD 0.48 mm). These errors are in the same order of magnitude as the error calculated for the accuracy of the entire technique; however examining the data set shows several outliers which skewed these data. During measurements, if the coordinate data was noticeably different the measurements were repeated. If the data were the same on the repeat, it was taken as accurately representing the sample. It was obvious that this error in reference marker measurement, in some instances is working statistically to decrease the calculated final accuracy but in an equal number it is increasing the calculated accuracy. It is assumed that the mean accuracy is hence controlled for this error.

The resolution of the coordinate measuring machine was not an issue as measurements of 0.0000001 mm are generated by the software; this is not a true measurement (as this is below the wavelength of visible light) but a calculated one. All measurements were rounded up to the nearest 0.001 mm⁵⁹.

5.4 Clinical Implications.

It can be concluded that despite the limitations of the current study, the accuracy of the model based NobelGuide[™] can be confirmed as comparable to the CT based NobelGuide[™]. This technique takes the absolute restorative driven approach of the CT based NobelGuide[™] and applies it to less complex but no less demanding, clinical situations.

Some useful applications of this technique are:

- Highly aesthetically important implant placements where the angulation, depth, mesio-distal position and labio-palatal inclination need to be precisely controlled. Flapless surgery may have advantages here as less tissue trauma from flap reflection may lead to better soft tissue outcomes certainly in the short term³³.
- Cases where bone volume is sufficient for implant placement in a number of positions or the bone volume will not dictate implant position. Here the NobelGuide[™] will help to achieve an optimal position for the fixture out of the many positions available.
- The stent does not require soft tissue contact and is completely supported by the adjacent teeth. As such there is no absolute requirement for flapless placement. The stent can be used with a conventional flap, or the implant placed flaplessly and then a flap raised for grafting procedures etc. The usefulness in cases with small bone volumes is in that, the implant can be placed in a prosthetically ideal position and then the exposed threads etc. grafted afterwards.

- Training for implant surgeons. The exercise of using a diagnostic wax-up and making the guided stent is a good exercise for the training implant surgeons or restorative dentist. The procedure highlights the restorative driven approach, the importance of three dimensional implant placements and an introduction to the NobelGuide™ system.
- The ability to fabricate provisional restorations prior to implant placement, this may allow immediate restoration, function or loading and allows the soft tissue to heal around a tooth shaped prosthesis which supports the soft tissues more anatomically than a healing cap.

5.5. Recommendations

In light of the results of this study the following recommendations can be made when using this system.

- In cases with a small bone volume preoperatively (less than 5 mm ridge width), the bone mapping data should be regarded as a guide only. If there is a likelihood of an exposed thread, pre placement grafting should be undertaken or a flap should be raised and grafting completed after placement.
- The system is suitable for placement in bounded edentulous spaces however the use of an anchor pin may help stabilise the stent in free end saddle areas. The accuracy of this however has not been investigated.
- Care must be taken when inserting the drills and fixture mounts into the guided sleeve to avoid premature binding on the metal components.

- Studies reporting the accuracy of guided surgery should include details of the statistical analysis and sign of the coordinate data to avoid overestimating the accuracy of the system being tested.
- Accuracy levels are satisfactory for dental implant placement. However at present the accuracy level is not sufficient for final prosthesis pre-production as an expandable abutment may not be suitable for single tooth replacement or short span fixed partial dentures.
- The cadaver model is an excellent analogue of the clinical situation, and is underutilised in dental implant research, however the lack of any biological response limits its use to purely mechanical tests.

6. Conclusions

Within the limitations of this study as discussed in Section 5, the following conclusions can be made.

1. The mean accuracy for the model based NobelGuide™ is 0.67 mm (SD +/- 0.55 mm) with an angular mean deviation of 3.473 degrees (SD +/- 2.51 degrees). The greatest measured error for the outliers was still within acceptable limits as set down in the published literature (linear deviations of less than 0.8mm, and angular deviations less than 3.8 degrees).
2. The current study demonstrates that the Model Based NobelGuide™ is of sufficient accuracy for dental implant placement in bounded edentulous spaces.
3. Bone mapping is of sufficient diagnostic value for implant placement in cases with large preoperative bone volumes (greater than 5 mm ridge width).
4. In small bone volumes (less than 5 mm ridge width) the need for grafting (simultaneous or otherwise) should always be suspected as the bone mapping data is not of sufficient accuracy in these cases to ensure total encasement of the implant in bone.

7. References

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Appendix 1

Appendix 2

Complete Computer Output for the Coordinate Measuring Machine software. The final values used are at the end of each output section. The angular measurement is DIM ANGL1 using the A value at the very end of each section. The B coordinate above this give the X, Y and Z coordinated the ACTL values were always used.

Procedures & Products – Powered by Procera®

NobelGuide™

perfect planning for perfect teeth

Important!
Read this manual before
proceeding with implant
system manuals!



Concept

Radiologists
Clinicians
Laboratories
and others working with NobelGuide™

40
ANNIVERSARY
Nobel Biocare™

First from Nobel Biocare.

*NOBELPERFECT® (NP, RP, WP), NOBELDIRECT® (NP, RP, WP), Brånemark System®, NOBELREPLACE™ and NOBELSPEEDY™ Implants. A complete assortment with **FDA clearance for Immediate Function™** in all single, partial and fully edentulous restorations in the mandible and maxilla.*

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ISO 13485:2003 and Council Directive 93/42/EEC
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quick start

Congratulations! You have made an excellent choice.
Welcome to the Nobel Biocare family.

Getting started

Guided System Kits

- Brånemark System® Guided Surgery Kit
- NobelReplace™ Tapered Guided Surgery Kit
- NobelReplace™ Straight Guided Surgery Kit
- NobelDirect® Guided Surgery Kit

Guided Drill Stop Kit

- For combination with
- Parallell wall implants

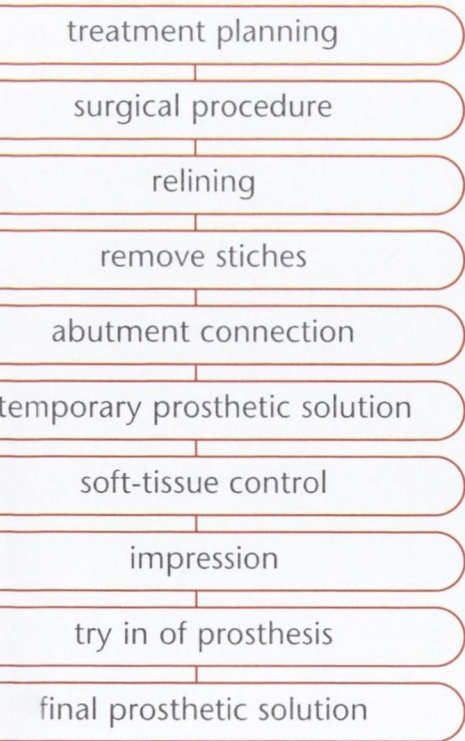
Procera Software

- Clinical Design Pro
- Clinical Design Premium

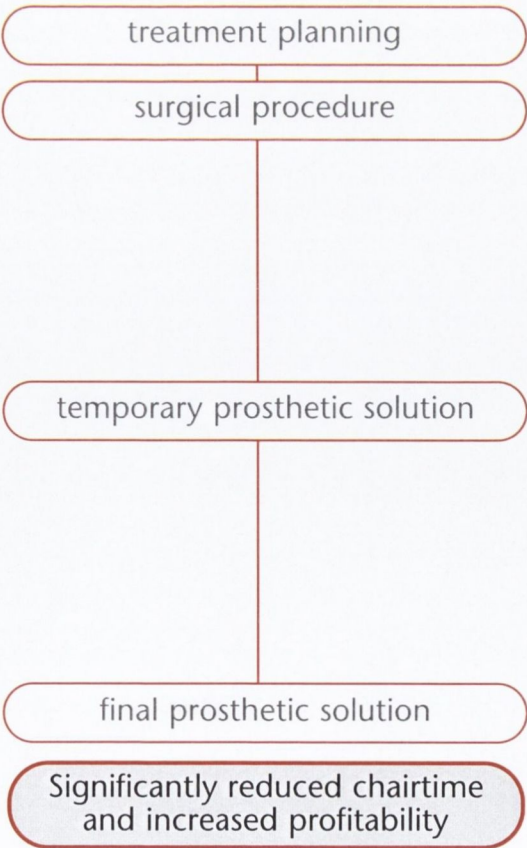


How does it work (example)

Conventional approach

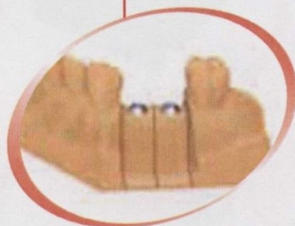


NobelGuide™ approach



quick start

model-based planning



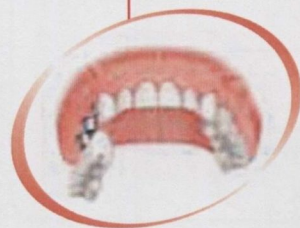
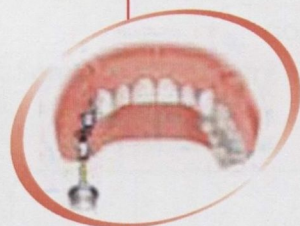
computer-based planning



visualization of anatomy



temporization



Teeth-in-an-Hour™



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Beautiful Teeth Now™

Nobel Biocare is providing dentists with more choices than ever before. But our goals remain the same:

- To ensure that your patients leave the treatment room satisfied, comfortable, with beautiful teeth and with an improved quality of life.
- To help your practice run more smoothly, efficiently and profitably.

This Concept Manual is designed to provide quick access to important information regarding NobelGuide™, read it before the implant system related manuals. The first section gives a general overall of the concept. The remaining sections go into more detail concerning Procera® Software, laboratory and CT scan procedures included in the concept.

A NobelGuide™ Training CD is included in the back cover of this manual complete with clinical movies featuring NobelGuide™.



Other related NobelGuide™ Instruction Material

- NobelGuide™ Procedures & Products Manuals for the following implant systems:
Brånemark System® MkIII Groovy, NobelReplace™ Tapered Groovy, NobelReplace™ Straight Groovy, NobelSpeedy™ Groovy, NobelSpeedy™ Replace
- NobelGuide™ manual for NobelDirect®
- Integrated Procera® Software tutorials and help files
- NobelGuide™ Interactive Training CD
- NobelGuide™ area on the Nobel Biocare Extranet. This area includes online training and FAQs

Important! *While the NobelGuide™ methods described herein give you the opportunity to pre-plan and realize patient cases, medical responsibility for planning and treatment remains that of the clinician.*

For abstracts, study references and for more information, please visit our website; www.nobelbiocare.com

Perfect Planning for Perfect Teeth

The NobelGuide™ treatment concept from Nobel Biocare enables you to transform pre-planned treatment into clinical reality.

You decide! We provide!

You decide which planning method to use (model-based or computer-based). We provide you with the components you need to create a customized Surgical Template according to your planning.

Based on the design of the Surgical Template, we then supply you with the relevant surgical and laboratory instruments and implants to facilitate the surgical procedure.

Prior to surgery, you can produce a temporary or final prosthesis that can be attached in the same session as the implant installation.

Indications: Totally and partially edentulous jaws, as well as single unit cases.

Main Benefit: Enables an easy, predictable, fast and minimally invasive dental implant and prosthetic delivery according to planning performed in advance.

NobelGuide™ components and instruments are available for treatment planning made in both computer-based and model-based environments.

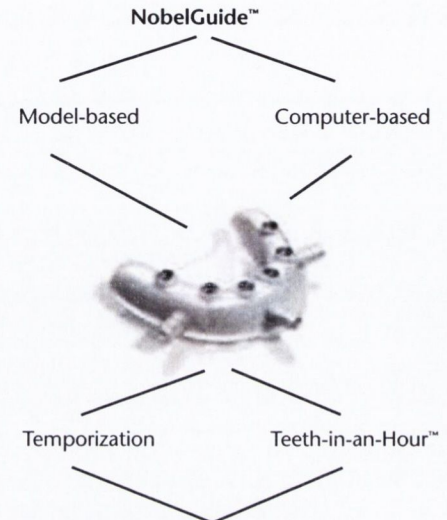
Definitions

NobelGuide™: Cases where a Surgical Template, based on model- or computer-based planning, is used to guide the clinician during surgery.

Model-based planning: Surgical planning on stone model using established techniques. No CT scan data is required. Surgical Template is made at laboratory.

Computer-based planning: CT scan data is basis for surgical planning in 3D computer environment. Surgical Template is made by Nobel Biocare.

Teeth-in-an-Hour™: The screw-retained, permanent prosthesis is attached in the same surgery session.



Patient Benefits

Maximum Comfort

The surgical treatment is based on guided keyhole surgery that is minimally invasive. This reduces pain and swelling considerably for the patient compared to conventional treatment. The new concept also reduces the number of appointments and chairtime for the patient, which means fewer interruptions in everyday life.

Cost-Saving

The patient can immediately return to work and/or social life after the treatment since the concept is built on Immediate **Function**™. For many patients this means a considerable cost-savings.

Fast Treatment

The combination of Immediate **Function**™ with temporary or final prosthesis (Teeth-in-an-Hour™) ready at surgery radically shortens treatment.

Dental Professional Benefits

Increased Predictability and Safety

By planning your treatment and transforming this into a Surgical Template you will achieve higher safety and predictability. Our 3D-surgical planning program results in exceptional predictability and optimal implant placement.

Pre-production of Prosthetics

The planning will allow for pre-production of either the final or temporary prosthetics at implant level, or combined with your choice of abutments.

Total Solution Concept

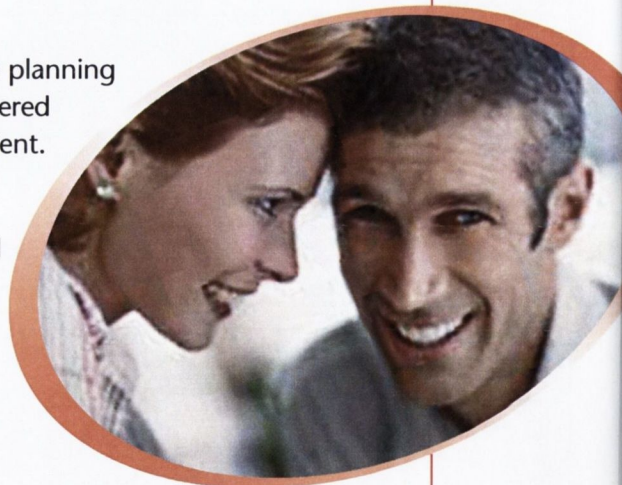
We provide a complete solution supporting you from the planning stage to completed oral rehabilitation. The concept is powered by Procera® which makes the process simple and convenient.

Business Opportunity

The NobelGuide™ concept allows you to differentiate and develop your business to stay competitive. Reducing chairtime and patient visits for treatments allows you to increase your profitability and grow your business.

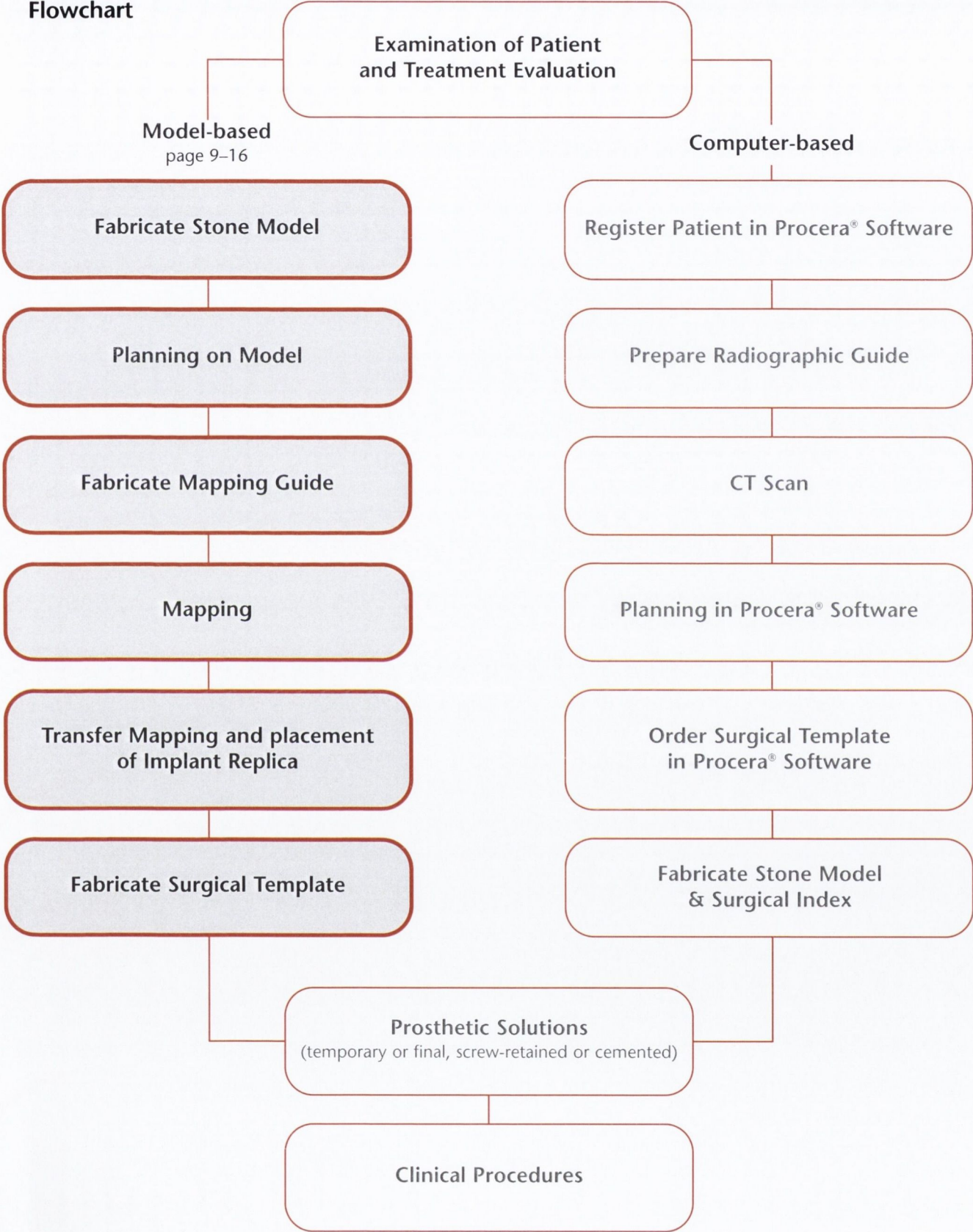
Reduced Inventory

Since clinicians know what instruments and components they need beforehand, this ensures minimal inventory requirements.



model-based planning & procedure

Flowchart



Examination of Patient and Treatment Evaluation

NobelGuide™ Model-Based Planning, is intended for single and partially edentulous jaws where the patient:

- meets general health requirements for undergoing oral surgery
- is fully healed after any dental grafting procedures
- has a sufficient amount of jaw bone
- has sufficient mouth opening capability to accommodate the surgical tooling instrumentation.

Careful preoperative evaluation and investigation has to be carried out, just as with any surgery using diagnostic radiographic imaging and other available investigation methods.

Note! *Length of implants and mesio-distal direction has to be decided based on radiographic imaging to avoid interference with adjacent roots and other anatomical structures.*

There are several methods available for model-based planning. This manual will cover one mapping technique and two different methods to place the implant replicas.

- Make impressions of both jaws and take a bite registration.

Fabricate Stone Model

- Produce a stone model.

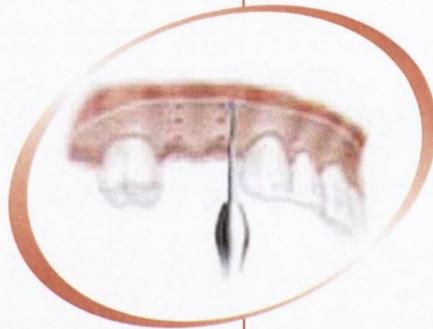
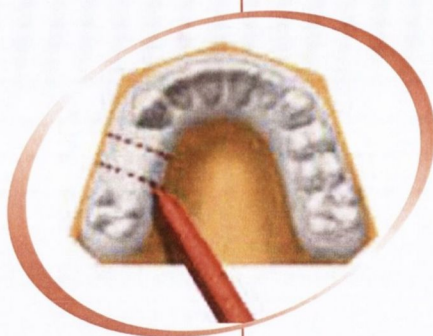
Planning of Model

- Mark the positions of the implants on the stone model with a string of wax going from the buccal to the lingual side over the soft tissue.



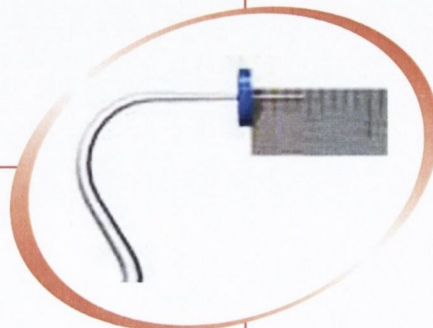
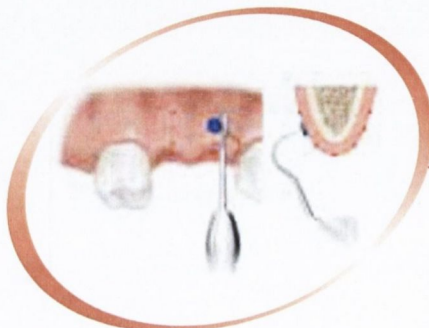
Fabricate Mapping Guide

- Press a vacuum-pressed template over the stone model to make a Mapping Guide.
- Make a series of holes in the line marked by the string of wax. It is recommended to have three buccal holes, three lingual/palatinal holes and one hole on top of the crest.



Mapping

- The Mapping Guide is placed in the patients mouth.
- Use a probe to perforate the soft tissue through the Mapping Guide.
- Measure the thickness of the soft tissue after removing the Mapping Guide by using a probe with a plastic endodontic disc.



Transfer mapping

- Mark the positions of the holes on the stone model.
- Draw lines to connect the holes as indicated in the picture.



- **Method A** Section the stone model in the line previously marked with the string of wax – where the implant should be placed.

Method A



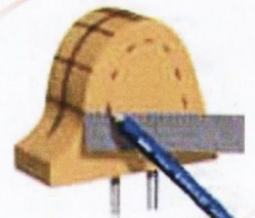
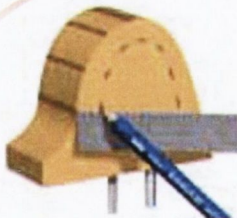
- **Method B** Section the stone model according ordinary crown and bridge work.

Method B



- The lines previously drawn on the stone model give the correct position for each depth measurement.

- Mark the mucosa thickness measurements on the side of the sectioned stone model.



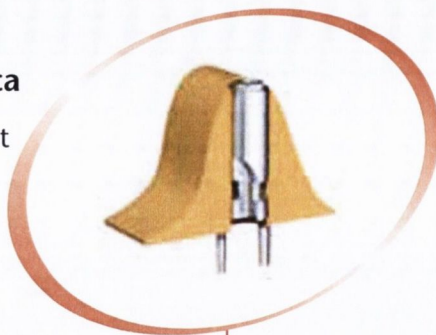
- Grind down the stone model sections according to the bone-profile, exposing the topography of the underlying bone.



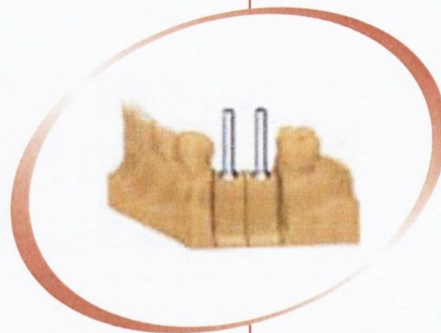
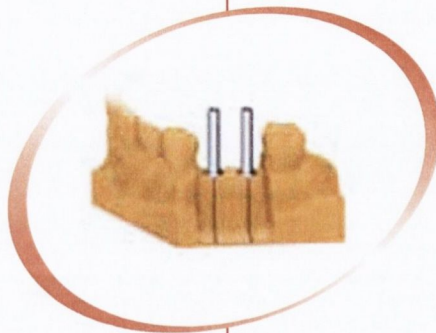
model-based planning & procedure

Placement of Implant Replica

- Grind/drill a hole for the Implant Replica in the planned implant site.
- Glue the Implant Replicas into the stone model in relation to the bone and planned implant position.



- The exact orientation and angulation of the implant can further be checked with **Guide Pins**.



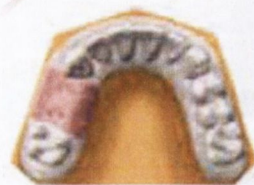
- Implant Replica in position.



model-based planning & procedure

Soft Tissue Replica

- Use the Mapping Guide as a mold for Soft Tissue Replica.



- Uncover the Implant Replica by using a Soft Tissue Punch.

Fabricate Surgical Template

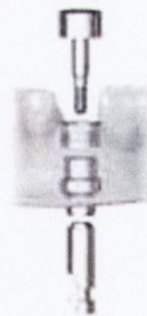
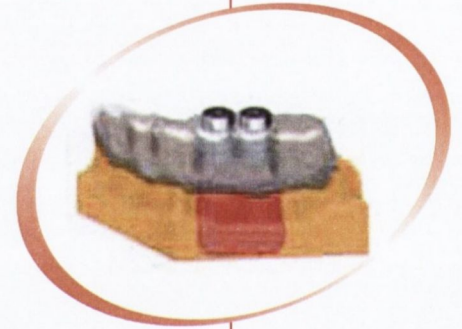
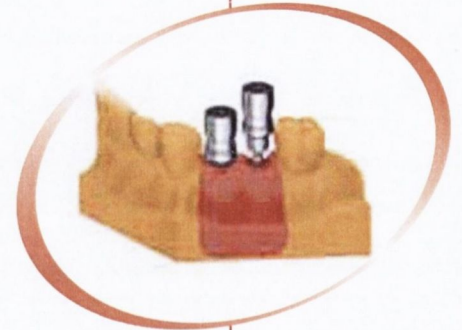
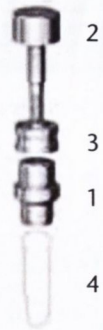
A key component to produce a Surgical Template is the **Guided cylinder w. Pin**. These two components, **Guided cylinder(1)** and **Pin(2)**, ensure the geometrical relation between the **Guided Sleeve(3)** (to be embedded in the template) and the **Implant(4)**.

- Place a **Guided Sleeve** between the **Guided Cylinder** and the **Pin** and screw it on the **Unigrip™ Screwdriver** to the **Implant Replica**.

- Block undercuts and lubricate all surfaces that are not to be embedded in the Surgical Template.
- Embed the entire jaw and the **Guided Sleeve** in acrylic. Be sure to use enough material to produce a stiff and strong Surgical Template.

- Let the acrylic set, unscrew the **Guided Cylinder w Pin** and remove the Surgical Template.
- Grind the Surgical Template into the desired shape.
- Make sure that the top of the Guided Sleeves are exposed without damaging the sleeves.

- Grind the Inspection Windows through the top of the Surgical Template to allow for inspection of the underlying dentition, and confirming the proper seating of the Surgical Template.
- The Inspection Windows should be monitored throughout the surgery in order to verify correct seating.



model-based planning & procedure

When carrying out a Guided Surgery prosthetic procedure, a wide range of Nobel Biocare abutments can be used, such as:

- Immediate Temporary Abutment (for single cases)
- Guided Abutment (for partial edentulous cases)
- Procera® Abutment
- Snappy Abutment™
- Esthetic Abutment
- Multi-Unit Abutment

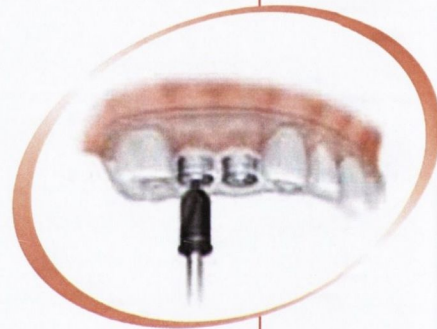
- For this indication the Procera® Abutment Zirconia is fabricated.
- A temporary bridge is fabricated in the laboratory prior to surgery.

Implant Placement

- The Surgery is performed according to the surgical procedure as described in the relevant NobelGuide™ Procedures & Products manuals using the lab-made Surgical Template.

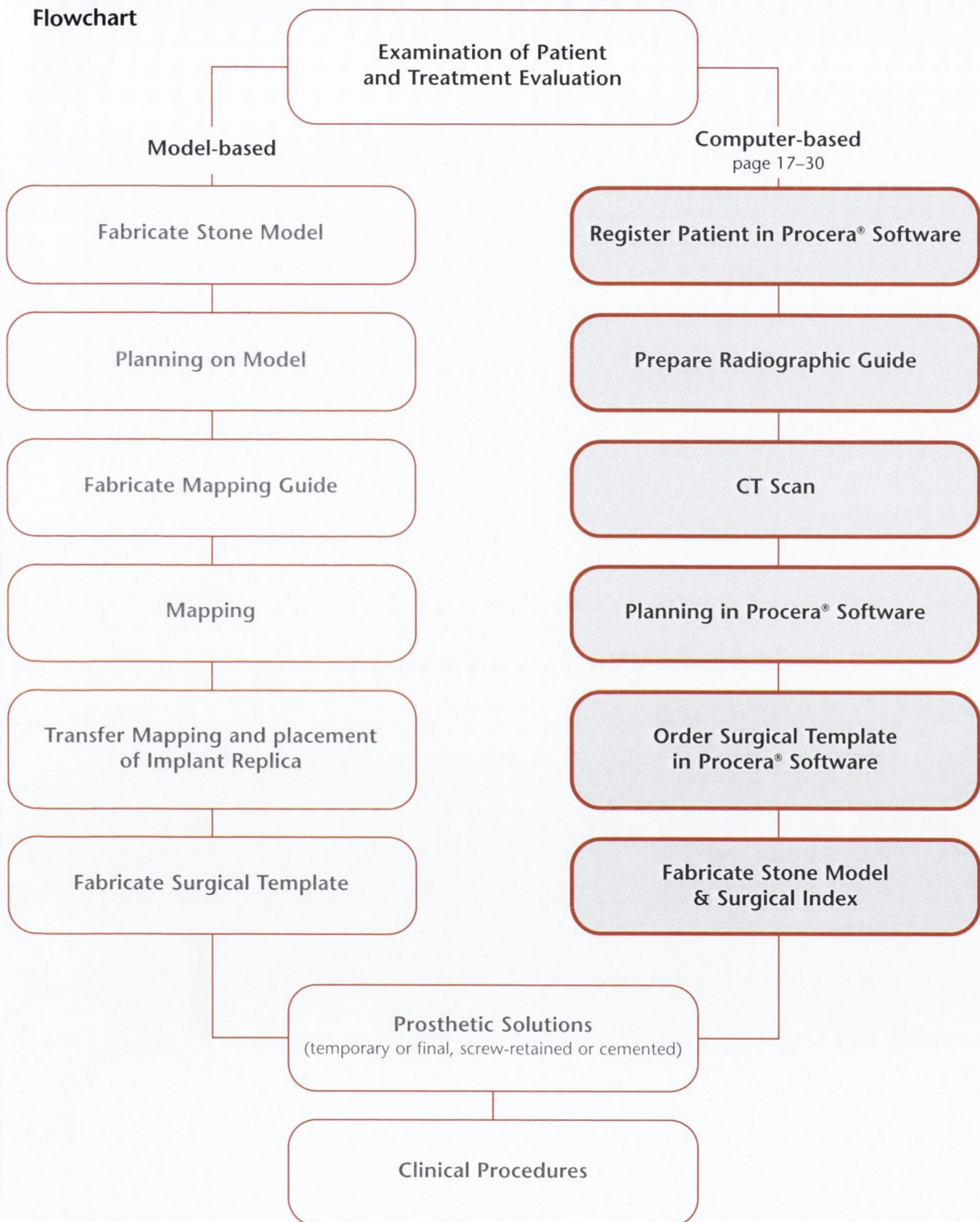
Prosthetic Procedure

- Proceed with the prosthetic procedures to connect the abutments and make a temporary cementation of the bridge.
- Follow established prosthetic procedures to make the final restoration after a sufficient healing period.



computer-based planning & procedure

Flowchart



Examination of Patient and Treatment Evaluation

NobelGuide™ Computer-Based Planning is intended for single, partial and fully edentulous jaws where the patient:

- meets general health requirements for undergoing oral surgery
- is fully healed after any dental grafting procedures
- has a sufficient amount of jaw bone
- has sufficient mouth opening capability to accommodate the surgical tooling

Register Patient in Procera® Software

Procera® Software guides you through the computer-based NobelGuide™ process. It is also used to access the Procera® Software Planning Program – Surgical (see page 24).

- Use Procera® Software to register the patient and to receive a Treatment ID number.

Prepare Radiographic Guide

- Make an impression of both jaws and a bite registration index. The index should be made using stiff material.
- For **fully edentulous jaws**, the bite registration should be made using the existing optimized prosthesis or, if needed, a newly produced prosthesis = Radiographic Guide.

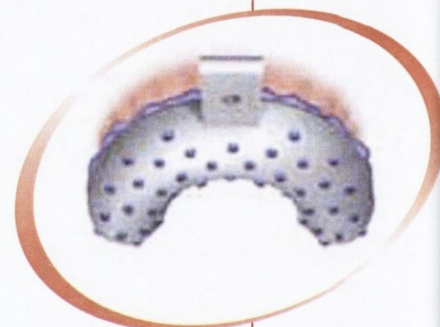
If the patient only has a few teeth in the opposing jaw and does not wear a partial prosthesis, make sure to fill up the area where the teeth are missing with occlusion index material to make contact with the alveolar ridge. This is to ensure that you have a horizontal, well-balanced bite registration.

Radiographic Guide

The Radiographic Guide is used to simulate the teeth, the soft tissue surface and edentulous space during the CT scan (see page 37). The correct design of the Radiographic Guide is a pre-requisite for successful treatment since the final outcome of the rehabilitation is determined by the Radiographic Guide.

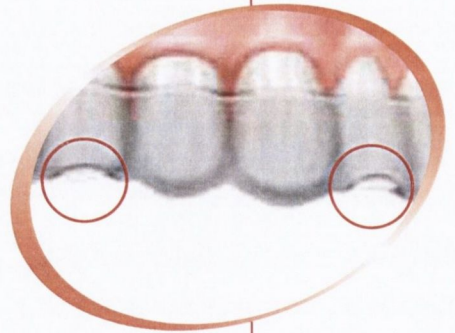
When fabricating a Radiographic Guide, please note that material has to be of acrylic or with similar density.

- In **fully edentulous cases**, the existing optimized prosthesis or, if needed, a newly produced prosthesis should be used.
- In **single and partial cases**, instruct your laboratory to fabricate an acrylic Radiographic Guide.



General design requirements Radiographic Guide

- Optimal representation of position of the restored teeth
- Optimal fit to anatomy, including;
 - Palate (if applicable)
 - Gingiva
 - Existing denture (if applicable), covering buccal, lingual and occlusal aspects
- Extend over the buccal and lingual soft tissue to the vestibular extension
- Has an ideal set-up of teeth in terms of occlusion, position, occlusal height & lip support
- Inspection windows should be made in partial and single cases
- Made in a non radio-opaque material, i.e. acrylic
- Extend back to the retromolar area
- Gutta-percha markers should be inserted



Radiographic Guide – Surgical Template

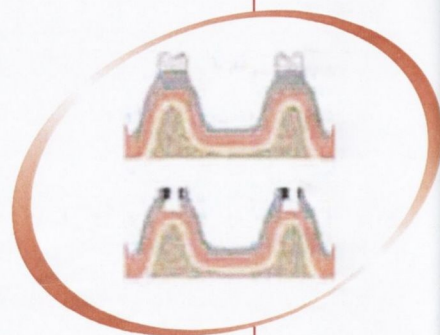
The geometry of Radiographic Guide is transferred to the Surgical Template.

Fully edentulous cases

- Use existing optimized prosthesis, or a specially produced prosthesis, Radiographic Guide, where the teeth are more optimally placed for lip support, height etc
- Cover a sufficient part of the gingiva to accommodate for **Guided Anchor Pin** placement
- Ensure that the Anchor Pins have a large enough base of thick material for optimal stiffness of the **Anchor Pin Sleeves**
- This can be further verified in the Planning Program

Single & Partial case

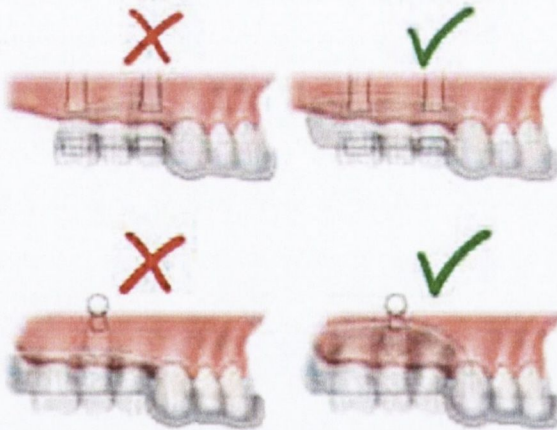
- Fabricate stone models of the patient's jaws based on the impressions
- Set up the stone model in the articulator using the bite registration index



computer-based planning & procedure

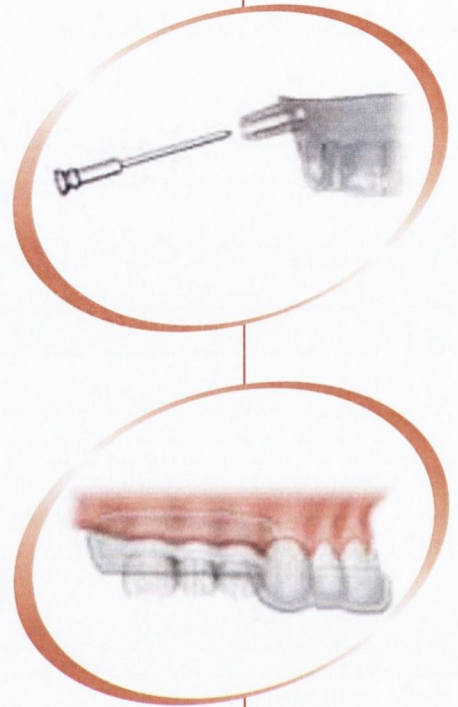
- Make a diagnostic wax-up of the patient's tooth/teeth to be restored on the stone model
- Cover the existing teeth down to the vestibular extension with a >2,5–3 mm thick resin material. Also, cover palate if applicable. Be sure to block all undercuts.
- Ensure
 - that the **Guided Anchor Pin** has a large enough base of thick material for optimal stiffness of the **Anchor Pin Sleeve**. This can be further verified in the Planning Program.
 - to cover buccal, lingual and occlusal sides for optimal retention of the Surgical Template

Maintain occlusal plane untouched in areas to be restored. Cover only the buccal and lingual aspects with plastic. This ensures that the correct occlusal plane is transferred to the Planning Program.



Prepare and make Radiographic Guide (for all indications)

- Attach the resin cover to the lingual and buccal sides of the diagnostic wax-up, but do not add material on the occlusal aspect of the diagnostic wax-up.
- Be sure that there is an optimal and homogenous bond between wax-up and acrylic.
- Make sure that the Radiographic Guide extends all the way back to rest on the retromolar area.
- Option: The set-up of teeth can also be made of acrylic as long as the geometry is optimal.
- Make the Radiographic guide of homogenous and uniform acrylic. This can be beneficial during the CT-scan.



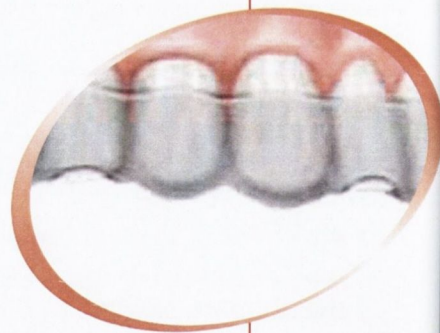
Reference Points (for all indications)

To facilitate the double CT scanning technique and the subsequent matching of the two CT scans in Procera® Software, six reference points must be inserted into the Radiographic Guide.

- Make 6 small holes ($\varnothing$ 1.5 mm) in the Radiographic Guide. The holes should be no more than 1 mm deep.
 - Place two of the reference points lingually/palatally to the canines, two disto-buccally to the premolars and two in the molar region.
 - Place the reference points at different levels in relation to the occlusal plane.
 - Fill the holes with gutta-percha.
- In single and partial cases where metal fillings are present in the existing denture, place the reference points on levels other than those of the fillings, for example, below the teeth.

Inspection windows (Partial and Single cases)

- The inspection windows made on single and partial Radiographic Guides are transferred to the Surgical Template where they allow inspection of the underlying dentition, thus confirming the proper seating of the Surgical Template during surgery.
- Make inspection windows in the Radiographic Guide through the occlusal surface over the existing dentition.
- Make 3–4 windows evenly distributed over the entire arch where one or two windows are located adjacent to the area to be restored.
- The inspection windows should preferably be placed over a cusp or a corner of a tooth so that the underlying dentition protrudes through the window.



computer-based planning & procedure

Radiographic Index

For fully edentulous cases the bite registration index is the Radiographic Index.

For partial and single cases prepare Radiographic Index.

- Insert the Radiographic Guide in the articulator and, using stiff material make an occlusal index between the Radiographic Guide and the opposing dentition.

Note in partial cases! If the patient only has a few teeth in the opposing jaw and does not wear a partial prosthesis, make sure to fill up the area where the teeth are missing with occlusion index material to make contact with the alveolar ridge. This is to ensure that you have a horizontal, well-balanced bite registration.

Deliver the Radiographic Guide and the Radiographic Index to be used during CT scan.

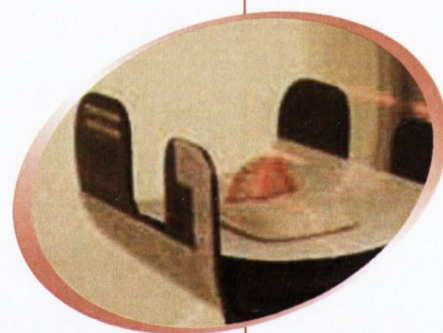
CT Scan

Double scanning technique (see page 37)

1. Patient wearing Radiographic Guide and Radiographic Index.
2. Radiographic Guide on its own Planning Program Surgical application, and order Convert the CT DICOM files into a file format compatible with Procera® Software Planning Program – Surgical.

Computer-based Planning

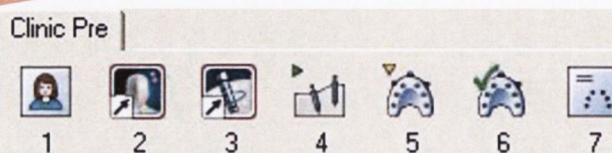
- Plan the patient in the Procera® Software Planning Program Surgical application, and order all necessary components including the customized Surgical Template and Duplicate Denture (if needed for lab work).



Planning in Procera® Software

Procera® Software is used to guide you through the computer-based NobelGuide™ process. It is also used to access the Procera® Software Planning Program – Surgical (see next page). Procera® Software is available in two versions for NobelGuide™ applications:

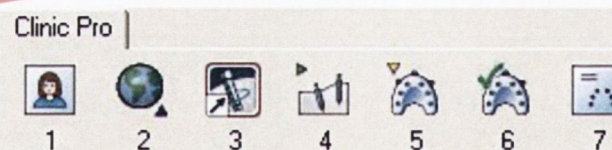
CLINICAL DESIGN PREMIUM



Clinical Design Premium includes the file conversion application for converting CT scans to a 3D planning model. When you receive the CD with CT data from your radiologist you can convert the files directly yourself, saving time and conversion costs.

1. Register and edit patient information, and receive Treatment ID
2. Start Procera® Software CT scan file converter application
3. Open Procera® Software Planning Program – Surgical (see next page)
4. Import planning into Procera® CadDesign
5. Create Surgical Template
6. Verify Surgical Template
7. Verify products (drills, instruments, etc) print operation specification documents.
Order Surgical Template and surgical/laboratory products

CLINICAL DESIGN PRO



When using Clinical Design Pro, you upload your CT scan files to Nobel Biocare's website (the NobelGuide Extranet Area) where they are converted to a 3D planning file and sent back to you for a fee.

1. Register and edit patient information, and receive Treatment ID
2. Send CT scan data to Nobel Biocare and receive 3D planning files from Nobel Biocare.
3. Open Procera® Software Planning Program – Surgical (see next page)
4. Import planning into Procera® CadDesign
5. Create Surgical Template
6. Verify Surgical Template
7. Verify products (drills, instruments, etc) print Operation Specification. Order Surgical Template and surgical/laboratory products

Important! *It is the responsibility of the clinician to store all planning and CT scan files in the same way as other radiographic material.*

Procera® Software Planning Program – Clinical Design

Procera® Software – Computer Requirements

	Requirements
Operating system	Windows 2000, Service Pack 4 or Windows XP Professional, Service Pack 2
Processor	2 GHz Pentium® IV or equivalent
Internal memory	512 MB
Graphics card*	Recent nVIDIA card with nVIDIA's latest drivers installed & internal memory of 128 MB
Monitor resolution	1024x768 or higher
Hard disk	40GB
Internet connection	Broadband

*Please note that an nVIDIA graphics card is required for the software to function

We recommend that you install the Procera® System on a dedicated stand-alone computer according to the latest hardware recommendations.

- Procera® Software Planning Program – Clinical Design is a three-dimensional (3D) image-based environment for planning the position and orientation of dental implants. It is used to determine the optimal sites for implant placement, taking into account anatomical constraints and also prosthetic and esthetic considerations.
- The planning environment is based on the concept of representing a 3D medical image volume as a 3D scene.
- This approach bridges the gap between conventional (stacks of) two-dimensional radiological images and the actual view on a patient in the operating theatre.
- In a 3D scene, you gain a good understanding of the patient's anatomy in relation to implant components, as well as to the prosthetic situation.
- Each planning process is unique and is based entirely upon the specific considerations and prerequisites that are present for each individual patient.
- The implant sites have to be planned with a minimum distance from center-to-center depending on which platform(s) you are using.
- The yellow zone around implants indicates a distance of 1.5 mm.



All Teeth Missing: Three Anchor Pins ($\varnothing$ 1.5 mm) are planned in the jawbone between the implants in an axial plane to enable proper stabilization of the Surgical Template during surgery.

Several Teeth Missing: A minimum of one Anchor Pin is recommended.

One Tooth Missing: The Surgical Template is retained on the existing denture only.

For more information about the planning procedure and Procera® Software Planning Program – Clinical Design, see:

- NobelGuide™ area on Nobel Biocare Extranet
- Integrated Software tutorial
- Procera® Software Planning Program help file

Order Surgical Template in Procera® Software

- When you have finished your planning, you must verify and approve it.
- Order the Surgical Template using the Procera® Software.

Surgical Template and Surgical Index

- Once you have received the surgical Template, verify that the Treatment ID Number is correct and instruct your lab to fabricate:
 - Stone model
 - Surgical Index
 - Temporary/final prosthesis
- Ensure that the mechanical strength of the Surgical Template is sufficient. Recommended thickness is 2.5–3 mm. Reinforce, if required, by adding plates or gel from a light cured tray material (e.g. Triad). If adding material, be sure to leave the top of the Sleeves untouched so that the reference level is maintained.
- Ensure that the Surgical Template can be correctly positioned on the teeth. Use the Inspection Window to check the position. Adjust, if required.
- Make the Surgical Index



Fabricate Stone Model and Surgical Index

General

The Surgical Index is used during surgery to position the Surgical Template on the jaw before anchoring it with Anchor Pins.

The Surgical Template is developed in a CAD environment and contains all the necessary information for making the stone model, on which a permanent or a temporary prosthesis can be fabricated.

Important information about Surgical Template

- The Surgical Template is made of a material that is sensitive to moisture and UV light. Store the Surgical Template together with a moisture absorbent in the UV protective plastic bag in which it was delivered.
- Always store the Surgical Template in a dry and dark location.
- Never expose the Surgical Template to direct sunlight.
- Never remove the moisture absorbent.
- Use a high level disinfectant (eg CidexOPA Solution) for 12 minutes at room temperature. Rinse thoroughly with sterile water. Dry quickly but without using heat.

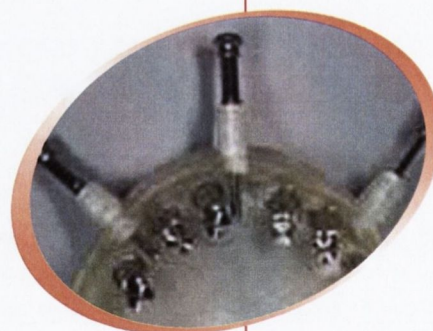
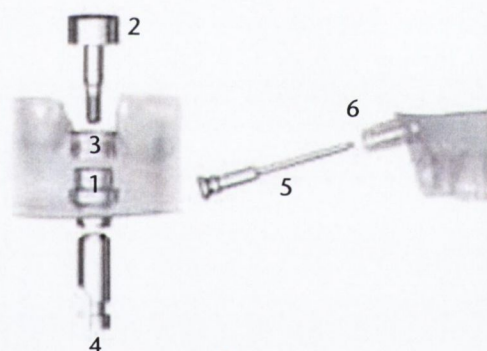
Caution! The Surgical Template may deform if exposed to liquids (even water) for more than 30 minutes.

Workflow (Fully Edentulous Case)

- Verify that the Surgical Template has the correct Treatment ID engraved on the lingual aspect and that the overall geometry of the Surgical Template is similar to that of the Radiographic Guide.

A key component to produce a Surgical Template is the **Guided cylinder w. Pin**. These two components **Guided cylinder(1)** and **Pin(2)** ensure the geometrical relation between the **Guided Sleeve(3)** and the **Implant**.

- Mount **Implant Replicas(4)** in each of the holes in the Surgical Template using the **Guided Cylinder with Pin**. The replicas and type of Guided Cylinder to use are specified in the documents accompanying the case.
- Insert **Anchor Pins(5)** into **Anchor Pin sleeves(6)**.
- Use vaseline to lubricate the bottom of the Guided Cylinder with Pin and the top surface of the Surgical Template for easier dismounting of the soft-tissue replica.
- Add soft-tissue replica. Use a very small tube to ensure that you can reach right down to the Guided Cylinder with Pin.



computer-based planning & procedure

- Use soft-tissue replica or boxing wax on the buccal side of the vestibular extension to prevent the Surgical Template from locking after the plaster has set.
- Pour in die stone model plaster.
- Use a plaster box to facilitate the manufacturing of the stone model.
- After the plaster has set, remove the Anchor Pins.
- Next remove the Guided Cylinder with Pin, using a Unigrip™ Screw-driver, and the Surgical Template.

- Use a cutter to remove the high edges around the holes.

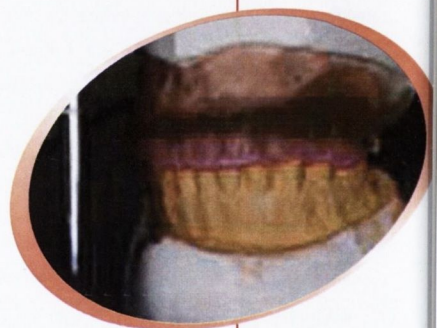
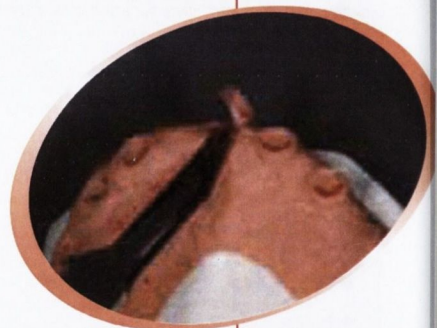
- Attach the Duplicate Denture (ordered via Procera® Software Planning Program – Surgical) or the patient's optimized prosthesis onto the stone model and mount the stone model in an articulator together with the model of the opposing jaw. Use the Radiographic Occlusal Index to verify the correct occlusion.

- Replace the Radiographic Guide with the Surgical Template and secure it with Anchor Pins.
- Add index material (e.g. A-silicone) on top of the Surgical Template.

Note! If the patient only has front teeth in the opposing jaw and does not wear a partial prosthesis, build up the bite in the area where the teeth are missing to ensure contact with the alveolar ridge. This is to ensure that you have a horizontal, well-balanced bite registration.

- Add a string of index material on the opposite jaw and bite the jaws together.
- Make sure you have enough material to get a good index.
- Put the Surgical Template back in the UV-protective plastic bag in which it was delivered (see storage instructions on page 27).

You now have a finished Surgical Template and Surgical Index, to be used during surgery.



Workflow (Single & Partially Edentulous Cases)

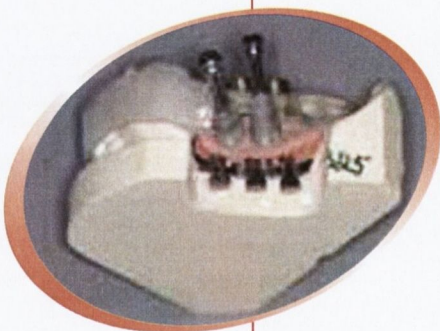
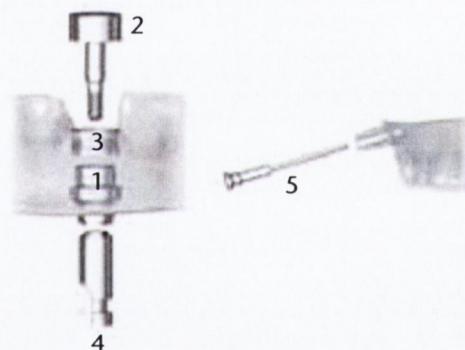
- Verify that the Surgical Template has the correct Treatment ID engraved on the lingual aspect.
- Verify the proper seating of the Surgical Template onto the original stone model of the patient using visual inspection through the inspection windows.
- Mark the approximate locations of the implants on the model.
- Cut away the section to be restored on the stone model in order to make room for the Implant Replicas.

A key component to produce a Surgical Template is the **Guided cylinder w. Pin**. These two components **Guided cylinder(1)** and **Pin(2)** ensure the geometrical relation between the **Guided Sleeve(3)** and the **Implant**.

- Mount **Implant Replicas(4)** in each of the holes in the Surgical Template using the **Guided Cylinder with Pin**. The replicas and type of Guided Cylinder to use are specified in the documents accompanying the case.
- Verify that the mounted Implant Replicas fit in the cut-away section of the stone model.
- Mount **Anchor Pins(5)** in Surgical Template if applicable.

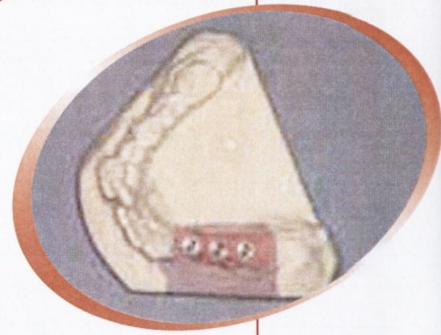
Note! When you use an engaging abutment (i.e. a rotational lock abutment), care must be taken to rotate the Implant Replicas so that the side of the hex is parallel with the curvature of the jaw (Brånemark System®), or so that a lobe of the internal connection is oriented buccally (NobelReplace™).

- Use vaseline to lubricate the bottom of the Guided Cylinder with Pin and the surface of the Surgical Template for easier dismounting of the soft-tissue replica.
- Add soft-tissue replica in the area of the restoration. Use a very small tube to ensure that you can reach right down to the Guided Cylinder with Pin.
- Position the Surgical Template on the Stone Model. Add some sticky wax to secure the proper positioning of the Surgical Template. Verify the proper seating of the Surgical Template via the inspection windows.
- Fill the area to be restored with die stone.
- Verify the proper seating of the Surgical Template via the inspection windows throughout the stone's setting process.

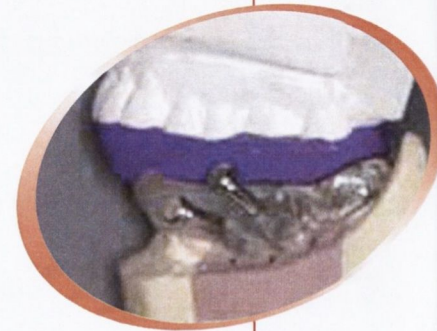


computer-based planning & procedure

- Once the plaster has set, unscrew and remove the Guided Cylinder with Pin, the Anchor Pins and the Surgical Template.
- Remove any high edges around the template cylinder holes.



- Attach the Radiographic Guide onto the stone model and mount it in an articulator together with a stone model of the opposing jaw and the Radiographic Index.
- Replace the Radiographic Guide with the Surgical Template and verify the correct position through the inspection windows.
- If applicable, secure the Surgical Template with Anchor Pins.
- Add index material (e.g. Silicone A) between the Surgical Template and the opposite jaw, and bite the jaws together.



- Make sure you have enough material to get a good index.

Note! If the patient only has front teeth in the opposing jaw and does not wear a partial prosthesis, build up the bite in the area where the teeth are missing to ensure contact with the alveolar ridge. This is to ensure that you have a horizontal, well-balanced bite registration.



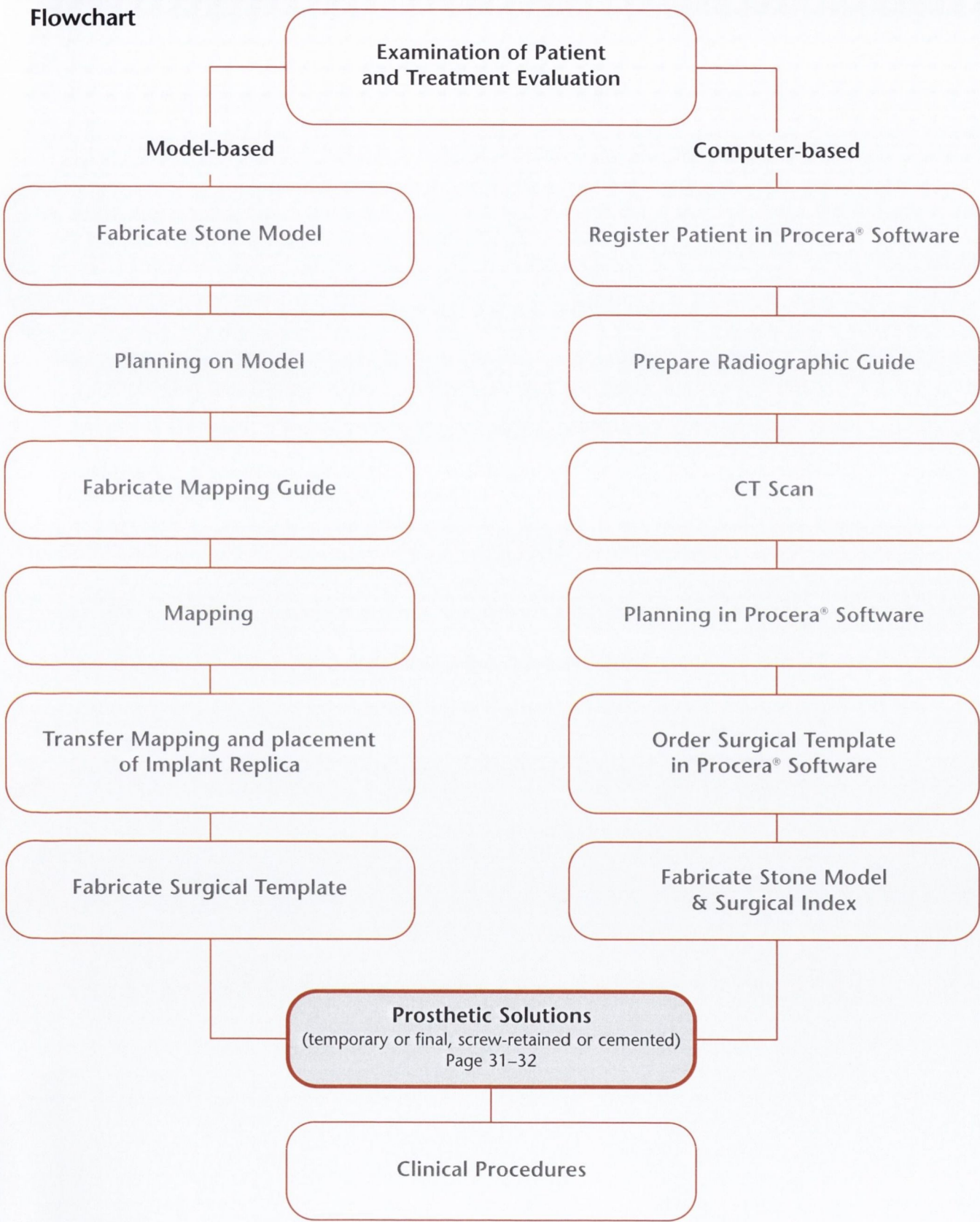
- Put the Surgical Template back in the UV-protective plastic bag in which it was delivered (see storage instructions on page 27)



You now have a finished Surgical Template and a Surgical Index, to be used during surgery.

prosthetic solutions

Flowchart



Prosthetic Solutions

NobelGuide™ provides you with complete freedom to choose the appropriate prosthetic solution to satisfy patient requirements as well as the clinical situation.

When carrying out a Guided Surgery prosthetic procedure, a wide range of Nobel Biocare abutments can be used, such as:

- Immediate Temporary Abutment (for single cases)
- Guided Abutment (for partial and fully edentulous cases)
- Procera® Abutment
- Snappy Abutment™
- Esthetic Abutment
- Multi-Unit Abutment

In both model-based and computer-based procedures, after the production of the stone model, most prosthetic procedures are the same as those for conventional treatment.

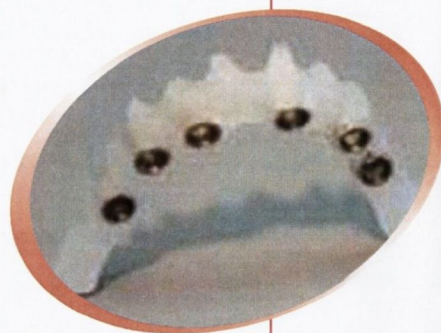
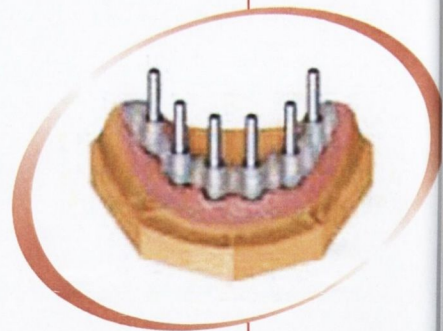
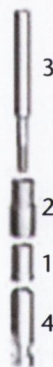
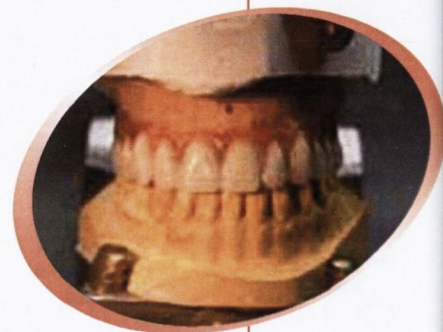
Teeth-in-an-Hour™ solutions

Below is a description for NobelGuide™ screw-retained solutions based on adjustable Guided Abutments:

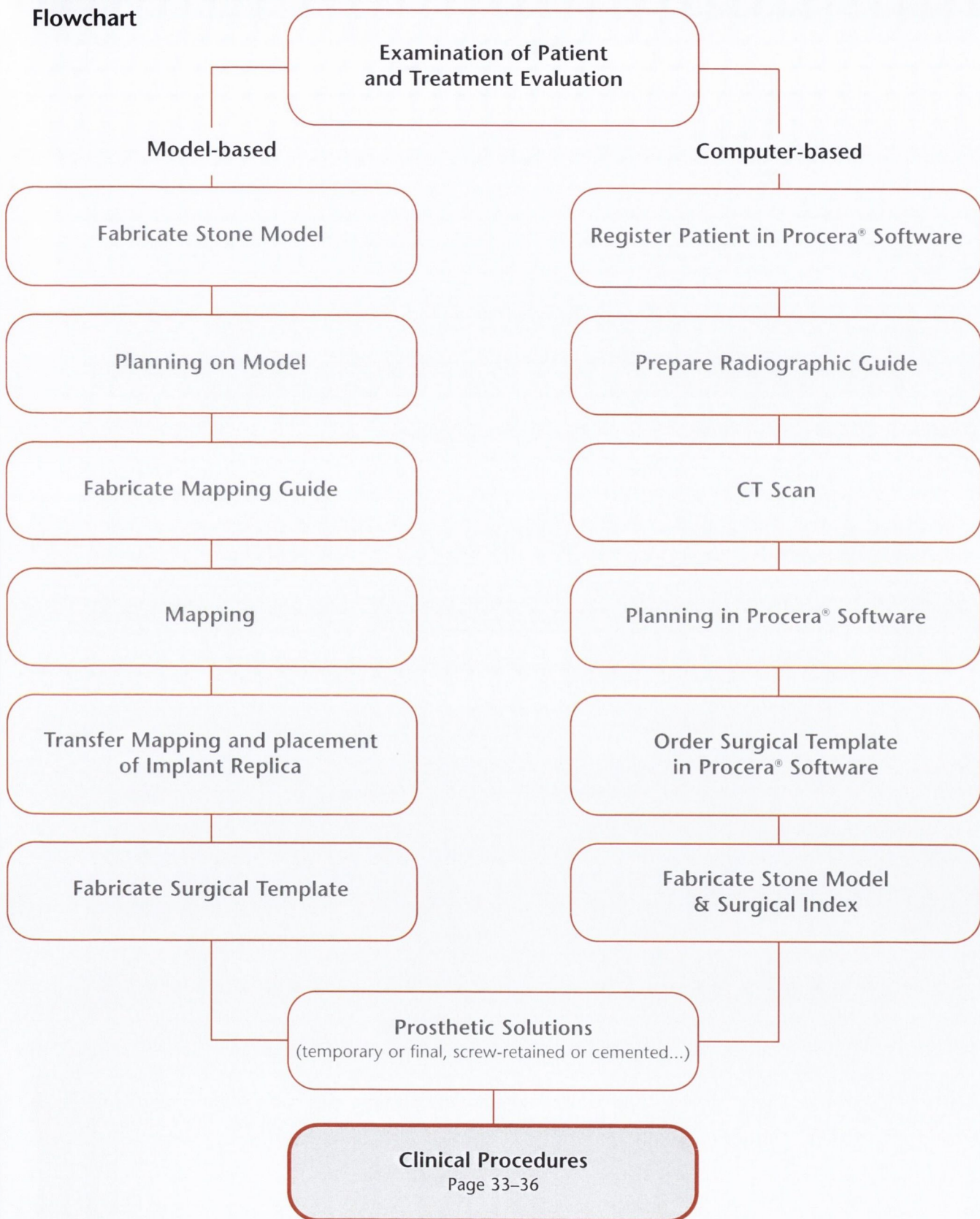
- Make a set-up of teeth in the articulator.
- If possible, use the set-up of the Radiographic Guide as a template.
- Make a silicone key to be able to replace the teeth in the same position on top of the model.
- Mount the **Guided Laboratory Abutment(1)** and **Guided Ti Temporary Coping(2)** together and connect them to the **Implant Replica(4)** using **Guide Pin(3)** and **Unigrip™ Screwdriver**.
- Make a resin replica of the bridge frame into which the **Guided Ti Temporary Copings** are embedded.
- Make a new silicone key that follows the frame. Put some silicone under the frame to create the space for the surrounding acrylic.
- Send the Resin Frame and Stone Model to Nobel Biocare's production facilities according to normal procedures for Procera® Implant Bridge.
- Once it is returned, follow normal finishing procedures.

Note! The Guided Ti Copings can also be used for temporary restorations.

See the Nobel Biocare Laboratory Procedures manual for more information relating to other prosthetic procedures.



Flowchart



Below are Quick Start examples of the surgical and prosthetic procedures relating to NobelGuide™. For a complete description see the relevant NobelGuide™ Clinical Procedure and Product Catalog.

One Tooth Missing

surgical procedure



Position Surgical Template

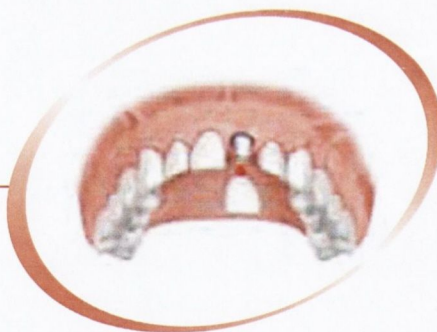


Installation of Implant

prosthetic option: temporization



Abutment Connection



Cementation of Temporary

Several Teeth Missing

surgical procedure



Anchor Surgical Template



Installation of Implants

prosthetic option: Teeth-in-an-Hour™



Guided Abutment/Final
Bridge Connection



Final Procera®
Implant Bridge

prosthetic option: temporization



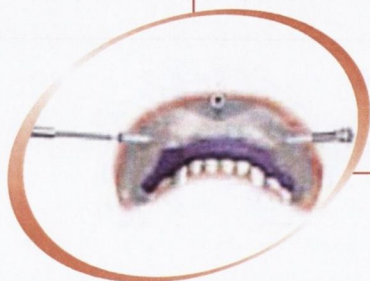
Abutment Connection



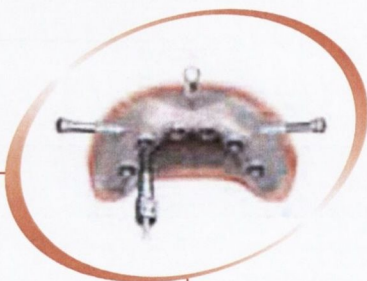
Cementation of Temporary

All Teeth Missing

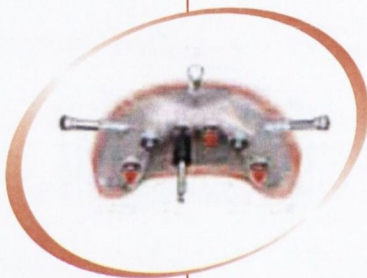
surgical procedure



Anchor Surgical Template

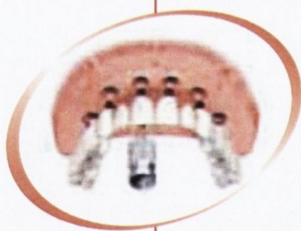


Installation of Anchor Implants



Installation of Remaining Implants

prosthetic option: Teeth-in-an-Hour™



Guided Abutment/Final
Bridge Connection

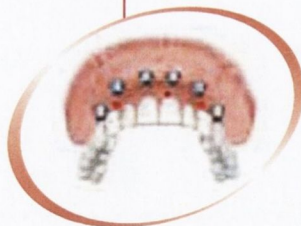


Final Procera®
Implant Bridge

prosthetic option: temporization



Abutment Connection



Cementation of Temporary

Double-scan Technique

In computer-based NobelGuide™ cases, CT scan data is used as a basis for surgical planning and for the production of a Surgical Template that guides the surgery during installation of dental implants. It is, therefore, important that the CT-scan data is a true representation of the dental anatomy of the patient.

The purpose of the double-scan is to get clear and precise data of the patient's alveolar bone and of the Radiographic Guide. These can then be shown clearly in the Procera® Software Planning Program – Surgical application.

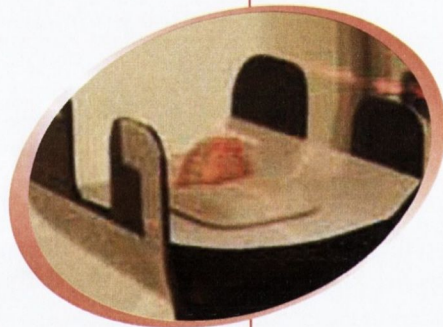
Our double-scan technique is the key to realizing this, with two CT scans being performed:

- (1) **patient scan with radiographic guide and index**
- (2) **radiographic guide scan without index**

Since the Hounsfield Units generated for the radiographic guide resemble so closely those of soft tissue, the double-scan is used to solve the problem of extracting the guide from a single CT scan.

The gutta percha markers on the Radiographic Guide are vital as reference points to perform an accurate fusion of both scans.

Important! In fully edentulous cases the patient's existing optimized prosthesis or, if needed, a newly produced prosthesis, should be used as the Radiographic Guide.



Radiographic Guide and Index

Apart from the referral with the Treatment ID number, there are two important things the patient should bring from his or her referring physician to the CT scan:

- **The Radiographic Guide**

The properties and production of the Radiographic Guide are explained on page 20. An optimal Radiographic Guide is required for a successful treatment.

- **A Radiographic Index**

This index ensures the optimal bite of the patient and is used to make sure the Radiographic Guide is in the optimal position during CT scan.

If the patient does not bring the Radiographic Guide and/or Radiographic Index:

The CT scan cannot be completed and the patient must return to the referring physician, collect the guide and/or index and be scanned some later time.

If the Radiographic Guide has no markers:

The CT scan cannot be completed and the radiologist should contact the referring dentist.



CT Scan Protocol

First Scan

The first CT scan in the procedure is a scan of the patient wearing the prepared Radiographic Guide and the Radiographic Index.

The following routine is recommended:

- Position the patient in the CT scan with the Radiographic Guide in the proper edentulous place in the mouth.

In single and partially edentulous cases: There should be holes, or “inspection windows”, drilled on the radiographic guide to verify the correct position over the remaining teeth.

- Ask the patient to lean his or her head forward with the chin close to the chest, while remaining comfortable.
- Make sure that the patient is positioned with the occlusal plane and the horizontal laser indicator parallel and coinciding (if the CT scan has a vertical laser indicator, this should be positioned between the central incisors). No gantry tilt is allowed.

In single and partially edentulous cases: When the patient has metal restorations on his or her remaining teeth, they may create disturbing artifacts on the CT scans. Try to position the patient so that most of the field of interest of the axial slices through the radiographic guide avoids passing through the metal restorations.

- The patient should be advised to remain very still during the whole scanning process, and avoid swallowing.
- Choose the correct distance between the axial slices, with a recommended maximum distance of 0.5 mm.



- When the “scout image” is shown on the screen, correction of the position of the patient should be done to a horizontal position of the hard palate. Then the field of interest for axial slices, parallel with the horizontally positioned hard palate, can be assigned.

In single and partially edentulous cases:

The “scout image” point above applies to the upper jaw. For the lower jaw, either the occlusal plane, if enough teeth remain, or the alveolar crest, alternatively the middle part of the basis mandibule around the pre-molar region will be horizontally positioned giving almost horizontal axial slices in the field of interest. No gantry tilt is allowed.

- Insert the Radiographic Index in the correct position between the Radiographic Guide and the opposing teeth. It is very important that the patient bites firmly on the index and Radiographic Guide during the scanning, to align the guide well to the soft tissue of the patient eliminating any potential air pockets.

Note: *The patient should not bite so hard that the Radiographic Guide deforms in any way.*

- Check that the position of the patient remains stable, and start scanning.

Second Scan

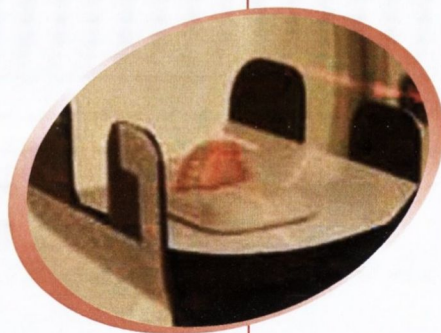
- After the first CT scan, allow the patient to leave the scanner and remove the Radiographic Guide from his or her mouth in order to scan the guide alone, without the index.
- The Radiographic Guide should be scanned in a similar position as the patient scan. Therefore, attach the guide to a suitable object of radiolucent material and position it in the CT scanner, as close to possible as it was located in the patient's mouth during the first scan.

Note! *The positioning of the Radiographic Guide is only important for a good orientation. An accurate final match is performed during pre-processing of the data using the Procera® Software Planning Program – Surgical data, based on the gutta percha-markers.*

- The material used to properly position the Radiographic Guide should be as radiolucent as possible. Make sure that the material is significantly darker after scanning than the Radiographic Guide. Paper boxes or other head-sized objects made of polyethylene and polyurethane-foam materials are suitable. Use adhesive tape to attach the Radiographic Guide to the material, such as Leukoflex, Leukosilk (BSNmedical); or Nexcare paper tape series, Durapore tapes (3M).
- Apply the same CT settings for the second scan used for the first scan, including the same distance of the axial slices.
- Start scanning.

Data Transfer of CT Data once the double-scan is completed and the Radiographic Guide and Radiographic Index have been returned to the patient, transfer the CT data to the dentist in the uncompressed DICOM 3 format for pre-processing.

Important! *It is the responsibility of the surgeon, or the radiologist, to generate CT images of optimal quality according to the standard routine of programs available for each specific device, at as low a radiation dose as possible.*



Generic CT protocol

Single slice CT scanner

Scan settings

- Spiral CT
- No gantry tilt
- Tube voltage: 120 kV
- Effective tube current: 100 mAs
- Collimation: 1 mm
- Table speed: 1 mm/rotation
- Gantry rotation speed: 1 rotation/s

Reconstruction settings

- Reconstruction interval is 0.5 mm.
- Reconstruction kernel: a sharp bone filter is preferred

Multi-slice CT scanner

Scan settings

- Spiral CT
- No gantry tilt
- Tube voltage: 120 kV
- Effective tube current: 90 mAs
- Collimation equals (number of detectors $\times$) smallest detector width
- Feed /rotation is set equal to collimation $\times$ 0.7
- Gantry rotation speed is about 0.75 seconds for one rotation

Reconstruction settings

- Reconstruction interval is half detector width (typically: 0.3 mm or 0.5 mm)
- Reconstruction kernel: a sharp bone filter is preferred.

Cone-beam CT scanner

- The cone-beam CT scanners are dedicated for imaging the skull. Follow the manufacturer's instructions to scan a jaw for oral implant planning. The side of a cubic voxel should be within the range of 0.3 – 0.5 mm.
- During reconstruction, no tilting of the axial slices is allowed.

appendix II – NobelGuide™ Implant Systems

The following Nobel Biocare implant systems are included in the NobelGuide™ treatment concept:



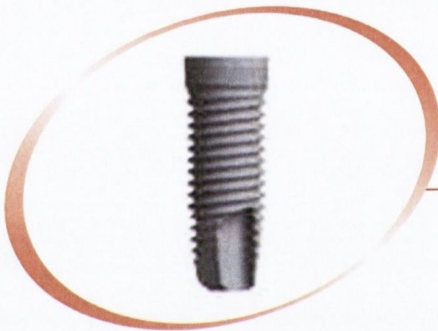
Brånemark System® Mk III Groovy
Brånemark System® Mk III Shorty



NOBELSPEEDY™ Groovy
NOBELSPEEDY™ Shorty



NOBELSPEEDY™ Replace



NOBELREPLACE™ Straight Groovy



NOBELREPLACE™ Tapered Groovy



NOBELDIRECT® Groovy Implant

Procera® Software

(for Computer-Based Planning)



- 15400 Procera® Software Clinical Design Pro*
- 15401 Procera® Software Clinical Design Premium*
- 15402 Procera® Software Clinical Premium upgrade
- 15403 Procera® Software Premium Suite*
- 15849 Procera® Software Clinical Design – Add-on Licence
- 16113 Procera® Software Clinical Premium for Lab* (for Procera® Lab)

* Please note that the Procera® Software requires an annual licence fee which is included the first year.

- 15653 Procera® Software CT Conversion

Surgical Templates

(to be ordered in Procera® Software Clinical Design Pro or Premium)



- 14750 Finished Surgical Template 5 implants and more
- 15404 Finished Surgical Template 2–4 implants
- 15405 Finished Surgical Template 1 implant
- 14751 Duplicate Denture

NobelGuide™ Surgical Kits

- 32306 **Brånemark System® Guided Surgery Kit**

Kit includes products for RP-platform

Note! Instruments for np and wp need to be ordered separately.



- 32320 Brånemark System® Guided Surgery Kit Box
- 30909 Guided Anchor Pin Ø 1.5 mm
- 32110 Brånemark System® Manual Torque Wrench Surgical
- 29167 Manual Torque Wrench Adapter Prosthetic
- 32865 Guided Implant Mount Bmk Syst RP
- 32804 Guided Template Abutment w Screw Bmk Syst RP
- 29081 Connection to handpiece
- 29149 Screwdriver Manual Unigrip™ 28 mm
- 29151 Screwdriver Machine Unigrip™ 20 mm

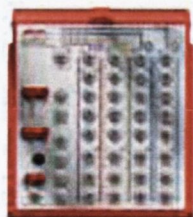


- 32797 Guided Drill Guide Kit Box
- 32813 Handle for Guided Drill Guide
- 32815 Guided Drill Guide RP to Ø 2 mm
- 32818 Guided Drill Guide RP to Ø 2.8 mm
- 32820 Guided Drill Guide RP to Ø 3 mm
- 32822 Guided Drill Guide RP to Ø 3.2 mm
- 32823 Guided Drill Guide RP to Ø 3.4 mm
- 29543 Implant sleeve holder
- 33132 Brånemark System® Guided Surgery Wall chart

- 32954 **NOBELREPLACE™ Tapered Guided Surgery Kit**

Includes instruments for NP and RP Implants.

Note! Instruments for wp and 6.0 need to be ordered separately



- 32955 NobelReplace™ Tapered Guided Surgery Kit Box
- 30909 Guided Anchor Pin Δ 1.5 mm
- 32827 Guided Drill Tapered NP 3.5 × (+) 8 mm
- 32828 Guided Drill Tapered NP 3.5 × (+) 10 mm
- 32829 Guided Drill Tapered NP 3.5 × (+) 13 mm
- 32830 Guided Drill Tapered NP 3.5 × (+) 16 mm
- 32831 Guided Drill Tapered RP 4.3 × (+) 8 mm
- 32832 Guided Drill Tapered RP 4.3 × (+) 10 mm
- 32833 Guided Drill Tapered RP 4.3 × (+) 13 mm
- 32834 Guided Drill Tapered RP 4.3 × (+) 16 mm
- 29167 Manual Torque Wrench Adapter Prosthetic





- 32856 Guided Screw Tap Tapered NP
- 32858 Guided Screw Tap Tapered RP
- 33065 NobelReplace™ Connection to Handpiece
- 29149 Screwdriver Manual Unigrip™ 28 mm
- 29151 Screwdriver Machine Unigrip™ 20 mm
- 32844 Guided Dense Bone Drill Tapered NP 3.5 × 13 mm
- 32845 Guided Dense Bone Drill Tapered NP 3.5 × 16 mm
- 32847 Guided Dense Bone Drill Tapered RP 4.3 × 13 mm
- 32848 Guided Dense Bone Drill Tapered RP 4.3 × 16 mm
- 32957 Guided Drill Guide Tapered Kit Box
- 32813 Handle for Guided Drill Guide
- 32814 Guided Drill Guide NP to Ø 2 mm
- 32815 Guided Drill Guide RP to Ø 2 mm
- 33018 Guided Drill Guide Tapered RP to NP
- 32864 Guided Implant Mount NobRpl NP
- 32866 Guided Implant Mount NobRpl RP
- 32803 Guided Template Abutment w Screw NobRpl NP
- 32805 Guided Template Abutment w Screw NobRpl RP
- 29543 Implant Sleeve Holder
- 33134 NobelReplace™ Tapered Guided Surgery Wall chart

32794

NobelReplace™ Straight Guided Surgery Kit

Includes instruments for RP Implants.

Note! Instruments for NP, WP and 6.0 need to be ordered separately



- 32796 NobelReplace™ Straight Guided Surgery Kit Box
- 30909 Guide Anchor Pin Ø 1.5 mm
- 29167 Manual Torque Wrench Adapter Prosthetic
- 32866 Guided Implant Mount NobRpl RP
- 32805 Guided Template Abutment w Screw NobRpl RP
- 33065 NobelReplace™ Connection to handpiece
- 29149 Screwdriver Manual Unigrip™ 28 mm
- 29151 Screwdriver Machine Unigrip™ 20 mm



- 32797 Guided Drill Guide Kit Box
- 32813 Handle for Guided Drill Guide
- 32815 Guided Drill Guide RP to Ø 2 mm
- 32818 Guided Drill Guide RP to Ø 2.8 mm
- 32820 Guided Drill Guide RP to Ø 3 mm
- 32822 Guided Drill Guide RP to Ø 3.2 mm
- 32823 Guided Drill Guide RP to Ø 3.4 mm
- 29543 Implant sleeve holder
- 33133 NobelReplace™ Straight Guided Surgery Wall chart

Drill Stops

33085

Guided Drill Stop Kit

Included in kit:

- 33086 Guided Drill Stop Kit Box
- 33063 Drill Stop Ø 2
- 33064 Drill Stop Ø 2.8
- 33075 Drill Stop Ø 3
- 33077 Drill Stop Ø 3.2
- 33078 Drill Stop Ø 3.4
- 33080 Drill Stop Ø 3.8
- 33081 Drill Stop Ø 4.2



Manuals



- 15684 GB Procedures & Products NobelGuide™ NOBELSPEEDY™ Groovy
- 15691 GB Procedures & Products NobelGuide™ NOBELSPEEDY™ Replace
- 15699 GB Procedures & Products NobelGuide™ NOBELREPLACE™ Straight
- 15706 GB Procedures & Products NobelGuide™ NOBELREPLACE™ Tapered
- 15713 GB Procedures & Products NobelGuide™ Brånemark System®
- 15662 GB Procedures & Products NobelGuide™ NOBELDIRECT®

Lab Components



- 32754 Guided Sleeve NP
- 32765 Guided Sleeve RP
- 32766 Guided Sleeve 6.0/WP



- 30909 Guided Anchor Pin Ø 1.5mm
- 30908 Guided Anchor Pin Sleeve Ø 1.5mm 3/pkg



- 32873 Guided Ti Temporary Coping NP
- 32874 Guided Ti Temporary Coping RP
- 32876 Guided Ti Temporary Coping 6.0/WP

- 15-1026 Procera® Implant Bridge Teeth-in-an-Hour™ NP
- 15-1027 Procera® Implant Bridge Teeth-in-an-Hour™ RP
- 15-1028 Procera® Implant Bridge Teeth-in-an-Hour™ 6.0/WP

Lab Components Brånemark System®



- 32768 Guided Cylinder w Pin Unigrip™ Bmk Syst NP
- 32770 Guided Cylinder w Pin Unigrip™ Bmk Syst RP
- 32774 Guided Cylinder w Pin Unigrip™ Bmk Syst WP



- 32879 Guided Pin 28 mm Bmk Syst NP
- 32881 Guided Pin 28 mm Bmk Syst RP
- 32884 Guided Pin 28 mm Bmk Syst WP



- 32887 Guided Laboratory Screw Bmk Syst NP
- 32889 Guided Laboratory Screw Bmk Syst RP
- 32892 Guided Laboratory Screw Bmk Syst WP



- 32895 Guided Laboratory Abutment Bmk Syst NP
- 32897 Guided Laboratory Abutment Bmk Syst RP
- 32899 Guided Laboratory Abutment Bmk Syst WP



- 32903 Guided Abutment Bmk Syst NP
- 32905 Guided Abutment Bmk Syst RP
- 32907 Guided Abutment Bmk Syst WP



Lab Components NOBELREPLACE™

32769	Guided Cylinder w Pin Unigrip™ NobRpl NP
32771	Guided Cylinder w Pin Unigrip™ NobRpl RP
32775	Guided Cylinder w Pin Unigrip™ NobRpl WP
32778	Guided Cylinder w Pin Unigrip™ NobRpl 6.0
32880	Guided Pin 28mm NobRpl NP
32882	Guided Pin 28mm NobRpl RP
32885	Guided Pin 28mm NobRpl WP/6.0
32888	Guided Laboratory Screw NobRpl NP
32890	Guided Laboratory Screw NobRpl RP
32893	Guided Laboratory Screw NobRpl WP/6.0
32896	Guided Laboratory Abutment NobRpl NP
32898	Guided Laboratory Abutment NobRpl RP
32900	Guided Laboratory Abutment NobRpl WP
32902	Guided Laboratory Abutment NobRpl 6.0
32904	Guided Abutment NobRpl NP
32906	Guided Abutment NobRpl RP
32908	Guided Abutment NobRpl WP
32910	Guided Abutment NobRpl 6.0

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Guided Drill Guide RP to Ø3.2mm	.32822	.46,47
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Guided Drill Guide Tapered RP to NP	.33018	.47
G		
Guided Cylinder		
Guided Cylinder w Pin Unigrip™ NobRpl NP	.32769	.49
Guided Cylinder w Pin Unigrip™ NobRpl RP	.32771	.49
Guided Cylinder w Pin Unigrip™ NobRpl WP	.32775	.49
Guided Cylinder w Pin Unigrip™ NobRpl 6.0	.32778	.49
Guided Cylinder w Pin Unigrip™ Bmk Syst NP	.32768	.48
Guided Cylinder w Pin Unigrip™ Bmk Syst RP	.32770	.48
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Drill Stop Ø3	.33075	.47
Drill Stop Ø3.2	.33077	.47
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Drill Stop Ø3.8	.33080	.47
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Guided Pin 28mm NobRpl RP	.32882	.49
Guided Pin 28mm NobRpl WP/6.0	.32885	.49
Guided Pin 28mm Bmk Syst NP	.32879	.48
Guided Pin 28mm Bmk Syst RP	.32881	.48
Guided Pin 28mm Bmk Syst WP	.32884	.48
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Guided Laboratory Abutment NobRpl RP	.32898	.49
Guided Laboratory Abutment NobRpl WP	.32900	.49
Guided Laboratory Abutment NobRpl 6.0	.32902	.49

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Guided Laboratory Abutment Bmk Syst RP	.32897	.48
Guided Laboratory Abutment Bmk Syst WP	.32899	.48

Laboratory Screw

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Guided Laboratory Screw NobRpl RP	.32890	.49
Guided Laboratory Screw NobRpl WP/6.0	.32893	.49

Guided Laboratory Screw Bmk Syst NP	.32887	.48
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GS NOBELSPEEDY™ Replace	.15691	GB .48
GS NOBELREPLACE™ Straight	.15699	GB .48
GS NOBELREPLACE™ Tapered	.15706	GB .48
GS Brånemark System® Mk III	.15713	GB .48
GS NOBELDIRECT®	.15662	GB .48

P**Procera® Implant Bridge**

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Procera® Implant Bridge Teeth-in-an-Hour™ RP	.15-1027	.35,36,48
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15691 GB	GS NOBELSPEEDY™ Replace	48
15699 GB	GS NOBELREPLACE™ Straight	48
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our qualifications are

your security

Achievements

- Inheritors and developers of the work of Professor Brånemark – founder of modern implantology. World leaders in the field
- Providers of the most comprehensive and flexible crown, bridge and implant solutions in the world
- Creators of unique biocompatible material TiUnite® for optimal osseointegration, Immediate **Function**™ and Soft Tissue Integration™
- Creators of CAD/CAM dentistry
- Creators of unique Procera® System – one seamless procedure from 3D planning to fully guided surgery right through to customized ceramic restoration
- FDA cleared for Immediate **Function**™ (except 3.0 and Zygoma)
- FDA cleared for Teeth-in-an-Hour™ in 2004

Quality

- Zero non-conformities in 2004 FDA inspection of Nobel Biocare production units in Göteborg, Karlskoga and Stockholm

Research

- Formal collaboration with over 50 academic institutions and 600 independent scientists around the world
- More clinical studies on immediate or early loading than all other competitors combined (Medline Feb 2005)
- More prospective clinical studies with at least 5-year follow-up than all other competitors combined (Berglund et al 2002)

Support

- 165.000 customers trained by 1.985 dental professionals in 37 countries and in 19 languages, during 2004
- Own sales organizations with local Nobel Biocare staff in 29 countries
- Leading business website in 8 languages, with complete online service supplying all products and at least 500 courses available at all times



SOS-CHILDREN'S VILLAGES



Nobel Biocare cares about the environment and all production units are certified according to Environmental Management System ISO 14001

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ANNIVERSARY
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R 10 MAX – 2 IMPLANTS – Distal Implant

STARTUP =ALIGNMENT/START,RECALL:, LIST= YES

ALIGNMENT/END

MODE/MANUAL

LOADPROBE/SEAN

TIP/T1A0B0, SHANKIJK=0, 0, 1, ANGLE=0

PNT1 =FEAT/POINT,RECT

THEO/-33.847,10.499,-605.142,0,0,1

ACTL/-33.847,10.499,-605.142,0,0,1

MEAS/POINT,1

HIT/BASIC,-33.847,10.499,-605.142,0,0,1,-33.847,10.499,-605.142,USE THEO

= YES

ENDMEAS/

PNT2 =FEAT/POINT,RECT

THEO/-32.918,10.612,-589.904,0,0,1

ACTL/-32.918,10.612,-589.904,0,0,1

MEAS/POINT,1

HIT/BASIC,-32.918,10.612,-589.904,0,0,1,-32.918,10.612,-589.904,USE THEO

= YES

ENDMEAS/

LIN1 =FEAT/LINE,RECT,UNBND

THEO/-33.847,10.499,-605.142,0.0608445,0.0074243,0.9981196

ACTL/-33.847,10.499,-605.142,0.0608445,0.0074243,0.9981196

CONSTR/LINE,BF,3D,PNT1,PNT2,,

A1 =ALIGNMENT/START,RECALL:STARTUP, LIST= YES

ALIGNMENT/TRANS,XAXIS,PNT1

ALIGNMENT/TRANS,YAXIS,PNT1

ALIGNMENT/TRANS,ZAXIS,PNT1

ALIGNMENT/END

A2 =ALIGNMENT/START,RECALL:A1, LIST= YES

ALIGNMENT/ROTATE,ZPLUS,TO,LIN1,ABOUT,ZPLUS

ALIGNMENT/END

A =FEAT/POINT,RECT

THEO/7.495,-0.858,10.285,0,0,1

ACTL/7.495,-0.858,10.285,0,0,1

MEAS/POINT,1

HIT/BASIC,7.495,-0.858,10.285,0,0,1,7.495,-0.858,10.285,USE THEO = YES

ENDMEAS/

B =FEAT/POINT,RECT

THEO/2.651,-6.272,9.138,0,0,1

ACTL/2.651,-6.272,9.138,0,0,1

MEAS/POINT,1

HIT/BASIC,2.651,-6.272,9.138,0,0,1,2.651,-6.272,9.138,USE THEO = YES

ENDMEAS/

C =FEAT/POINT,RECT

```

THEO/-4.603,9.1,7.182,0,0,1
ACTL/-4.603,9.1,7.182,0,0,1
MEAS/POINT,1
HIT/BASIC,-4.603,9.1,7.182,0,0,1,-4.603,9.1,7.182,USE THEO = YES
ENDMEAS/
PLN1    =FEAT/PLANE,RECT
THEO/2.208,0.642,8.912,-0.2408793,0.0098014,0.9705056
ACTL/2.208,0.642,8.912,-0.2408793,0.0098014,0.9705056
CONSTR/PLANE,BFRE,A,B,C,,
LIN2    =FEAT/LINE,RECT,UNBND
THEO/7.495,-0.858,10.285,-0.7573805,0.6234084,-0.1942595
ACTL/7.495,-0.858,10.285,-0.7573555,0.6234349,-0.1942718
CONSTR/LINE,BF,3D,A,C,,
A0      =ALIGNMENT/START,RECALL:A2, LIST= YES
ALIGNMENT/ROTATE,XPLUS,TO,LIN2,ABOUT,ZPLUS
ALIGNMENT/END
B       =FEAT/POINT,RECT
THEO/-6.033,3.158,9.138,0,0,1
ACTL/-6.033,3.158,9.138,0,0,1
MEAS/POINT,1
HIT/BASIC,-6.033,3.158,9.138,0,0,1,-6.033,3.158,9.138,USE THEO = YES
ENDMEAS/
DIM ANGL2= 3D ANGLE (TRUE) FROM PLANE PLN1 TO LINE LIN1 ,$
GRAPH=OFF TEXT=OFF MULT=10.00 OUTPUT=BOTH
AX NOMINAL  +TOL  -TOL  MEAS    MAX    MIN    DEV
OUTTOL
A   72.573    0.010   0.010   72.573   72.573   72.573   0.000   0.000 ----#----
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Mesial Implant

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STARTUP  =ALIGNMENT/START,RECALL:, LIST= YES
ALIGNMENT/END
MODE/MANUAL
LOADPROBE/SEAN
TIP/T1A0B0, SHANKIJK=0, 0, 1, ANGLE=0
PNT1    =FEAT/POINT,RECT
THEO/-35.657,17.075,-591.041,0,0,1
ACTL/-35.657,17.075,-591.041,0,0,1
MEAS/POINT,1
HIT/BASIC,-35.657,17.075,-591.041,0,0,1,-35.657,17.075,-591.041,USE THEO
= YES
ENDMEAS/
PNT2    =FEAT/POINT,RECT
THEO/-37.039,16.857,-606.039,0,0,1
ACTL/-37.039,16.857,-606.039,0,0,1
MEAS/POINT,1
```



```

HIT/BASIC,-37.039,16.857,-606.039,0,0,1,-37.039,16.857,-606.039,USE THEO
= YES
ENDMEAS/
LIN1  =FEAT/LINE,RECT,UNBND
      THEO/-37.039,16.857,-606.039,0.0917693,0.0144546,0.9956754
      ACTL/-37.039,16.857,-606.039,0.0917693,0.0144546,0.9956754
      CONSTR/LINE,BF,3D,PNT2,PNT1,,
A0    =ALIGNMENT/START,RECALL:STARTUP, LIST= YES
      ALIGNMENT/TRANS,XAXIS,PNT2
      ALIGNMENT/TRANS,YAXIS,PNT2
      ALIGNMENT/TRANS,ZAXIS,PNT2
      ALIGNMENT/END
A1    =ALIGNMENT/START,RECALL:A0, LIST= YES
      ALIGNMENT/ROTATE,ZPLUS,TO,LIN1,ABOUT,ZPLUS
      ALIGNMENT/END
A      =FEAT/POINT,RECT
      THEO/10.586,-7.554,11.291,0,0,1
      ACTL/10.586,-7.554,11.291,0,0,1
      MEAS/POINT,1
      HIT/BASIC,10.586,-7.554,11.291,0,0,1,10.586,-7.554,11.291,USE THEO = YES
      ENDMEAS/
B      =FEAT/POINT,RECT
      THEO/5.525,-13.123,10.143,0,0,1
      ACTL/5.525,-13.123,10.143,0,0,1
      MEAS/POINT,1
      HIT/BASIC,5.525,-13.123,10.143,0,0,1,5.525,-13.123,10.143,USE THEO = YES
      ENDMEAS/
C      =FEAT/POINT,RECT
      THEO/-1.208,2.919,8.045,0,0,1
      ACTL/-1.208,2.919,8.045,0,0,1
      MEAS/POINT,1
      HIT/BASIC,-1.208,2.919,8.045,0,0,1,-1.208,2.919,8.045,USE THEO = YES
      ENDMEAS/
PLN1  =FEAT/PLANE,RECT
      THEO/5.334,-5.955,9.873,-0.2456545,0.0236434,0.9690691
      ACTL/5.334,-5.955,9.873,-0.2456545,0.0236434,0.9690691
      CONSTR/PLANE,BFRE,A,B,C,,
LIN2  =FEAT/LINE,RECT,UNBND
      THEO/10.586,-7.554,11.291,-0.7323931,0.6503606,-0.2015727
      ACTL/10.586,-7.554,11.291,-0.7323836,0.6503863,-0.201524
      CONSTR/LINE,BF,3D,A,C,,
A2    =ALIGNMENT/START,RECALL:A1, LIST= YES
      ALIGNMENT/ROTATE,XPLUS,TO,LIN2,ABOUT,ZPLUS
      ALIGNMENT/END
B      =FEAT/POINT,RECT
      THEO/-12.845,6.144,10.143,0,0,1

```

ACTL/-12.844,6.144,10.143,0,0,1

MEAS/POINT,1

HIT/BASIC,-12.844,6.144,10.143,0,0,1,-12.844,6.144,10.143,USE THEO = YES

ENDMEAS/

DIM ANGL2= 3D ANGLE (TRUE) FROM PLANE PLN1 TO LINE LIN1 , \$

GRAPH=OFF TEXT=OFF MULT=10.00 OUTPUT=BOTH

AX	NOMINAL	+TOL	-TOL	MEAS	MAX	MIN	DEV
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OUTTOL

A	70.506	0.010	0.010	70.506	70.506	70.506	0.000	0.000	----#----
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R226 – 2 IMPLANTS test

DISTAL IMPLANT

```
STARTUP  =ALIGNMENT/START,RECALL:, LIST= YES
          ALIGNMENT/END
          MODE/MANUAL
          LOADPROBE/SEAN
          TIP/T1A0B0, SHANKIJK=0, 0, 1, ANGLE=0
PNT1     =FEAT/POINT,RECT
          THEO/10.252,33.774,-611.105,0,0,1
          ACTL/10.252,33.774,-611.105,0,0,1
          MEAS/POINT,1
          HIT/BASIC,10.252,33.774,-611.105,0,0,1,10.252,33.774,-611.105,USE THEO =
YES
          ENDMEAS/
PNT2     =FEAT/POINT,RECT
          THEO/10.253,33.775,-626.075,0,0,1
          ACTL/10.253,33.775,-626.075,0,0,1
          MEAS/POINT,1
          HIT/BASIC,10.253,33.775,-626.075,0,0,1,10.253,33.775,-626.075,USE THEO =
YES
          ENDMEAS/
LIN1     =FEAT/LINE,RECT,UNBND
          THEO/10.253,33.775,-626.075,-0.0000882,-0.0000688,1
          ACTL/10.253,33.775,-626.075,-0.0000882,-0.0000688,1
          CONSTR/LINE,BF,3D,PNT2,PNT1,,
A2        =ALIGNMENT/START,RECALL:STARTUP, LIST= YES
          ALIGNMENT/TRANS,XAXIS,PNT2
          ALIGNMENT/TRANS,YAXIS,PNT2
          ALIGNMENT/TRANS,ZAXIS,PNT2
          ALIGNMENT/END
A3        =ALIGNMENT/START,RECALL:A2, LIST= YES
          ALIGNMENT/ROTATE,ZPLUS,TO,LIN1,ABOUT,ZPLUS
          ALIGNMENT/END
A         =FEAT/POINT,RECT
          THEO/2.836,10.143,11.459,0,0,1
          ACTL/2.836,10.143,11.459,0,0,1
          MEAS/POINT,1
          HIT/BASIC,2.836,10.143,11.459,0,0,1,2.836,10.143,11.459,USE THEO = YES
          ENDMEAS/
B         =FEAT/POINT,RECT
          THEO/-4.866,6.732,10.394,0,0,1
          ACTL/-4.866,6.732,10.394,0,0,1
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MEAS/POINT,1
HIT/BASIC,-4.866,6.732,10.394,0,0,1,-4.866,6.732,10.394,USE THEO = YES
ENDMEAS/
C    =FEAT/POINT,RECT
THEO/13.05,-19.092,13.699,0,0,1
ACTL/13.05,-19.092,13.699,0,0,1
MEAS/POINT,1
HIT/BASIC,13.05,-19.092,13.699,0,0,1,13.05,-19.092,13.699,USE THEO = YES
ENDMEAS/
PLN1  =FEAT/PLANE,RECT
THEO/3.894,-0.775,11.867,-0.1473826,0.0242784,0.9887815
ACTL/3.894,-0.775,11.867,-0.1473826,0.0242784,0.9887815
CONSTR/PLANE,BFRE,A,B,C,,
LIN2  =FEAT/LINE,RECT,UNBND
THEO/2.836,10.143,11.459,0.3289659,-0.941582,0.0721445
ACTL/2.836,10.143,11.459,0.328959,-0.9415838,0.0721525
CONSTR/LINE,BF,3D,A,C,,
A4    =ALIGNMENT/START,RECALL:A3, LIST= YES
ALIGNMENT/ROTATE,XPLUS,TO,LIN2,ABOUT,ZPLUS
ALIGNMENT/END
B    =FEAT/POINT,RECT
THEO/-7.96,-2.373,10.394,0,0,1
ACTL/-7.96,-2.373,10.394,0,0,1
MEAS/POINT,1
HIT/BASIC,-7.96,-2.373,10.394,0,0,1,-7.96,-2.373,10.394,USE THEO = YES
ENDMEAS/
DIM ANGL1= 3D ANGLE (TRUE) FROM PLANE PLN1 TO LINE LIN1,$
GRAPH=OFF TEXT=OFF MULT=10.00 OUTPUT=BOTH
AX NOMINAL  +TOL   -TOL   MEAS    MAX    MIN    DEV
OUTTOL
A   81.414    0.010    0.010   81.414   81.414   81.414    0.000    0.000 ----#----
```

Mesial Implant

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STARTUP  =ALIGNMENT/START,RECALL:, LIST= YES
ALIGNMENT/END
MODE/MANUAL
LOADPROBE/SEAN
TIP/T1A0B0, SHANKIJK=0, 0, 1, ANGLE=0
PNT1    =FEAT/POINT,RECT
THEO/15.695,23.583,-625.795,0,0,1
ACTL/15.695,23.583,-625.795,0,0,1
MEAS/POINT,1
HIT/BASIC,15.695,23.583,-625.795,0,0,1,15.695,23.583,-625.795,USE THEO =
YES
ENDMEAS/
```


PNT2 =FEAT/POINT,RECT
 THEO/15.007,24.896,-610.591,0,0,1
 ACTL/15.007,24.896,-610.591,0,0,1
 MEAS/POINT,1
 HIT/BASIC,15.007,24.896,-610.591,0,0,1,15.007,24.896,-610.591,USE THEO =
 YES
 ENDMEAS/
 LIN1 =FEAT/LINE,RECT,UNBND
 THEO/15.695,23.583,-625.795,-0.045028,0.0859515,0.9952813
 ACTL/15.695,23.583,-625.795,-0.045028,0.0859515,0.9952813
 CONSTR/LINE,BF,3D,PNT1,PNT2,,
 A3 =ALIGNMENT/START,RECALL:STARTUP, LIST= YES
 ALIGNMENT/TRANS,XAXIS,PNT1
 ALIGNMENT/TRANS,YAXIS,PNT1
 ALIGNMENT/TRANS,ZAXIS,PNT1
 ALIGNMENT/END
 A4 =ALIGNMENT/START,RECALL:A3, LIST= YES
 ALIGNMENT/ROTATE,ZPLUS,TO,LIN1,ABOUT,ZPLUS
 ALIGNMENT/END
 A =FEAT/POINT,RECT
 THEO/-2.264,20.569,11.089,0,0,1
 ACTL/-2.264,20.569,11.089,0,0,1
 MEAS/POINT,1
 HIT/BASIC,-2.264,20.569,11.089,0,0,1,-2.264,20.569,11.089,USE THEO = YES
 ENDMEAS/
 B =FEAT/POINT,RECT
 THEO/-10.402,16.788,10.062,0,0,1
 ACTL/-10.402,16.788,10.062,0,0,1
 MEAS/POINT,1
 HIT/BASIC,-10.402,16.788,10.062,0,0,1,-10.402,16.788,10.062,USE THEO =
 YES
 ENDMEAS/
 C =FEAT/POINT,RECT
 THEO/7.635,-8.956,13.403,0,0,1
 ACTL/7.635,-8.956,13.403,0,0,1
 MEAS/POINT,1
 HIT/BASIC,7.635,-8.956,13.403,0,0,1,7.635,-8.956,13.403,USE THEO = YES
 ENDMEAS/
 PLN1 =FEAT/PLANE,RECT
 THEO/-1.469,9.421,11.533,-0.139292,0.0308727,0.98977
 ACTL/-1.469,9.421,11.533,-0.139292,0.0308727,0.98977
 CONSTR/PLANE,BFRE,A,B,C,,
 LIN2 =FEAT/LINE,RECT,UNBND
 THEO/-2.264,20.569,11.089,0.3170103,-0.9455226,0.0741046
 ACTL/-2.264,20.569,11.089,0.3170078,-0.9455234,0.0741056
 CONSTR/LINE,BF,3D,A,C,,

```

A5    =ALIGNMENT/START,RECALL:A4, LIST= YES
      ALIGNMENT/ROTATE,XPLUS,TO,LIN2,ABOUT,ZPLUS
      ALIGNMENT/END
B      =FEAT/POINT,RECT
      THEO/-19.224,-4.526,10.062,0,0,1
      ACTL/-19.224,-4.526,10.062,0,0,1
      MEAS/POINT,1
      HIT/BASIC,-19.224,-4.526,10.062,0,0,1,-19.224,-4.526,10.062,USE THEO =
YES
      ENDMEAS/
DIM ANGL1= 3D ANGLE (TRUE) FROM PLANE PLN1 TO LINE LIN1 ,$
GRAPH=OFF TEXT=OFF MULT=10.00 OUTPUT=BOTH
AX  NOMINAL  +TOL   -TOL   MEAS    MAX    MIN    DEV
OUTTOL
A   83.734   0.010   0.010   83.734   83.734   83.734   0.000   0.000 ----#----

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Distal

STARTUP =ALIGNMENT/START,RECALL:, LIST= YES

ALIGNMENT/END

MODE/MANUAL

LOADPROBE/SEAN

TIP/T1A0B0, SHANKIJK=0, 0, 1, ANGLE=0

PNT1 =FEAT/POINT,RECT

THEO/-4.274,26.437,-601.304,0,0,1

ACTL/-4.274,26.437,-601.304,0,0,1

MEAS/POINT,1

HIT/BASIC,-4.274,26.437,-601.304,0,0,1,-4.274,26.437,-601.304,USE THEO =

YES

ENDMEAS/

PNT2 =FEAT/POINT,RECT

THEO/-3.93,26.472,-616.488,0,0,1

ACTL/-3.93,26.472,-616.488,0,0,1

MEAS/POINT,1

HIT/BASIC,-3.93,26.472,-616.488,0,0,1,-3.93,26.472,-616.488,USE THEO =

YES

ENDMEAS/

LIN1 =FEAT/LINE,RECT,UNBND

THEO/-4.274,26.437,-601.304,0.0226407,0.0022531,-0.9997411

ACTL/-4.274,26.437,-601.304,0.0226407,0.0022531,-0.9997411

CONSTR/LINE,BF,3D,PNT1,PNT2,,

A6 =ALIGNMENT/START,RECALL:STARTUP, LIST= YES

ALIGNMENT/TRANS,XAXIS,PNT2

ALIGNMENT/TRANS,YAXIS,PNT2

ALIGNMENT/TRANS,ZAXIS,PNT2

ALIGNMENT/END

A7 =ALIGNMENT/START,RECALL:A6, LIST= YES

ALIGNMENT/ROTATE,ZPLUS,TO,LIN1,ABOUT,ZPLUS

ALIGNMENT/END

A =FEAT/POINT,RECT

THEO/4.557,2.81,12.109,0,0,1

ACTL/4.557,2.81,12.109,0,0,1

MEAS/POINT,1

HIT/BASIC,4.557,2.81,12.109,0,0,1,4.557,2.81,12.109,USE THEO = YES

ENDMEAS/

B =FEAT/POINT,RECT

THEO/0.903,8.437,12.35,0,0,1

ACTL/0.903,8.437,12.35,0,0,1

MEAS/POINT,1

HIT/BASIC,0.903,8.437,12.35,0,0,1,0.903,8.437,12.35,USE THEO = YES

ENDMEAS/

```

C      =FEAT/POINT,RECT
      THEO/-17.652,-12.493,15.492,0,0,1
      ACTL/-17.652,-12.493,15.492,0,0,1
      MEAS/POINT,1
      HIT/BASIC,-17.652,-12.493,15.492,0,0,1,-17.652,-12.493,15.492,USE THEO =
YES
      ENDMEAS/
PLN1   =FEAT/PLANE,RECT
      THEO/-4.25,-0.473,13.33,0.1244814,0.0384767,0.9914756
      ACTL/-4.25,-0.473,13.33,0.1244814,0.0384767,0.9914756
      CONSTR/PLANE,BFRE,A,B,C,,
LIN2   =FEAT/LINE,RECT,UNBND
      THEO/4.557,2.81,12.109,-0.8170453,-0.5629809,0.1244569
      ACTL/4.557,2.81,12.109,-0.8170534,-0.5629751,0.1244301
      CONSTR/LINE,BF,3D,A,C,,
A8     =ALIGNMENT/START,RECALL:A7, LIST= YES
      ALIGNMENT/ROTATE,XPLUS,TO,LIN2,ABOUT,ZPLUS
      ALIGNMENT/END
B      =FEAT/POINT,RECT
      THEO/-5.531,-6.435,12.35,0,0,1
      ACTL/-5.531,-6.435,12.35,0,0,1
      MEAS/POINT,1
      HIT/BASIC,-5.531,-6.435,12.35,0,0,1,-5.531,-6.435,12.35,USE THEO = YES
      ENDMEAS/
DIM ANGL1= 3D ANGLE (TRUE) FROM PLANE PLN1 TO LINE LIN1 ,$
GRAPH=OFF TEXT=OFF MULT=10.00 OUTPUT=BOTH
AX NOMINAL  +TOL  -TOL  MEAS  MAX  MIN  DEV
OUTTOL
A  -81.232   0.010   0.010  -81.232  -81.232  -81.232   0.000   0.000 ----#----

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Mesial

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STARTUP  =ALIGNMENT/START,RECALL:, LIST= YES
      ALIGNMENT/END
      MODE/MANUAL
      LOADPROBE/SEAN
      TIP/T1A0B0, SHANKIJK=0, 0, 1, ANGLE=0
PNT1     =FEAT/POINT,RECT
      THEO/-13.727,19.665,-616.957,0,0,1
      ACTL/-13.727,19.665,-616.957,0,0,1
      MEAS/POINT,1
      HIT/BASIC,-13.727,19.665,-616.957,0,0,1,-13.727,19.665,-616.957,USE THEO
= YES
      ENDMEAS/
PNT2     =FEAT/POINT,RECT

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      THEO/-13.772,20.756,-601.842,0,0,1
      ACTL/-13.772,20.756,-601.842,0,0,1
      MEAS/POINT,1
      HIT/BASIC,-13.772,20.756,-601.842,0,0,1,-13.772,20.756,-601.842,USE THEO
= YES
      ENDMEAS/
LIN1    =FEAT/LINE,RECT,UNBND
      THEO/-13.727,19.665,-616.957,-0.0029713,0.0720051,0.9973998
      ACTL/-13.727,19.665,-616.957,-0.0029713,0.0720051,0.9973998
      CONSTR/LINE,BF,3D,PNT1,PNT2,,
A7      =ALIGNMENT/START,RECALL:STARTUP, LIST= YES
      ALIGNMENT/TRANS,XAXIS,PNT1
      ALIGNMENT/TRANS,YAXIS,PNT1
      ALIGNMENT/TRANS,ZAXIS,PNT1
      ALIGNMENT/END
A8      =ALIGNMENT/START,RECALL:A7, LIST= YES
      ALIGNMENT/ROTATE,ZPLUS,TO,LIN1,ABOUT,ZPLUS
      ALIGNMENT/END
A      =FEAT/POINT,RECT
      THEO/13.792,9.957,12.565,0,0,1
      ACTL/13.792,9.957,12.565,0,0,1
      MEAS/POINT,1
      HIT/BASIC,13.792,9.957,12.565,0,0,1,13.792,9.957,12.565,USE THEO = YES
      ENDMEAS/
B      =FEAT/POINT,RECT
      THEO/10.527,15.15,12.752,0,0,1
      ACTL/10.527,15.15,12.752,0,0,1
      MEAS/POINT,1
      HIT/BASIC,10.527,15.15,12.752,0,0,1,10.527,15.15,12.752,USE THEO = YES
      ENDMEAS/
C      =FEAT/POINT,RECT
      THEO/-7.998,-5.614,16.072,0,0,1
      ACTL/-7.998,-5.614,16.072,0,0,1
      MEAS/POINT,1
      HIT/BASIC,-7.998,-5.614,16.072,0,0,1,-7.998,-5.614,16.072,USE THEO = YES
      ENDMEAS/
PLN1    =FEAT/PLANE,RECT
      THEO/5.25,6.431,13.81,0.1276602,0.0445186,0.9908183
      ACTL/5.25,6.431,13.81,0.1276602,0.0445186,0.9908183
      CONSTR/PLANE,BFRE,A,B,C,,
LIN2    =FEAT/LINE,RECT,UNBND
      THEO/13.792,9.957,12.565,-0.8067277,-0.5764826,0.1298391
      ACTL/13.792,9.957,12.565,-0.8067198,-0.5764928,0.1298429
      CONSTR/LINE,BF,3D,A,C,,
A5      =ALIGNMENT/START,RECALL:A8, LIST= YES
      ALIGNMENT/ROTATE,XPLUS,TO,LIN2,ABOUT,ZPLUS

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ALIGNMENT/END
B   =FEAT/POINT,RECT
    THEO/-17.373,-6.206,12.752,0,0,1
    ACTL/-17.373,-6.205,12.752,0,0,1
    MEAS/POINT,1
    HIT/BASIC,-17.373,-6.206,12.752,0,0,1,-17.373,-6.205,12.752,USE THEO =
YES
    ENDMEAS/
DIM ANGL1= 3D ANGLE (TRUE) FROM PLANE PLN1 TO LINE LIN1 ,$
GRAPH=OFF TEXT=OFF MULT=10.00 OUTPUT=BOTH
AX  NOMINAL  +TOL  -TOL  MEAS  MAX  MIN  DEV
OUTTOL
A   -82.336   0.010   0.010  -82.336  -82.336  -82.336   0

```


Distal

STARTUP =ALIGNMENT/START,RECALL:, LIST= YES

ALIGNMENT/END

MODE/MANUAL

LOADPROBE/SEAN

TIP/T1A0B0, SHANKIJK=0, 0, 1, ANGLE=0

PNT1 =FEAT/POINT,RECT

THEO/-1.804,23.804,-610.501,0,0,1

ACTL/-1.804,23.804,-610.501,0,0,1

MEAS/POINT,1

HIT/BASIC,-1.804,23.804,-610.501,0,0,1,-1.804,23.804,-610.501,USE THEO =

YES

ENDMEAS/

PNT2 =FEAT/POINT,RECT

THEO/-1.73,23.191,-625.776,0,0,1

ACTL/-1.73,23.191,-625.776,0,0,1

MEAS/POINT,1

HIT/BASIC,-1.73,23.191,-625.776,0,0,1,-1.73,23.191,-625.776,USE THEO =

YES

ENDMEAS/

LIN1 =FEAT/LINE,RECT,UNBND

THEO/-1.73,23.191,-625.776,-0.004828,0.0401138,0.9991835

ACTL/-1.73,23.191,-625.776,-0.004828,0.0401138,0.9991835

CONSTR/LINE,BF,3D,PNT2,PNT1,,

A4 =ALIGNMENT/START,RECALL:STARTUP, LIST= YES

ALIGNMENT/TRANS,XAXIS,PNT2

ALIGNMENT/TRANS,YAXIS,PNT2

ALIGNMENT/TRANS,ZAXIS,PNT2

ALIGNMENT/END

A5 =ALIGNMENT/START,RECALL:A4, LIST= YES

ALIGNMENT/ROTATE,ZPLUS,TO,LIN1,ABOUT,ZPLUS

ALIGNMENT/END

A =FEAT/POINT,RECT

THEO/4.14,3.427,11.249,0,0,1

ACTL/4.14,3.427,11.249,0,0,1

MEAS/POINT,1

HIT/BASIC,4.14,3.427,11.249,0,0,1,4.14,3.427,11.249,USE THEO = YES

ENDMEAS/

B =FEAT/POINT,RECT

THEO/2.513,8.539,11.036,0,0,1

ACTL/2.513,8.539,11.036,0,0,1

MEAS/POINT,1

HIT/BASIC,2.513,8.539,11.036,0,0,1,2.513,8.539,11.036,USE THEO = YES

ENDMEAS/

C =FEAT/POINT,RECT

```

THEO/-18.328,-8.825,15.989,0,0,1
ACTL/-18.328,-8.825,15.989,0,0,1
MEAS/POINT,1
HIT/BASIC,-18.328,-8.825,15.989,0,0,1,-18.328,-8.825,15.989,USE THEO =
YES
ENDMEAS/
PLN1 =FEAT/PLANE,RECT
THEO/-4.127,0.911,12.783,0.1576993,0.0911985,0.9832669
ACTL/-4.127,0.911,12.783,0.1576993,0.0911985,0.9832669
CONSTR/PLANE,BFRE,A,B,C,,
LIN2 =FEAT/LINE,RECT,UNBND
THEO/4.14,3.427,11.249,-0.8632667,-0.470747,0.1821205
ACTL/4.14,3.427,11.249,-0.8632674,-0.4707477,0.1821155
CONSTR/LINE,BF,3D,A,C,,
A6 =ALIGNMENT/START,RECALL:A5, LIST= YES
ALIGNMENT/ROTATE,XPLUS,TO,LIN2,ABOUT,ZPLUS
ALIGNMENT/END
B =FEAT/POINT,RECT
THEO/-6.294,-6.294,11.036,0,0,1
ACTL/-6.295,-6.294,11.036,0,0,1
MEAS/POINT,1
HIT/BASIC,-6.295,-6.294,11.036,0,0,1,-6.295,-6.294,11.036,USE THEO = YES
ENDMEAS/
DIM ANGL1= 3D ANGLE (TRUE) FROM PLANE PLN1 TO LINE LIN1,$
GRAPH=OFF TEXT=OFF MULT=10.00 OUTPUT=BOTH
AX NOMINAL +TOL -TOL MEAS MAX MIN DEV
OUTTOL
A -80.184 0.010 0.010 -80.184 -80.184 -80.184 0.000 0.000 ----#----

Mesial

STARTUP =ALIGNMENT/START,RECALL:, LIST= YES
ALIGNMENT/END
MODE/MANUAL
LOADPROBE/SEAN
TIP/T1A0B0, SHANKIJK=0, 0, 1, ANGLE=0
PNT1 =FEAT/POINT,RECT
THEO/-12.466,18.657,-625.675,0,0,1
ACTL/-12.466,18.657,-625.675,0,0,1
MEAS/POINT,1
HIT/BASIC,-12.466,18.657,-625.675,0,0,1,-12.466,18.657,-625.675,USE THEO
= YES
ENDMEAS/
PNT2 =FEAT/POINT,RECT
THEO/-10.404,19.944,-610.531,0,0,1
ACTL/-10.404,19.944,-610.531,0,0,1

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MEAS/POINT,1
HIT/BASIC,-10.404,19.944,-610.531,0,0,1,-10.404,19.944,-610.531,USE THEO
= YES
ENDMEAS/
LIN1  =FEAT/LINE,RECT,UNBND
      THEO/-12.466,18.657,-625.675,0.1344467,0.0839696,0.9873567
      ACTL/-12.466,18.657,-625.675,0.1344467,0.0839696,0.9873567
      CONSTR/LINE,BF,3D,PNT1,PNT2,,
A3    =ALIGNMENT/START,RECALL:STARTUP, LIST= YES
      ALIGNMENT/TRANS,XAXIS,PNT1
      ALIGNMENT/TRANS,YAXIS,PNT1
      ALIGNMENT/TRANS,ZAXIS,PNT1
      ALIGNMENT/END
A2    =ALIGNMENT/START,RECALL:A3, LIST= YES
      ALIGNMENT/ROTATE,ZPLUS,TO,LIN1,ABOUT,ZPLUS
      ALIGNMENT/END
A     =FEAT/POINT,RECT
      THEO/14.876,7.962,11.147,0,0,1
      ACTL/14.876,7.962,11.148,0,0,1
      MEAS/POINT,1
      HIT/BASIC,14.876,7.962,11.148,0,0,1,14.876,7.962,11.148,USE THEO = YES
      ENDMEAS/
B     =FEAT/POINT,RECT
      THEO/13.249,13.074,10.934,0,0,1
      ACTL/13.249,13.074,10.934,0,0,1
      MEAS/POINT,1
      HIT/BASIC,13.249,13.074,10.934,0,0,1,13.249,13.074,10.934,USE THEO =
YES
      ENDMEAS/
C     =FEAT/POINT,RECT
      THEO/-7.592,-4.29,15.887,0,0,1
      ACTL/-7.592,-4.29,15.888,0,0,1
      MEAS/POINT,1
      HIT/BASIC,-7.592,-4.29,15.888,0,0,1,-7.592,-4.29,15.888,USE THEO = YES
      ENDMEAS/
PLN1  =FEAT/PLANE,RECT
      THEO/6.609,5.445,12.682,0.1576993,0.0911985,0.9832669
      ACTL/6.609,5.445,12.682,0.1576993,0.0911985,0.9832669
      CONSTR/PLANE,BFRE,A,B,C,,
LIN2  =FEAT/LINE,RECT,UNBND
      THEO/14.876,7.962,11.147,-0.8632667,-0.470747,0.1821205
      ACTL/14.876,7.962,11.148,-0.8632674,-0.4707477,0.1821155
      CONSTR/LINE,BF,3D,A,C,,
A0    =ALIGNMENT/START,RECALL:A2, LIST= YES
      ALIGNMENT/ROTATE,XPLUS,TO,LIN2,ABOUT,ZPLUS
      ALIGNMENT/END

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B      =FEAT/POINT,RECT
      THEO/-17.891,-5.135,10.934,0,0,1
      ACTL/-17.891,-5.135,10.934,0,0,1
      MEAS/POINT,1
      HIT/BASIC,-17.891,-5.135,10.934,0,0,1,-17.891,-5.135,10.934,USE THEO =
YES
      ENDMEAS/
DIM ANGL1= 3D ANGLE (TRUE) FROM PLANE PLN1 TO LINE LIN1 ,$
GRAPH=OFF TEXT=OFF MULT=10.00 OUTPUT=BOTH
AX NOMINAL  +TOL   -TOL   MEAS    MAX    MIN    DEV
OUTTOL
A  -88.585   0.010   0.010  -88.585  -88.585  -88.585   0.000   0.000 ----#----
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R5 control

STARTUP =ALIGNMENT/START,RECALL:, LIST= YES

ALIGNMENT/END

MODE/MANUAL

LOADPROBE/SEAN

TIP/T1A0B0, SHANKIJK=0, 0, 1, ANGLE=0

PNT1 =FEAT/POINT,RECT

THEO/12.479,79.819,-607.763,0,0,1

ACTL/12.479,79.819,-607.763,0,0,1

MEAS/POINT,1

HIT/BASIC,12.479,79.819,-607.763,0,0,1,12.479,79.819,-607.763,USE THEO =

YES

ENDMEAS/

PNT2 =FEAT/POINT,RECT

THEO/12.48,79.821,-621.822,0,0,1

ACTL/12.48,79.821,-621.822,0,0,1

MEAS/POINT,1

HIT/BASIC,12.48,79.821,-621.822,0,0,1,12.48,79.821,-621.822,USE THEO =

YES

ENDMEAS/

LIN1 =FEAT/LINE,RECT,UNBND

THEO/12.48,79.821,-621.822,-0.0000498,-0.0000967,1

ACTL/12.48,79.821,-621.822,-0.0000498,-0.0000967,1

CONSTR/LINE,BF,3D,PNT2,PNT1,,

A1 =ALIGNMENT/START,RECALL:STARTUP, LIST= YES

ALIGNMENT/TRANS,XAXIS,PNT2

ALIGNMENT/TRANS,YAXIS,PNT2

ALIGNMENT/TRANS,ZAXIS,PNT2

ALIGNMENT/END

A2 =ALIGNMENT/START,RECALL:A1, LIST= YES

ALIGNMENT/ROTATE,ZPLUS,TO,LIN1,ABOUT,ZPLUS

ALIGNMENT/END

A =FEAT/POINT,RECT

THEO/-7.879,9.116,9.848,0,0,1

ACTL/-7.879,9.116,9.848,0,0,1

MEAS/POINT,1

HIT/BASIC,-7.879,9.116,9.848,0,0,1,-7.879,9.116,9.848,USE THEO = YES

ENDMEAS/

B =FEAT/POINT,RECT

THEO/0.186,-6.991,9.809,0,0,1

ACTL/0.186,-6.991,9.809,0,0,1

MEAS/POINT,1

HIT/BASIC,0.186,-6.991,9.809,0,0,1,0.186,-6.991,9.809,USE THEO = YES

ENDMEAS/

```

C      =FEAT/POINT,RECT
      THEO/7.95,-12.928,11.84,0,0,1
      ACTL/7.95,-12.928,11.84,0,0,1
      MEAS/POINT,1
      HIT/BASIC,7.95,-12.928,11.84,0,0,1,7.95,-12.928,11.84,USE THEO = YES
      ENDMEAS/
PLN1   =FEAT/PLANE,RECT
      THEO/0.661,-3.309,10.645,-0.385112,-0.1950131,0.9020303
      ACTL/0.661,-3.309,10.645,-0.385112,-0.1950131,0.9020303
      CONSTR/PLANE,BFRE,A,B,C,,
LIN2   =FEAT/LINE,RECT,UNBND
      THEO/-7.879,9.116,9.848,0.5817036,-0.8101,0.0732045
      ACTL/-7.879,9.116,9.848,0.581714,-0.8100911,0.07322
      CONSTR/LINE,BF,3D,A,C,,
A3     =ALIGNMENT/START,RECALL:A2, LIST= YES
      ALIGNMENT/ROTATE,XPLUS,TO,LIN2,ABOUT,ZPLUS
      ALIGNMENT/END
B      =FEAT/POINT,RECT
      THEO/5.787,-3.927,9.809,0,0,1
      ACTL/5.787,-3.926,9.809,0,0,1
      MEAS/POINT,1
      HIT/BASIC,5.787,-3.926,9.809,0,0,1,5.787,-3.926,9.809,USE THEO = YES
      ENDMEAS/
DIM ANGL2= 3D ANGLE (TRUE) FROM PLANE PLN1 TO LINE LIN1,$
GRAPH=OFF TEXT=OFF MULT=10.00 OUTPUT=BOTH
AX  NOMINAL  +TOL   -TOL   MEAS    MAX    MIN    DEV
OUTTOL
A   64.431   0.010   0.010   64.431   64.431

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STARTUP  =ALIGNMENT/START,RECALL:, LIST= YES
        ALIGNMENT/END
        MODE/MANUAL
        LOADPROBE/SEAN
        TIP/T1A0B0, SHANKIJK=0, 0, 1, ANGLE=0
PNT1    =FEAT/POINT,RECT
        THEO/12.168,66.82,-602.318,0,0,1
        ACTL/12.168,66.82,-602.318,0,0,1
        MEAS/POINT,1
        HIT/BASIC,12.168,66.82,-602.318,0,0,1,12.168,66.82,-602.318,USE THEO =
YES
        ENDMEAS/
PNT2    =FEAT/POINT,RECT
        THEO/12.161,66.821,-616.266,0,0,1
        ACTL/12.161,66.821,-616.266,0,0,1
        MEAS/POINT,1
        HIT/BASIC,12.161,66.821,-616.266,0,0,1,12.161,66.821,-616.266,USE THEO =
YES
        ENDMEAS/
LIN1    =FEAT/LINE,RECT,UNBND
        THEO/12.161,66.821,-616.266,0.0004868,-0.0000825,0.9999999
        ACTL/12.161,66.821,-616.266,0.0004868,-0.0000825,0.9999999
        CONSTR/LINE,BF,3D,PNT2,PNT1,,
A2      =ALIGNMENT/START,RECALL:STARTUP, LIST= YES
        ALIGNMENT/TRANS,XAXIS,PNT2
        ALIGNMENT/TRANS,YAXIS,PNT2
        ALIGNMENT/TRANS,ZAXIS,PNT2
        ALIGNMENT/END
A3      =ALIGNMENT/START,RECALL:A2, LIST= YES
        ALIGNMENT/ROTATE,ZPLUS,TO,LIN1,ABOUT,ZPLUS
        ALIGNMENT/END
A       =FEAT/POINT,RECT
        THEO/-9.154,8.154,8.581,0,0,1
        ACTL/-9.154,8.154,8.581,0,0,1
        MEAS/POINT,1
        HIT/BASIC,-9.154,8.154,8.581,0,0,1,-9.154,8.154,8.581,USE THEO = YES
        ENDMEAS/
B       =FEAT/POINT,RECT
        THEO/1.396,-6.109,9.378,0,0,1
        ACTL/1.396,-6.109,9.378,0,0,1
        MEAS/POINT,1
        HIT/BASIC,1.396,-6.109,9.378,0,0,1,1.396,-6.109,9.378,USE THEO = YES
        ENDMEAS/
C       =FEAT/POINT,RECT
        THEO/8.997,-11.273,11.686,0,0,1
        ACTL/8.997,-11.273,11.686,0,0,1

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```

MEAS/POINT,1
HIT/BASIC,8.997,-11.273,11.686,0,0,1,8.997,-11.273,11.686,USE THEO = YES
ENDMEAS/
PLN1    =FEAT/PLANE,RECT
THEO/1.087,-2.648,10.113,-0.4514157,-0.2866773,0.8450089
ACTL/1.087,-2.648,10.113,-0.4514157,-0.2866773,0.8450089
CONSTR/PLANE,BFRE,A,B,C,,
LIN2    =FEAT/LINE,RECT,UNBND
THEO/-9.154,8.154,8.581,0.6780941,-0.7257636,0.1159981
ACTL/-9.154,8.154,8.581,0.6780863,-0.7257675,0.1160198
CONSTR/LINE,BF,3D,A,C,,
A4      =ALIGNMENT/START,RECALL:A3, LIST= YES
ALIGNMENT/ROTATE,XPLUS,TO,LIN2,ABOUT,ZPLUS
ALIGNMENT/END
B       =FEAT/POINT,RECT
THEO/5.417,-3.151,9.378,0,0,1
ACTL/5.416,-3.151,9.378,0,0,1
MEAS/POINT,1
HIT/BASIC,5.416,-3.151,9.378,0,0,1,5.416,-3.151,9.378,USE THEO = YES
ENDMEAS/
DIM ANGL2= 3D ANGLE (TRUE) FROM PLANE PLN1 TO LINE LIN1,$
GRAPH=OFF TEXT=OFF MULT=10.00 OUTPUT=BOTH
AX NOMINAL  +TOL  -TOL  MEAS  MAX  MIN  DEV
OUTTOL
A  57.652   0.010   0.010   57.652  57.652

```


R7 MAN - CONTROL

STARTUP =ALIGNMENT/START,RECALL:, LIST= YES

ALIGNMENT/END

MODE/MANUAL

LOADPROBE/SEAN

TIP/T1A0B0, SHANKIJK=0, 0, 1, ANGLE=0

PNT1 =FEAT/POINT,RECT

THEO/-4.098,14.67,-609.716,0,0,1

ACTL/-4.098,14.67,-609.716,0,0,1

MEAS/POINT,1

HIT/BASIC,-4.098,14.67,-609.716,0,0,1,-4.098,14.67,-609.716,USE THEO =

YES

ENDMEAS/

PNT2 =FEAT/POINT,RECT

THEO/-4.578,15.796,-594.552,0,0,1

ACTL/-4.578,15.796,-594.552,0,0,1

MEAS/POINT,1

HIT/BASIC,-4.578,15.796,-594.552,0,0,1,-4.578,15.796,-594.552,USE THEO =

YES

ENDMEAS/

LIN1 =FEAT/LINE,RECT,UNBND

THEO/-4.098,14.67,-609.716,-0.0315845,0.0739979,0.9967581

ACTL/-4.098,14.67,-609.716,-0.0315845,0.0739979,0.9967581

CONSTR/LINE,BF,3D,PNT1,PNT2,,

A1 =ALIGNMENT/START,RECALL:STARTUP, LIST= YES

ALIGNMENT/TRANS,XAXIS,PNT1

ALIGNMENT/TRANS,YAXIS,PNT1

ALIGNMENT/TRANS,ZAXIS,PNT1

ALIGNMENT/END

A2 =ALIGNMENT/START,RECALL:A1, LIST= YES

ALIGNMENT/ROTATE,ZPLUS,TO,LIN1,ABOUT,ZPLUS

ALIGNMENT/END

A =FEAT/POINT,RECT

THEO/6.118,-11.738,12.277,0,0,1

ACTL/6.118,-11.738,12.277,0,0,1

MEAS/POINT,1

HIT/BASIC,6.118,-11.738,12.277,0,0,1,6.118,-11.738,12.277,USE THEO = YES

ENDMEAS/

B =FEAT/POINT,RECT

THEO/-7.942,5.771,12.437,0,0,1

ACTL/-7.942,5.771,12.437,0,0,1

MEAS/POINT,1

HIT/BASIC,-7.942,5.771,12.437,0,0,1,-7.942,5.771,12.437,USE THEO = YES

ENDMEAS/

C =FEAT/POINT,RECT

```

THEO/-3.951,8.676,12.591,0,0,1
ACTL/-3.951,8.676,12.591,0,0,1
MEAS/POINT,1
HIT/BASIC,-3.951,8.676,12.591,0,0,1,-3.951,8.676,12.591,USE THEO = YES
ENDMEAS/
PLN1  =FEAT/PLANE,RECT
THEO/-1.895,0.941,12.436,-0.0200318,-0.0252482,0.9994805
ACTL/-1.895,0.941,12.436,-0.0200318,-0.0252482,0.9994805
CONSTR/PLANE,BFRE,A,B,C,,
LIN2  =FEAT/LINE,RECT,UNBND
THEO/6.118,-11.738,12.277,-0.4423148,0.8967538,0.0137935
ACTL/6.118,-11.738,12.277,-0.4423241,0.8967493,0.0137879
CONSTR/LINE,BF,3D,A,C,,
A3    =ALIGNMENT/START,RECALL:A2, LIST= YES
ALIGNMENT/ROTATE,XPLUS,TO,LIN2,ABOUT,ZPLUS
ALIGNMENT/END
B     =FEAT/POINT,RECT
THEO/8.689,4.57,12.437,0,0,1
ACTL/8.688,4.57,12.437,0,0,1
MEAS/POINT,1
HIT/BASIC,8.688,4.57,12.437,0,0,1,8.688,4.57,12.437,USE THEO = YES
ENDMEAS/
DIM ANGL2= 3D ANGLE (TRUE) FROM PLANE PLN1 TO LINE LIN1,$
GRAPH=OFF TEXT=OFF MULT=10.00 OUTPUT=BOTH
AX NOMINAL  +TOL   -TOL   MEAS    MAX    MIN    DEV
OUTTOL
A  -84.271   0.010   0.010  -84.271  -84.271  -84.271   0.000   0.000 ----#----
```


R7 MAN – test

STARTUP =ALIGNMENT/START,RECALL:, LIST= YES

ALIGNMENT/END

MODE/MANUAL

LOADPROBE/SEAN

TIP/T1A0B0, SHANKIJK=0, 0, 1, ANGLE=0

PNT1 =FEAT/POINT,RECT

THEO/-29.954,28.732,-611.719,0,0,1

ACTL/-29.954,28.732,-611.719,0,0,1

MEAS/POINT,1

HIT/BASIC,-29.954,28.732,-611.719,0,0,1,-29.954,28.732,-611.719,USE THEO

= YES

ENDMEAS/

PNT2 =FEAT/POINT,RECT

THEO/-29.954,28.685,-625.771,0,0,1

ACTL/-29.954,28.685,-625.771,0,0,1

MEAS/POINT,1

HIT/BASIC,-29.954,28.685,-625.771,0,0,1,-29.954,28.685,-625.771,USE THEO

= YES

ENDMEAS/

LIN1 =FEAT/LINE,RECT,UNBND

THEO/-29.954,28.685,-625.771,0.0000057,0.0033518,0.9999944

ACTL/-29.954,28.685,-625.771,0.0000057,0.0033518,0.9999944

CONSTR/LINE,BF,3D,PNT2,PNT1,,

A2 =ALIGNMENT/START,RECALL:STARTUP, LIST= YES

ALIGNMENT/TRANS,XAXIS,PNT2

ALIGNMENT/TRANS,YAXIS,PNT2

ALIGNMENT/TRANS,ZAXIS,PNT2

ALIGNMENT/END

A3 =ALIGNMENT/START,RECALL:A2, LIST= YES

ALIGNMENT/ROTATE,ZPLUS,TO,LIN1,ABOUT,ZPLUS

ALIGNMENT/END

A =FEAT/POINT,RECT

THEO/2.745,-12.563,11.625,0,0,1

ACTL/2.745,-12.563,11.625,0,0,1

MEAS/POINT,1

HIT/BASIC,2.745,-12.563,11.625,0,0,1,2.745,-12.563,11.625,USE THEO = YES

ENDMEAS/

B =FEAT/POINT,RECT

THEO/-8.35,5.126,12.164,0,0,1

ACTL/-8.35,5.126,12.164,0,0,1

MEAS/POINT,1

HIT/BASIC,-8.35,5.126,12.164,0,0,1,-6.35,5.126,12.164,USE THEO = YES

ENDMEAS/

C =FEAT/POINT,RECT

THEO/-2.343,7.3,12.979,0,0,1

```

        ACTL/-2.343,7.3,12.979,0,0,1
        MEAS/POINT,1
        HIT/BASIC,-2.343,7.3,12.979,0,0,1,-2.343,7.3,12.979,USE THEO = YES
        ENDMEAS/
PLN1    =FEAT/PLANE,RECT
        THEO/-2.499,0.094,12.27,-0.1005713,-0.0932766,0.9905478
        ACTL/-1.768,0.109,12.28,-0.1437113,-0.1038911,0.9841513
        CONSTR/PLANE,BFRE,A,B,C,,
LIN2    =FEAT/LINE,RECT,UNBND
        THEO/2.745,-12.563,11.625,-0.2476038,0.9666182,0.0658914
        ACTL/2.745,-12.563,11.625,-0.2476041,0.9666186,0.0658838
        CONSTR/LINE,BF,3D,A,C,,
A4      =ALIGNMENT/START,RECALL:A3, LIST= YES
        ALIGNMENT/ROTATE,XPLUS,TO,LIN2,ABOUT,ZPLUS
        ALIGNMENT/END
B       =FEAT/POINT,RECT
        THEO/8.541,4.879,12.164,0,0,1
        ACTL/8.541,4.879,12.164,0,0,1
        MEAS/POINT,1
        HIT/BASIC,8.541,4.879,12.164,0,0,1,6.541,4.879,12.164,USE THEO = YES
        ENDMEAS/
DIM ANGL1= 3D ANGLE (TRUE) FROM PLANE PLN1 TO LINE LIN1 ,$
GRAPH=OFF TEXT=OFF MULT=10.00 OUTPUT=BOTH
AX NOMINAL  +TOL   -TOL   MEAS    MAX    MIN    DEV
OUTTOL
A   -79.672   0.010   0.010  -79.672  -79.672

```


STARTUP =ALIGNMENT/START,RECALL:, LIST= YES
 ALIGNMENT/END
 MODE/MANUAL
 LOADPROBE/SEAN
 TIP/T1A0B0, SHANKIJK=0, 0, 1, ANGLE=0
 PNT1 =FEAT/POINT,RECT
 THEO/5.763,11.717,-613.434,0,0,1
 ACTL/5.763,11.717,-613.434,0,0,1
 MEAS/POINT,1
 HIT/BASIC,5.763,11.717,-613.434,0,0,1,5.763,11.717,-613.434,USE THEO =
 YES
 ENDMEAS/
 PNT2 =FEAT/POINT,RECT
 THEO/5.908,12.514,-628.52,0,0,1
 ACTL/5.908,12.514,-628.52,0,0,1
 MEAS/POINT,1
 HIT/BASIC,5.908,12.514,-628.52,0,0,1,5.908,12.514,-628.52,USE THEO = YES
 ENDMEAS/
 LIN1 =FEAT/LINE,RECT,UNBND
 THEO/5.763,11.717,-613.434,0.0095985,0.0527296,-0.9985627
 ACTL/5.763,11.717,-613.434,0.0095985,0.0527296,-0.9985627
 CONSTR/LINE,BF,3D,PNT1,PNT2,,
 A5 =ALIGNMENT/START,RECALL:STARTUP, LIST= YES
 ALIGNMENT/TRANS,XAXIS,PNT2
 ALIGNMENT/TRANS,YAXIS,PNT2
 ALIGNMENT/TRANS,ZAXIS,PNT2
 ALIGNMENT/END
 A6 =ALIGNMENT/START,RECALL:A5, LIST= YES
 ALIGNMENT/ROTATE,ZPLUS,TO,LIN1,ABOUT,ZPLUS
 ALIGNMENT/END
 A =FEAT/POINT,RECT
 THEO/0.894,5.236,4.827,0,0,1
 ACTL/0.894,5.236,4.827,0,0,1
 MEAS/POINT,1
 HIT/BASIC,0.894,5.236,4.827,0,0,1,0.894,5.236,4.827,USE THEO = YES
 ENDMEAS/
 B =FEAT/POINT,RECT
 THEO/-5.037,4.481,10.181,0,0,1
 ACTL/-5.037,4.481,10.181,0,0,1
 MEAS/POINT,1
 HIT/BASIC,-5.037,4.481,10.181,0,0,1,-5.037,4.481,10.181,USE THEO = YES
 ENDMEAS/
 C =FEAT/POINT,RECT
 THEO/5.875,1.179,9.372,0,0,1
 ACTL/5.875,1.179,9.372,0,0,1
 MEAS/POINT,1

```

HIT/BASIC,5.875,1.179,9.372,0,0,1,5.875,1.179,9.372,USE THEO = YES
ENDMEAS/
PLN1    =FEAT/PLANE,RECT
THEO/0.144,2.362,8.962,0.2897463,0.8495096,0.4408861
ACTL/0.144,2.362,8.962,0.2897463,0.8495096,0.4408861
CONSTR/PLANE,BFRE,A,B,C,,
LIN2    =FEAT/LINE,RECT,UNBND
THEO/0.894,5.236,4.827,0.6329622,-0.5155446,0.5775574
ACTL/0.894,5.236,4.827,0.6328702,-0.5156196,0.5775914
CONSTR/LINE,BF,3D,A,C,,
A7      =ALIGNMENT/START,RECALL:A6, LIST= YES
ALIGNMENT/ROTATE,XPLUS,TO,LIN2,ABOUT,ZPLUS
ALIGNMENT/END
B       =FEAT/POINT,RECT
THEO/-6.735,0.293,10.181,0,0,1
ACTL/-6.735,0.292,10.181,0,0,1
MEAS/POINT,1
HIT/BASIC,-6.735,0.293,10.181,0,0,1,-6.735,0.292,10.181,USE THEO = YES
ENDMEAS/
PNT6    =FEAT/POINT,RECT
THEO/-5.531,0.813,9.657,0,0,1
ACTL/-5.531,0.813,9.657,0,0,1
MEAS/POINT,1
HIT/BASIC,-5.531,0.813,9.657,0,0,1,-5.531,0.813,9.657,USE THEO = YES
ENDMEAS/
PNT7    =FEAT/POINT,RECT
THEO/-6.26,0.708,10.02,0,0,1
ACTL/-6.26,0.708,10.02,0,0,1
MEAS/POINT,1
HIT/BASIC,-6.26,0.708,10.02,0,0,1,-6.26,0.708,10.02,USE THEO = YES
ENDMEAS/
DIM ANGL1= 3D ANGLE (TRUE) FROM PLANE PLN1 TO LINE LIN1 ,$
GRAPH=OFF TEXT=OFF MULT=10.00 OUTPUT=BOTH
AX NOMINAL  +TOL   -TOL   MEAS    MAX    MIN    DEV
OUTTOL
A  -23.121   0.010   0.010  -23.121  -23.121  -23.121   000 ----#----

```


STARTUP =ALIGNMENT/START,RECALL:, LIST= YES
 ALIGNMENT/END
 MODE/MANUAL
 LOADPROBE/SEAN
 TIP/T1A0B0, SHANKIJK=0, 0, 1, ANGLE=0
 PNT1 =FEAT/POINT,RECT
 THEO/5.763,11.717,-613.434,0,0,1
 ACTL/5.763,11.717,-613.434,0,0,1
 MEAS/POINT,1
 HIT/BASIC,5.763,11.717,-613.434,0,0,1,5.763,11.717,-613.434,USE THEO =
 YES
 ENDMEAS/
 PNT2 =FEAT/POINT,RECT
 THEO/5.908,12.514,-628.52,0,0,1
 ACTL/5.908,12.514,-628.52,0,0,1
 MEAS/POINT,1
 HIT/BASIC,5.908,12.514,-628.52,0,0,1,5.908,12.514,-628.52,USE THEO = YES
 ENDMEAS/
 LIN1 =FEAT/LINE,RECT,UNBND
 THEO/5.763,11.717,-613.434,0.0095985,0.0527296,-0.9985627
 ACTL/5.763,11.717,-613.434,0.0095985,0.0527296,-0.9985627
 CONSTR/LINE,BF,3D,PNT1,PNT2,,
 A5 =ALIGNMENT/START,RECALL:STARTUP, LIST= YES
 ALIGNMENT/TRANS,XAXIS,PNT2
 ALIGNMENT/TRANS,YAXIS,PNT2
 ALIGNMENT/TRANS,ZAXIS,PNT2
 ALIGNMENT/END
 A6 =ALIGNMENT/START,RECALL:A5, LIST= YES
 ALIGNMENT/ROTATE,ZPLUS,TO,LIN1,ABOUT,ZPLUS
 ALIGNMENT/END
 A =FEAT/POINT,RECT
 THEO/0.894,5.236,4.827,0,0,1
 ACTL/0.894,5.236,4.827,0,0,1
 MEAS/POINT,1
 HIT/BASIC,0.894,5.236,4.827,0,0,1,0.894,5.236,4.827,USE THEO = YES
 ENDMEAS/
 B =FEAT/POINT,RECT
 THEO/-5.037,4.481,10.181,0,0,1
 ACTL/-5.037,4.481,10.181,0,0,1
 MEAS/POINT,1
 HIT/BASIC,-5.037,4.481,10.181,0,0,1,-5.037,4.481,10.181,USE THEO = YES
 ENDMEAS/
 C =FEAT/POINT,RECT
 THEO/5.875,1.179,9.372,0,0,1
 ACTL/5.875,1.179,9.372,0,0,1
 MEAS/POINT,1

```

HIT/BASIC,5.875,1.179,9.372,0,0,1,5.875,1.179,9.372,USE THEO = YES
ENDMEAS/
PLN1  =FEAT/PLANE,RECT
      THEO/0.144,2.362,8.962,0.2897463,0.8495096,0.4408861
      ACTL/0.144,2.362,8.962,0.2897463,0.8495096,0.4408861
      CONSTR/PLANE,BFRE,A,B,C,,
LIN2  =FEAT/LINE,RECT,UNBND
      THEO/0.894,5.236,4.827,0.6329622,-0.5155446,0.5775574
      ACTL/0.894,5.236,4.827,0.6328702,-0.5156196,0.5775914
      CONSTR/LINE,BF,3D,A,C,,
A7    =ALIGNMENT/START,RECALL:A6, LIST= YES
      ALIGNMENT/ROTATE,XPLUS,TO,LIN2,ABOUT,ZPLUS
      ALIGNMENT/END
B     =FEAT/POINT,RECT
      THEO/-6.735,0.293,10.181,0,0,1
      ACTL/-6.735,0.292,10.181,0,0,1
      MEAS/POINT,1
      HIT/BASIC,-6.735,0.293,10.181,0,0,1,-6.735,0.292,10.181,USE THEO = YES
      ENDMEAS/
DIM ANGL1= 3D ANGLE (TRUE) FROM PLANE PLN1 TO LINE LIN1 ,$
GRAPH=OFF TEXT=OFF MULT=10.00 OUTPUT=BOTH
AX  NOMINAL  +TOL  -TOL  MEAS  MAX *  MIN  DEV
OUTTOL
A   -23.121   0.010   0.010  -23.121  -23.121  -23.121   0.000   0.000 ----#----

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R7 MAN - TEST

```
STARTUP  =ALIGNMENT/START,RECALL:, LIST= YES
ALIGNMENT/END
MODE/MANUAL
LOADPROBE/SEAN
TIP/T1A0B0, SHANKIJK=0, 0, 1, ANGLE=0
PNT1     =FEAT/POINT,RECT
THEO/-33.393,68.599,-595.631,0,0,1
ACTL/-33.393,68.599,-595.631,0,0,1
MEAS/POINT,1
HIT/BASIC,-33.393,68.599,-595.631,0,0,1,-33.393,68.599,-595.631,USE THEO
= YES
ENDMEAS/
PNT2     =FEAT/POINT,RECT
THEO/-33.392,68.597,-609.707,0,0,1
ACTL/-33.392,68.597,-609.707,0,0,1
MEAS/POINT,1
HIT/BASIC,-33.392,68.597,-609.707,0,0,1,-33.392,68.597,-609.707,USE THEO
= YES
ENDMEAS/
LIN1     =FEAT/LINE,RECT,UNBND
THEO/-33.392,68.597,-609.707,-0.0000298,0.0000924,1
ACTL/-33.392,68.597,-609.707,-0.0000298,0.0000924,1
CONSTR/LINE,BF,3D,PNT2,PNT1,,
A0       =ALIGNMENT/START,RECALL:STARTUP, LIST= YES
ALIGNMENT/TRANS,XAXIS,PNT2
ALIGNMENT/TRANS,YAXIS,PNT2
ALIGNMENT/TRANS,ZAXIS,PNT2
ALIGNMENT/END
A1       =ALIGNMENT/START,RECALL:A0, LIST= YES
ALIGNMENT/ROTATE,ZPLUS,TO,LIN1,ABOUT,ZPLUS
ALIGNMENT/END
A        =FEAT/POINT,RECT
THEO/16.004,-5.985,8.368,0,0,1
ACTL/16.004,-5.986,8.369,0,0,1
MEAS/POINT,1
HIT/BASIC,16.004,-5.986,8.369,0,0,1,16.004,-5.986,8.369,USE THEO = YES
ENDMEAS/
B        =FEAT/POINT,RECT
THEO/4.004,-2.961,8.588,0,0,1
ACTL/4.004,-2.961,8.588,0,0,1
MEAS/POINT,1
HIT/BASIC,4.004,-2.961,8.588,0,0,1,4.004,-2.961,8.588,USE THEO = YES
ENDMEAS/
C        =FEAT/POINT,RECT
```

```

THEO/-12.071,15.063,10.667,0,0,1
ACTL/-12.07,15.062,10.668,0,0,1
MEAS/POINT,1
HIT/BASIC,-12.07,15.062,10.668,0,0,1,-12.07,15.062,10.668,USE THEO = YES
ENDMEAS/
PLN1  =FEAT/PLANE,RECT
THEO/2.667,2.228,9.22,-0.0137928,-0.1267264,0.9918418
ACTL/2.667,2.228,9.22,-0.0137928,-0.1267264,0.9918418
CONSTR/PLANE,BFRE,A,B,C,,
LIN2  =FEAT/LINE,RECT,UNBND
THEO/16.004,-5.985,8.368,-0.798401,0.5985661,0.0653793
ACTL/16.004,-5.986,8.369,-0.7983931,0.5985769,0.0653768
CONSTR/LINE,BF,3D,A,C,,
A2    =ALIGNMENT/START,RECALL:A1, LIST= YES
ALIGNMENT/ROTATE,XPLUS,TO,LIN2,ABOUT,ZPLUS
ALIGNMENT/END
B     =FEAT/POINT,RECT
THEO/-4.98,-0.033,8.588,0,0,1
ACTL/-4.98,-0.033,8.588,0,0,1
MEAS/POINT,1
HIT/BASIC,-4.98,-0.033,8.588,0,0,1,-4.98,-0.033,8.588,USE THEO = YES
ENDMEAS/
DIM ANGL1= 3D ANGLE (TRUE) FROM PLANE PLN1 TO LINE LIN1,$
GRAPH=OFF TEXT=OFF MULT=10.00 OUTPUT=BOTH
AX NOMINAL  +TOL  -TOL  MEAS  MAX  MIN  DEV
OUTTOL
A  -82.671  0.010  0.010  -82.671  -82.671

```


R9 MAX TEST

```
STARTUP  =ALIGNMENT/START,RECALL:, LIST= YES
ALIGNMENT/END
MODE/MANUAL
LOADPROBE/SEAN
TIP/T1A0B0, SHANKIJK=0, 0, 1, ANGLE=0
PNT1     =FEAT/POINT,RECT
THEO/-28.399,39.611,-610.594,0,0,1
ACTL/-28.399,39.611,-610.594,0,0,1
MEAS/POINT,1
HIT/BASIC,-28.399,39.611,-610.594,0,0,1,-28.399,39.611,-610.594,USE THEO
= YES
ENDMEAS/
PNT2     =FEAT/POINT,RECT
THEO/-28.492,39.611,-624.689,0,0,1
ACTL/-28.492,39.611,-624.689,0,0,1
MEAS/POINT,1
HIT/BASIC,-28.492,39.611,-624.689,0,0,1,-28.492,39.611,-624.689,USE THEO
= YES
ENDMEAS/
LIN1     =FEAT/LINE,RECT,UNBND
THEO/-28.492,39.611,-624.689,0.0066447,-0.0000142,0.9999779
ACTL/-28.492,39.611,-624.689,0.0066447,-0.0000142,0.9999779
CONSTR/LINE,BF,3D,PNT2,PNT1,,
A3       =ALIGNMENT/START,RECALL:STARTUP, LIST= YES
ALIGNMENT/TRANS,XAXIS,PNT2
ALIGNMENT/TRANS,YAXIS,PNT2
ALIGNMENT/TRANS,ZAXIS,PNT2
ALIGNMENT/END
A2       =ALIGNMENT/START,RECALL:A3, LIST= YES
ALIGNMENT/ROTATE,ZPLUS,TO,LIN1,ABOUT,ZPLUS
ALIGNMENT/END
A        =FEAT/POINT,RECT
THEO/13.604,-9.61,8.181,0,0,1
ACTL/13.604,-9.61,8.181,0,0,1
MEAS/POINT,1
HIT/BASIC,13.604,-9.61,8.181,0,0,1,13.604,-9.61,8.181,USE THEO = YES
ENDMEAS/
B        =FEAT/POINT,RECT
THEO/1.497,-2.855,10.085,1,0,0
ACTL/1.497,-2.855,10.085,1,0,0
MEAS/POINT,1
HIT/BASIC,1.497,-2.855,10.085,1,0,0,1.497,-2.855,10.085,USE THEO = YES
ENDMEAS/
C        =FEAT/POINT,RECT
```

```

THEO/-6.364,19.325,12.631,0,0,1
ACTL/-6.364,19.325,12.632,0,0,1
MEAS/POINT,1
HIT/BASIC,-6.364,19.325,12.632,0,0,1,-6.364,19.325,12.632,USE THEO = YES
ENDMEAS/
PLN1  =FEAT/PLANE,RECT
THEO/3.564,2.616,9.846,-0.102518,-0.2199733,0.970104
ACTL/3.564,2.616,9.846,-0.102518,-0.2199733,0.970104
CONSTR/PLANE,BFRE,A,B,C,,
LIN2  =FEAT/LINE,RECT,UNBND
THEO/13.604,-9.61,8.181,-0.5634841,0.816527,0.1255761
ACTL/13.604,-9.61,8.181,-0.563491,0.8165187,0.1255993
CONSTR/LINE,BF,3D,A,C,,
A1    =ALIGNMENT/START,RECALL:A2, LIST= YES
ALIGNMENT/ROTATE,XPLUS,TO,LIN2,ABOUT,ZPLUS
ALIGNMENT/END
B     =FEAT/POINT,RECT
THEO/-3.2,0.389,10.085,-0.5679802,-0.8230422,0
ACTL/-3.2,0.39,10.085,-0.5679889,-0.8230362,0
MEAS/POINT,1
HIT/BASIC,-3.2,0.39,10.085,-0.5679802,-0.8230422,0,-3.2,0.39,10.085,USE
THEO = YES
ENDMEAS/
DIM ANGL1= 3D ANGLE (TRUE) FROM PLANE PLN1 TO LINE LIN1 ,$
GRAPH=OFF TEXT=OFF MULT=10.00 OUTPUT=BOTH
AX NOMINAL  +TOL   -TOL   MEAS    MAX    MIN    DEV
OUTTOL
A   -75.790   0.010   0.010  -75.790  -75.790

```


Distal

STARTUP =ALIGNMENT/START,RECALL:, LIST= YES

ALIGNMENT/END

MODE/MANUAL

LOADPROBE/SEAN

TIP/T1A0B0, SHANKIJK=0, 0, 1, ANGLE=0

PNT1 =FEAT/POINT,RECT

THEO/-8.478,24.133,-599.556,0,0,1

ACTL/-8.478,24.133,-599.556,0,0,1

MEAS/POINT,1

HIT/BASIC,-8.478,24.133,-599.556,0,0,1,-8.478,24.133,-599.556,USE THEO =

YES

ENDMEAS/

PNT2 =FEAT/POINT,RECT

THEO/-8.482,24.131,-614.659,0,0,1

ACTL/-8.482,24.131,-614.659,0,0,1

MEAS/POINT,1

HIT/BASIC,-8.482,24.131,-614.659,0,0,1,-8.482,24.131,-614.659,USE THEO =

YES

ENDMEAS/

LIN1 =FEAT/LINE,RECT,UNBND

THEO/-8.482,24.131,-614.659,0.0002768,0.0001106,1

ACTL/-8.482,24.131,-614.659,0.0002768,0.0001106,1

CONSTR/LINE,BF,3D,PNT2,PNT1,,

A0 =ALIGNMENT/START,RECALL:STARTUP, LIST= YES

ALIGNMENT/TRANS,XAXIS,PNT2

ALIGNMENT/TRANS,YAXIS,PNT2

ALIGNMENT/TRANS,ZAXIS,PNT2

ALIGNMENT/END

A1 =ALIGNMENT/START,RECALL:A0, LIST= YES

ALIGNMENT/ROTATE,ZPLUS,TO,LIN1,ABOUT,ZPLUS

ALIGNMENT/END

A =FEAT/POINT,RECT

THEO/-6.421,8.684,12.959,1,0,0

ACTL/-6.421,8.684,12.959,1,0,0

MEAS/POINT,1

HIT/BASIC,-6.421,8.684,12.959,1,0,0,-6.421,8.684,12.959,USE THEO = YES

ENDMEAS/

B =FEAT/POINT,RECT

THEO/5.085,-10.53,9.477,0,0,1

ACTL/5.085,-10.53,9.477,0,0,1

MEAS/POINT,1

HIT/BASIC,5.085,-10.53,9.477,0,0,1,5.085,-10.53,9.477,USE THEO = YES

ENDMEAS/

C =FEAT/POINT,RECT

THEO/-2.282,-10.311,9.952,0,0,1

```

        ACTL/-2.282,-10.311,9.952,0,0,1
        MEAS/POINT,1
        HIT/BASIC,-2.282,-10.311,9.952,0,0,1,-2.282,-10.311,9.952,USE THEO = YES
        ENDMEAS/
PLN1    =FEAT/PLANE,RECT
        THEO/-0.801,-3.947,10.305,0.0622108,-0.0706167,0.9955617
        ACTL/-0.801,-3.947,10.305,0.0622108,-0.0706167,0.9955617
        CONSTR/PLANE,BFRE,A,B,C,,
LIN2    =FEAT/LINE,RECT,UNBND
        THEO/-6.421,8.684,12.959,0.2104017,-0.9655908,-0.1528577
        ACTL/-6.421,8.684,12.959,0.2104007,-0.9655911,-0.1528573
        CONSTR/LINE,BF,3D,A,C,,
A2      =ALIGNMENT/START,RECALL:A1, LIST= YES
        ALIGNMENT/ROTATE,XPLUS,TO,LIN2,ABOUT,ZPLUS
        ALIGNMENT/END
B       =FEAT/POINT,RECT
        THEO/11.371,2.727,9.477,0,0,1
        ACTL/11.371,2.726,9.477,0,0,1
        MEAS/POINT,1
        HIT/BASIC,11.371,2.726,9.477,0,0,1,11.371,2.726,9.477,USE THEO = YES
        ENDMEAS/
DIM ANGL1= 3D ANGLE (TRUE) FROM PLANE PLN1 TO LINE LIN1,$
GRAPH=OFF TEXT=OFF MULT=10.00 OUTPUT=BOTH
AX NOMINAL  +TOL  -TOL  MEAS  MAX  MIN  DEV
OUTTOL
A   84.606   0.010   0.010   84.606   84.606   84.606   0.000   0.000 ----#----

Masial

STARTUP  =ALIGNMENT/START,RECALL:, LIST= YES
        ALIGNMENT/END
        MODE/MANUAL
        LOADPROBE/SEAN
        TIP/T1A0B0, SHANKIJK=0, 0, 1, ANGLE=0
PNT1    =FEAT/POINT,RECT
        THEO/2.058,9.483,-597.611,0,0,1
        ACTL/2.058,9.483,-597.611,0,0,1
        MEAS/POINT,1
        HIT/BASIC,2.058,9.483,-597.611,0,0,1,2.058,9.483,-597.611,USE THEO = YES
        ENDMEAS/
PNT2    =FEAT/POINT,RECT
        THEO/-0.024,8.287,-612.474,0,0,1
        ACTL/-0.024,8.287,-612.474,0,0,1
        MEAS/POINT,1
        HIT/BASIC,-0.024,8.287,-612.474,0,0,1,-0.024,8.287,-612.474,USE THEO =
YES

```



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ENDMEAS/
LIN1  =FEAT/LINE,RECT,UNBND
      THEO/-0.024,8.287,-612.474,0.1382747,0.0794121,0.9872051
      ACTL/-0.024,8.287,-612.474,0.1382747,0.0794121,0.9872051
      CONSTR/LINE,BF,3D,PNT2,PNT1,,
A0    =ALIGNMENT/START,RECALL:STARTUP, LIST= YES
      ALIGNMENT/TRANS,XAXIS,PNT2
      ALIGNMENT/TRANS,YAXIS,PNT2
      ALIGNMENT/TRANS,ZAXIS,PNT2
      ALIGNMENT/END
A1    =ALIGNMENT/START,RECALL:A0, LIST= YES
      ALIGNMENT/ROTATE,ZPLUS,TO,LIN1,ABOUT,ZPLUS
      ALIGNMENT/END
A      =FEAT/POINT,RECT
      THEO/-14.879,24.528,10.774,1,0,0
      ACTL/-14.879,24.528,10.775,1,0,0
      MEAS/POINT,1
      HIT/BASIC,-14.879,24.528,10.775,1,0,0,-14.879,24.528,10.775,USE THEO =
YES
      ENDMEAS/
B      =FEAT/POINT,RECT
      THEO/-3.373,5.314,7.292,0,0,1
      ACTL/-3.374,5.314,7.292,0,0,1
      MEAS/POINT,1
      HIT/BASIC,-3.374,5.314,7.292,0,0,1,-3.374,5.314,7.292,USE THEO = YES
      ENDMEAS/
C      =FEAT/POINT,RECT
      THEO/-10.74,5.533,7.767,0,0,1
      ACTL/-10.74,5.533,7.768,0,0,1
      MEAS/POINT,1
      HIT/BASIC,-10.74,5.533,7.768,0,0,1,-10.74,5.533,7.768,USE THEO = YES
      ENDMEAS/
PLN1  =FEAT/PLANE,RECT
      THEO/-9.259,11.897,8.12,0.0622108,-0.0706167,0.9955617
      ACTL/-9.259,11.897,8.12,0.0622108,-0.0706167,0.9955617
      CONSTR/PLANE,BFRE,A,B,C,,
LIN2  =FEAT/LINE,RECT,UNBND
      THEO/-14.879,24.528,10.774,0.2104017,-0.9655908,-0.1528577
      ACTL/-14.879,24.528,10.775,0.2104007,-0.9655911,-0.1528573
      CONSTR/LINE,BF,3D,A,C,,
A2    =ALIGNMENT/START,RECALL:A1, LIST= YES
      ALIGNMENT/ROTATE,XPLUS,TO,LIN2,ABOUT,ZPLUS
      ALIGNMENT/END
B      =FEAT/POINT,RECT
      THEO/-5.91,-2.165,7.292,0,0,1
      ACTL/-5.91,-2.165,7.292,0,0,1

```

MEAS/POINT,1

HIT/BASIC,-5.91,-2.165,7.292,0,0,1,-5.91,-2.165,7.292,USE THEO = YES

ENDMEAS/

DIM ANGL1= 3D ANGLE (TRUE) FROM PLANE PLN1 TO LINE LIN1 ,

GRAPH=OFF TEXT=OFF MULT=10.00 OUTPUT=BOTH

AX	NOMINAL	+TOL	-TOL	MEAS	MAX	MIN	DEV
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OUTTOL

A	80.339	0.010	0.010	80.339	80.339	80.339	0.000	0.000	---#---
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Distal

STARTUP =ALIGNMENT/START,RECALL:, LIST= YES

ALIGNMENT/END

MODE/MANUAL

LOADPROBE/SEAN

TIP/T1A0B0, SHANKIJK=0, 0, 1, ANGLE=0

PNT1 =FEAT/POINT,RECT

THEO/3.138,9.647,-604.44,0,0,1

ACTL/3.138,9.647,-604.44,0,0,1

MEAS/POINT,1

HIT/BASIC,3.138,9.647,-604.44,0,0,1,3.138,9.647,-604.44,USE THEO = YES

ENDMEAS/

PNT2 =FEAT/POINT,RECT

THEO/2.805,10.186,-619.426,0,0,1

ACTL/2.805,10.186,-619.426,0,0,1

MEAS/POINT,1

HIT/BASIC,2.805,10.186,-619.426,0,0,1,2.805,10.186,-619.426,USE THEO =

YES

ENDMEAS/

LIN1 =FEAT/LINE,RECT,UNBND

THEO/2.805,10.186,-619.426,0.0222184,-0.0359328,0.9991072

ACTL/2.805,10.186,-619.426,0.0222184,-0.0359328,0.9991072

CONSTR/LINE,BF,3D,PNT2,PNT1,,

A1 =ALIGNMENT/START,RECALL:STARTUP, LIST= YES

ALIGNMENT/TRANS,XAXIS,PNT2

ALIGNMENT/TRANS,YAXIS,PNT2

ALIGNMENT/TRANS,ZAXIS,PNT2

ALIGNMENT/END

A2 =ALIGNMENT/START,RECALL:A1, LIST= YES

ALIGNMENT/ROTATE,ZPLUS,TO,LIN1,ABOUT,ZPLUS

ALIGNMENT/END

A =FEAT/POINT,RECT

THEO/1.788,10.011,10.556,0,0,1

ACTL/1.788,10.011,10.556,0,0,1

MEAS/POINT,1

HIT/BASIC,1.788,10.011,10.556,0,0,1,1.788,10.011,10.556,USE THEO = YES

ENDMEAS/

B =FEAT/POINT,RECT

THEO/11.543,2.986,9.305,0,0,1

ACTL/11.543,2.986,9.305,0,0,1

MEAS/POINT,1

HIT/BASIC,11.543,2.986,9.305,0,0,1,-7.543,-6.986,8.305,USE THEO = YES

ENDMEAS/

C =FEAT/POINT,RECT

THEO/-2.065,-11.712,8.031,0,0,1

ACTL/-2.065,-11.712,8.031,0,0,1

```

MEAS/POINT,1
HIT/BASIC,-2.065,-11.712,8.031,0,0,1,-2.065,-11.712,8.031,USE THEO = YES
ENDMEAS/
PLN1   =FEAT/PLANE,RECT
THEO/3.697,0.611,9.31,0.0391612,-0.1221879,0.9917341
ACTL/-2.542,-2.735,8.974,-0.0433415,-0.1077298,0.993235
CONSTR/PLANE,BFRE,A,B,C,,
LIN2   =FEAT/LINE,RECT,UNBND
THEO/1.788,10.011,10.556,-0.173511,-0.9782456,-0.1137076
ACTL/1.788,10.011,10.556,-0.1735005,-0.9782512,-0.1136756
CONSTR/LINE,BF,3D,A,C,,
A3     =ALIGNMENT/START,RECALL:A2, LIST= YES
ALIGNMENT/ROTATE,XPLUS,TO,LIN2,ABOUT,ZPLUS
ALIGNMENT/END
B      =FEAT/POINT,RECT
THEO/11.196,2.207,9.305,0,0,1
ACTL/11.196,2.207,9.305,0,0,1
MEAS/POINT,1
HIT/BASIC,11.196,2.207,9.305,0,0,1,8.196,-6.207,8.305,USE THEO = YES
ENDMEAS/
DIM ANGL1= 3D ANGLE (TRUE) FROM PLANE PLN1 TO LINE LIN1 ,$
GRAPH=OFF TEXT=OFF MULT=10.00 OUTPUT=BOTH
AX  NOMINAL  +TOL   -TOL   MEAS    MAX    MIN    DEV
OUTTOL
A   84.417   0.010   0.010   84.417   84.417   84.417

```


First model R16

DIM LOC5= TRUE POSITION OF POINT PNT2 UNITS=MM,\$
GRAPH=OFF TEXT=OFF MULT=1.00 OUTPUT=BOTH DEV PERPEN
CENTERLINE=OFF DISPLAY=DIAMETER
AX NOMINAL MEAS +TOL -TOL BONUS DEV DEVANG
OUTTOL
X 0.000 0.000 0.000
Y 0.000 0.000 0.000
Z 0.000 0.000 0.000
TP RFS 0.000 0.000 0.001 69.717 0.001 ----->
END OF DIMENSION LOC5
DIM LOC6= TRUE POSITION OF POINT PNT3 UNITS=MM,\$
GRAPH=OFF TEXT=OFF MULT=1.00 OUTPUT=BOTH DEV PERPEN
CENTERLINE=OFF DISPLAY=DIAMETER
AX NOMINAL MEAS +TOL -TOL BONUS DEV DEVANG
OUTTOL
X -0.008 -0.008 0.000
Y 0.003 0.003 0.000
Z -15.321 -15.321 0.000
TP RFS 0.000 0.000 0.001 69.717 0.001 ----->
END OF DIMENSION LOC6
DIM LOC7= TRUE POSITION OF POINT A UNITS=MM,\$
GRAPH=OFF TEXT=OFF MULT=1.00 OUTPUT=BOTH DEV PERPEN
CENTERLINE=OFF DISPLAY=DIAMETER
AX NOMINAL MEAS +TOL -TOL BONUS DEV DEVANG
OUTTOL
X 16.134 16.134 0.000
Y -2.350 -2.350 0.000
Z -9.434 -9.434 0.000
TP RFS 0.000 0.000 0.001 3.731 0.001 ----->
END OF DIMENSION LOC7
DIM LOC8= TRUE POSITION OF POINT B UNITS=MM,\$
GRAPH=OFF TEXT=OFF MULT=1.00 OUTPUT=BOTH DEV PERPEN
CENTERLINE=OFF DISPLAY=DIAMETER
AX NOMINAL MEAS +TOL -TOL BONUS DEV DEVANG
OUTTOL
X 13.010 13.010 0.000
Y 3.135 3.135 0.000
Z -7.640 -7.640 0.000
TP RFS 0.000 0.000 0.001 -138.289 0.001 ----->
END OF DIMENSION LOC8
DIM LOC9= TRUE POSITION OF POINT C UNITS=MM,\$
GRAPH=OFF TEXT=OFF MULT=1.00 OUTPUT=BOTH DEV PERPEN
CENTERLINE=OFF DISPLAY=DIAMETER

	AX	NOMINAL	MEAS	+TOL	-TOL	BONUS	DEV	DEVANG
X	-7.503	-7.503			0.000			
Y	-5.420	-5.420			0.000			
Z	-7.416	-7.416			0.000			
TP	RFS		0.000		0.000	0.001	-104.621	0.001 ----->

END OF DIMENSION LOC9

DIM ANGL2= 3D ANGLE (TRUE) FROM PLANE PLN2 TO LINE LIN1 ,
 GRAPH=OFF TEXT=OFF MULT=10.00 OUTPUT=BOTH

	AX	NOMINAL	+TOL	-TOL	MEAS	MAX	MIN	DEV
A	74.100	0.010	0.010	74.100	74.100	74.100	0.000	0.000 ----#----

Position of a after realignment

A =FEAT/POINT,RECT

THEO/13.986,-8.379,-9.434,0,0,1

ACTL/13.987,-8.379,-9.434,0,0,1

MEAS/POINT,1

HIT/BASIC,13.987,-8.379,-9.434,0,0,1,13.987,-8.379,-9.434,USE THEO = YES

ENDMEAS/